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The **International Multidisciplinary Scientific GeoConference SGEM (Survey, Geology, Ecology, and Management)** serves as a global platform for pioneering research and scientific dialogue across the diverse fields of geosciences. It is dedicated to advancing interdisciplinary solutions for the most pressing environmental challenges of our time — **Global Warming, Climate Change, CO_2 Reduction, Biodiversity Conservation, and the Development of Green Technologies**. By fostering a collaborative exchange of knowledge and **aligning its objectives** with the **United Nations Sustainable Development Goals (SDGs), SGEM aims to inspire scientific excellence and drive sustainable practices toward a greener, more resilient future for our planet.**

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FOREWORD

Building on the themes of sustainable energy transitions, advanced technologies, and ecosystem preservation explored in Issue 4.2, this second issue of the Vienna Green Conference Proceedings delves deeper into the innovative solutions and interdisciplinary approaches shaping a greener future. As we continue to tackle global challenges such as reducing carbon emissions, managing resources sustainably, and fostering environmental resilience, the **research presented here demonstrates the critical role of green sciences in transforming our world**.

In section *Clean Energy Systems and Energy Storage Technologies*, **researchers address the challenges of integrating renewable energy into existing systems**. Contributions on wind energy's impact on land use, hydrogen export potential, and innovative storage system topologies emphasize the importance of infrastructure and policy advancements in driving the global energy transition.

The section on *Recycling, Waste Management, and Circular Economy* focuses on the vital need to close the loop on resource use. From biogas production and metallurgical waste recovery to biochar's potential in ore treatment, these studies illustrate how **circular economy practices can reduce waste, conserve resources, and lower environmental footprints, reinforcing the importance of sustainable industrial processes**.

Air Quality, Pollution Control, and Climate Change Mitigation continues the discourse on **minimizing environmental impact through innovative technologies and practice**s. Research on air quality monitoring using UAVs, methane mitigation in soils, and the role of geothermal heating plants in reducing emissions showcases practical approaches to **mitigating climate change and improving environmental health**.

In *Ecology, Biodiversity, and Environmental Protection*, the focus shifts to safeguarding ecosystems and promoting biodiversity. Contributions **exploring climate impacts on vegetation dynamics, ecotourism as an adaptive strategy**, and the resilience of agricultural systems highlight the interconnectedness of human and natural systems, offering actionable **insights into preserving the planet's ecological balance**.

The final sections on *Economics of Sustainability and Environmental Policies* and *Education, Training, and Capacity Building in Geosciences* underscore the importance of integrating sustainability principles into economic systems and education. Research on **reducing food waste, fostering environmental education, and enhancing geoscience training illustrates the necessity of informed policies** and capacity building to achieve long-term sustainability goals.

As a continuation of the SGEM Vienna Green Conference Proceedings, this issue exemplifies the **spirit of collaboration, innovation, and interdisciplinary thinking required to address the environmental challenges of our time**. By uniting researchers, practitioners, and policymakers, we can create actionable solutions that **promote sustainability and resilience in every facet of society**.

We are deeply grateful to the authors, reviewers, and organizers whose commitment has made this publication possible. **Your contributions illuminate the path toward a greener, healthier, and more equitable future**.

May this volume inspire further dialogue, innovation, and action as we continue our shared journey toward environmental sustainability.

Sincerely yours,

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SECTION

CLEAN ENERGY SYSTEMS AND ENERGY STORAGE TECHNOLOGIES. HYDROGEN

ASSESSMENT OF THE IMPACT OF THE WIND PARK ON LANDSCAPE AND FUTURE LAND USE

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ABSTRACT

Wind power is a source of renewable energy produced by harnessing the kinetic energy of the wind. Wind energy is converted into electricity using wind generators or wind turbines installed in wind farms. It is linked to the kinetic energy of the wind, which is produced when air moves. The energy can be used to create mechanical motion, such as the rotation of the rotors of a wind turbine. To harness wind energy, wind turbines or generators are installed to convert the kinetic energy of the wind into electricity.
According to the General Provisions of Chapter I of the Law on Spatial Development Planning issued by the Parliament of the Republic of Latvia on 1 December 2011, a number of plans are defined that are relevant to the long-term development of a city, county, municipality or property. Local plan is the long-term development of a local area planning document, which is developed for a part of a national city, a town or part of a township, a village or part of a village, or a part of a rural area to solve a planning task or to detail or amend a spatial plan.
In the face of climate change and geopolitics, wind parks for electricity generation is essential both globally and in Latvia. Wind energy resources is an environmentally friendly solution for energy generation. However, it is important to consider that wind power plants cannot be installed in every location to be cost-effective. Increasing the height of the wind turbine, the rotor diameter, also increases the electricity efficiency and becomes more commercially viable.
The exact location of wind power plants is important for their construction. The siting is strongly influenced by the opinions and proposals of local residents, the topography of the area, nearby settlements and the layout of the area.
The location of wind farms in relation to the landscape is one of the most important aspects when planning their construction.
Very little research has been carried out on the impact of wind farms on future land use, and as a result this study places a strong emphasis on future land use after wind farms are built.
In the research are used monographic method, data processing and analysis method, balance method. During the research, geographical and meteorological maps of the Republic of Latvia were analyzed and used.

Keywords: land use, wind park, renewable energies, territory planning

INTRODUCTION

Given climate change and the geopolitical situation, the development of wind farms for electricity generation is essential both globally and in Latvia. Harnessing wind energy resources is an environmentally friendly solution for energy generation. However, it is important to bear in mind that wind power plants cannot be installed in every location in order to be cost-effective. By increasing the height of the wind turbine and the rotor diameter, the efficiency of electricity production increases and it becomes more commercially viable. The exact location of wind power plants is important for their construction. The siting is strongly influenced by the opinions and proposals of local residents, the topography of the area, nearby settlements and the layout of the area. The terrain varies throughout Latvia. Despite the fact that only 2.5% of the total area of 64.6 thousand km2 is covered by landforms above 200 m above sea level, one of the most characteristic features of the Latvian relief is the alternation of hilly highlands with gently undulating plains [1]. The relief of Latvia's territory was formed by Quaternary glaciation. The period began about 1.7 million years ago, as the northern hemisphere was lowered air temperature. Extensive glaciations formed. In Latvia, the glaciation began 75 000 years ago, but the ice retreated 16 000 years ago. Glacier melted rapidly, large volumes of water formed where currents moved large large quantities of rock. As the glacier retreated northwards, the Baltic Ice Lake was formed. Glacial pressure and crustal uplift led to the formation of the terrain [2]. The shore of the Baltic Ice Lake (sea), which forms the West Latvian Baltic Sea coastal lowland, is recognised as suitable for the construction of wind farms. It is characterised by the abrasion cliffs of the Baltic Ice Lake (sea) at Kapsede, Medze, Alsunga, which located at an altitude of 17-22 m above sea level. The topography may affect the potential for wind farm construction and accessibility, infrastructure, soil type, overall environment and ecosystem, as well as aesthetic aspects. Relief affects wind flow and speed. Not only the Latvian coastal area is particularly favourable for wind power plants, but also the whole of the Latvian hinterland, as there is sufficient wind capacity. According to the wind map (Fig.1), the coastal zone and the Vidzeme uplands reach the highest average speeds at 50 m.

The location of wind farms in relation to the landscape is one of the most important aspects of wind farm planning. It should be borne in mind that the perception of the landscape is a subjective concept, and as a result can be based on psychology (personal, emotional, sentimental attachments and associations). Depending on the parameters of the NPP - its height, rotor diameter, number of stations, colour, and many other factors - its construction changes the landscape. Wind turbines cannot be invisible, as their large size and the large areas required to build them make them particularly prominent in the landscape. According to the definition of the European Landscape Convention, a landscape is the result of human activity affecting the environment. There should be no attempt to protect 'valuable' landscapes from the construction of wind turbines; on the contrary, wind park designers should develop a coherent model for integrating wind turbines into the landscape, while maintaining their harmony with the landscape of the site [3]. In Latvia, there is currently no document that directly defines the Latvian landscape policy, but various binding issues are integrated into normative documents/regulations and various sectoral policies.

MATERIALS AND METHODS

In the research is included land parcels located in Latvia in Vērgale municipality, South Kurzeme district. The site research area is located approximately 10 km from Liepaja to south-west of the boundary of the study area. The nearest villages are Vērgale to north and Ploce to the north-east approximately 2 km from the research area the boundary of the study area. There are no significant bodies of water in the research area of the planned park and there is not crossed by significant watercourses. The area includes the Salnāju pond. In the vicinity there is Lake, located more than 3 kilometres to the south of the study area. Ālande and the Karļupīte, which is located on the western side. Ploči swamp is located on the western side. The research area includes 45 land units or parts thereof, total area 704,2 ha. The dominant types of land use are agricultural and forest land. The research area includes two farmsteads ('Rieģe' and 'Kalna Stūrīši'). Land areas and ownership (natural or legal) is equivalent (Table 1). In Table 2 are information on the distribution of land use types in all 45 land parcels (Table 2).
In the research to analyses these data are used monographic method, data processing and analysis method, balance method. During the research, geographical and meteorological maps of the Republic of Latvia were analyzed and used.
The research uses freely available open data on land parcels, land use types and ownership status.

TABLES AND FIGURES

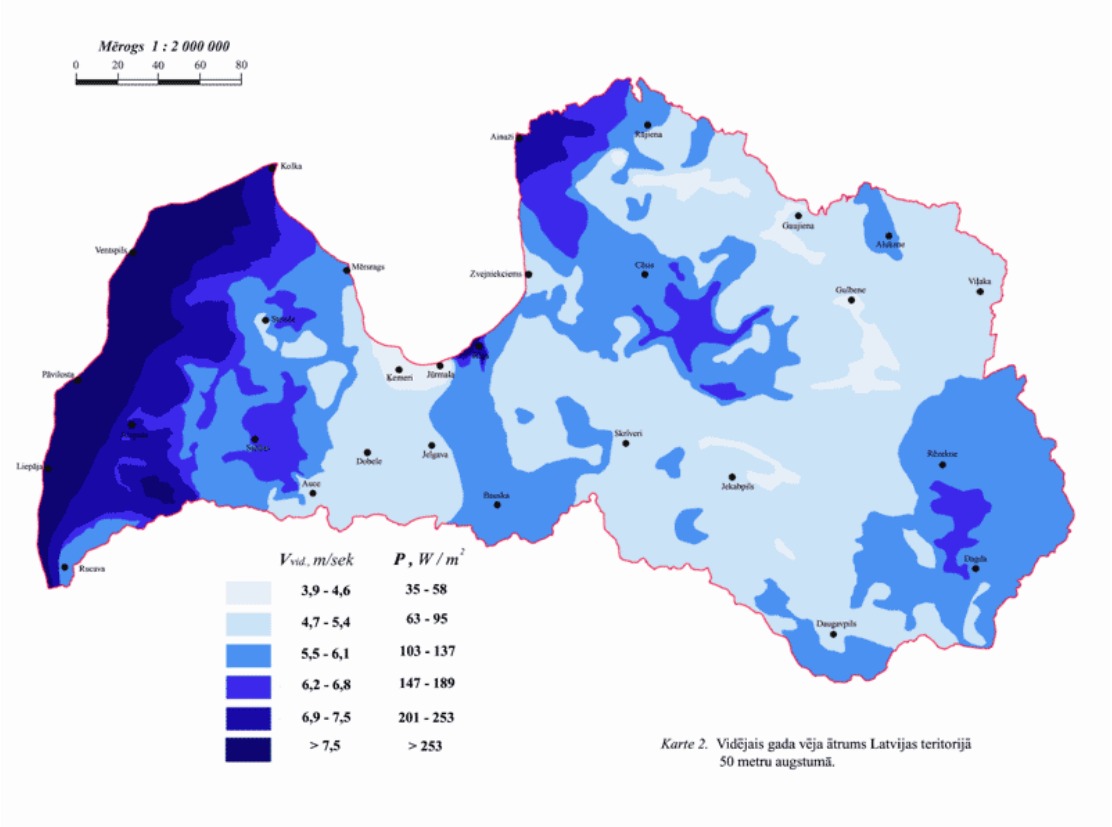


Fig.1. Average annual wind speed in Latvia at 50 m

Table 1. Ownership of the land units included in the research

Ownership of land	Number of properties	Area of properties, hectare
Owned by natural persons	22	305.5
Owned by legal persons	23	378.3
Total	**45**	**638.8**

Table 2. Land use types in the research land parcels

Category	Land use type	Area of land use, hectare	Percentage occupied area, %
Agricultural land	Arable land	550.41	80.17
	Orchard	0.90	0.13
	Meadow	14.76	2.15
	Pasture	7.50	1.09
Forest	Forest	66.66	9.71
Shrubbery	Shrubbery	2.86	0.42
Swamp	Swamp	8.78	1.28
Land of water features	Land under the waters	13.78	2.01
	The land under the fish ponds	0.10	0.01
Land under buildings and yards	Land under buildings and yards	1.37	0.20
Land under the roads	Land under the roads	1.99	0.29
Other lands	Other lands	17.44	2.54
Total		**686.55**	**100**

RESULTS AND DISCUSSION

In territory where are in the research included land parcels, are the areas of scenic value and cultural significance have been identified for almost most of the territory of the region, but if we focus on Vērgale and Vērgale municipality, where the wind park is planned, then in its surroundings the old seashore, Vērgale manor, Taši manor – the territory of the manor is assessed as a cultural and historical landscape. The traditional and characteristic building principles should be considered when developing this area. It should be noted that within a radius of ~ 1 km around the wind farm it will have a significant visual impact on the landscape depending on the topography, if the topography is flat then the distance may increase accordingly. Within a radius of 2 km the landscape will be transformed. From 1 to ~5 km radius, wind farms are intrusive, visible in the landscape and the movement of the rotor blades is visible depending on

weather conditions. Between 2 and 8 km are visible, less visible in the overall landscape. From a radius of 8 km and more, it is in principle not visible.
Changing lighting conditions and different weather conditions affect wind the visual integration of turbines into the landscape. An important aspect to focus on, when studying existing wind farms is the movement of the rotor blades themselves. Wind rotor blade movement affects people's perception of the landscape and raises the issue of so-called 'natural views'. The human eye can detect movement from a great distance. Rotating and very regular wind the movement of turbine blades is not a normal form of 'natural movement'. Color and shapes, the lightness or darkness of the turbines, the vertical lines of the background and the towers all contribute to the visibility at all distances. Turbine size and blade movement become more important for visibility at shorter distances, as the visibility of a wind turbine in a static position in the landscape is less affected than when in motion. In order to make a landscape assessment of how wind turbines will look photographic recordings and projection onto appropriate modelling equipment programs, considering buildings, topography, vegetation and are called the visibility zone maps. The maps are produced to seek the views of local residents whose properties affected or the views of those who live in the vicinity of the development. By clarifying the residents', the views of the developer, the layout may be modified to reduce its visibility and impact on the landscape changes. Landscape architects should consider the existing landscape situation, what crops, historical sites on the site and how aesthetically they will fit into the landscape.
Turbines are often placed in the landscape in regular or irregular patterns. The fewer the turbines, the easier it is to integrate them into the landscape, creating a positive impact with a visually balanced, simple and harmonious landscape. This can be achieved by locating turbines along simple lines on a flat surface. When turbines are placed outside these lines, the complexity of the design increases.
After this short research it is possible to say that wind parks can significantly impact land use by introducing new economic opportunities, altering land development patterns, and affecting local ecosystems. However, they can also coexist with other land uses such as agriculture, providing opportunities for sustainable land management. Balancing the benefits of renewable energy with the preservation of natural resources and local priorities is key to managing these impacts.

CONCLUSION

1. The mechanical properties of the soil may be affected as a result of the construction of wind parks.
2. The impact of wind parks on the visual landscape can affect the aesthetic view and reflect problems such as, how the area looks and what this means for its perceived beauty or appeal to tourists.
3. Wind parks can significantly alter the visual landscape, introducing large, mechanical structures into natural settings.
4. The aesthetics of the area may change, potentially affecting local perceptions of beauty and tourism appeal.
5. For wind parks it is positive that wind parks make efficient use of large expanses of land without the need for extensive infrastructure. While turbines are spread out, much of the land between them can still be used for agricultural activities like grazing or crop production, offering a balance between renewable energy production and land utility.

6. Wind parks can change and give impact of biodiversity. It is possible to disrupt local wildlife habitats. Certain species may be at risk, particularly birds and bats, which may collide with turbine blades. Conversely, wind parks may also support new habitats or conservation efforts, depending on the site management practices.
7. Wind parks can give impact on agriculture, for example, land traditionally used for farming.
8. In summary, wind parks influence land use and landscape in diverse ways, with both positive and negative outcomes that require careful planning and management.

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CHALLENGES OF GEORGA'S ENERGY POLICY IN THE PROCESS OF INTEGRATION WITHIN THE EUROPEAN UNION

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ABSTRACT

Georgia's positioning in the context of the European Union's foreign energy policy has become the subject of discussion in the context of the threats coming from the current Russia-Ukraine war. At the same time, determining the effectiveness of the country's energy policy is related to the seventh Sustainable Development Goal - affordable and safe energy. In 2016, Georgia signed the protocol of joining the Energy Community, which determines the conditions for the introduction of EU energy legislation in Georgia in order to deepen Georgia's energy integration with the EU.

The purpose of the study is to offer recommendations for the formation of an effective energy policy of Georgia, taking into account the demand for integration with the EU. In terms of theoretical approach, the work is based on the views of the followers of the Neorealist School of international relations, where the issue of energy security dominates. In the research process, Georgian energy policy documents, projects, reports of national and international organizations on energy policy, as well as general directives of the European Union were studied, as they determine energy policy priorities, such as sustainable energy development, energy efficiency improvement and use of renewable energy sources. The research is based on using the political-economic analysis method.

The research was conducted also using the method of bibliographic research and comparative analysis: the problems of Georgia's energy policy, their causes and consequences are analyzed; Recommendations for an effective policy of energy integration between Georgia and the European Union have been developed. The use of research foundlings will help to define differentiated tasks and activities for the development of energy development policy in Georgia.

Keywords: Georgia, Energy Policy, Energy Security, Green Energy.

INTRODUCTION

Relevance of the problem: Developing and implementing energy policy is an essential prerequisite for achieving strategic goals in the field of economic development as well as energy sector. The goal of Georgia's energy policy is 'to improve the country's energy security, ensuring the implementation of national interests through the continuous supply of sufficient amounts of high-quality energy at an affordable price'. [1]

Energy security is part of the country's overall security policy, and the issue has been relevant not only in the current phase of mega-challenges (such as the changes in World Economic Order, climate problems, and military actions) but throughout history. The high degree of interdependence between the energy market and politics is evident in the outcomes of crises in the 1970s-80s and conflicts in the Middle East.

After gaining independence, Georgia set a strategic goal to join the EU, which defines the direction and choices of the country's political and economic development. Following the signing of the 'Association Agreement'[2] with the EU in 2014, legislative obligations were established for Georgia in all areas, including energy and environmental protection. In 2016, Georgia signed the protocol for joining the Energy Community, which formalized the conditions for the introduction of EU energy legislation in Georgia.

However, after the start of the Russia-Ukraine war in 2023, the Georgian government took unclear steps toward EU integration [3], reflected in messages of distrust toward the strategic partner, non-constructive actions, and political manipulation. This situation raises questions about the deepening of the strategic partnership between Georgia and the EU, particularly in the energy sector.

As a result, Georgia's positioning in the context of the EU's foreign energy policy has become the subject of discussion, particularly against the backdrop of the EU's growing dependence on Russian energy resources during the ongoing Russia-Ukraine war and changes in the World Economic Order, which is shifting from a unipolar to a multipolar system. The logic of the research is based on the method of political-economic analysis, which encourages political thinking and action.

The purpose of the research is to offer recommendations for the formation of an effective energy policy for Georgia, taking into account the demand for EU integration. To achieve this goal, the following tasks were set:

1. Study the framework documents that define the energy policies of Georgia and the EU;
2. Conduct a political-economic analysis of Georgia's positioning in the energy market from political, economic, and scientific-practical perspectives;
3. Develop recommendations for an effective energy integration policy between Georgia and the European Union.

MATERIALS AND METHODS

The theoretical and methodological approach of the research consider the country's energy threats (insufficient energy supply, high prices, supply interruptions, seasonal supply difficulties, deviations from quality standards, etc.) not only in terms of economic benefits and losses but also in connection with national values and interests, such as political and social stability, economic development, the country's political course, and etc. Therefore, energy remains one of the main research directions of political-economic science.

In a nutshell, political economy analysis investigates the interaction of political and economic processes in society; it involves understanding the power and authority of groups in society, the role of formal and informal institutions in allocating scarce resources, and the influence of values and ideas, including culture, ideologies, and religion.[4] Political economy encompasses the complex political nature of decision-making to investigate how power and authority affect economic choices in society.

Political economy analysis can help deepen understanding of the political context and identify politically sensible and therefore more realistic and effective strategies and programs for a country's partnership. It can also expand the quality of dialogue around key political challenges and opportunities, supporting the consistent formation of joint

development goals based on a common analysis of key political and economic processes (Figure 1).

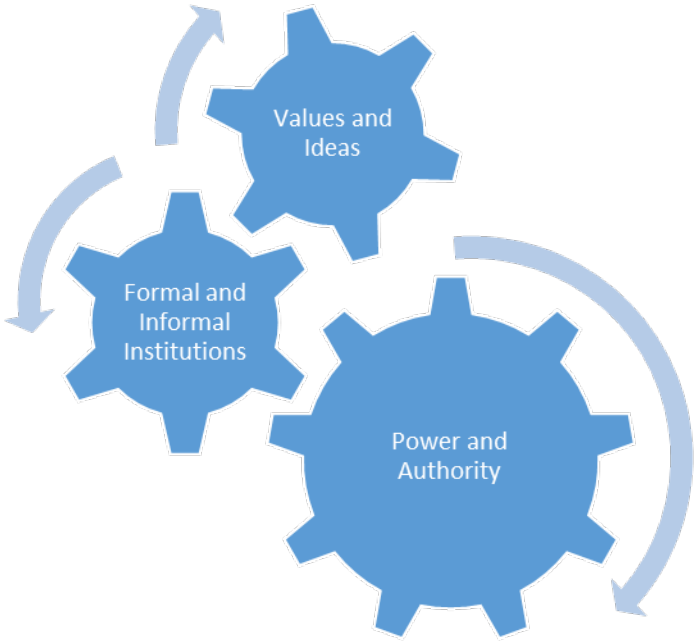


Figure 1: The Wheels of Political Economy Analysis [4]

Political economy analysis reveals institutional and governance weaknesses that cause problems and hinder progressive change. Frequently, weak governments and ineffective institutions create obstacles on the path to reform.

Thus, political economy analysis allows us to identify the limiting factors of development and answer the question, how to solve the problem? Accordingly, **our research should identify limiting factors of energy policy development and propose ways to solve these problems.**

Political economy analysis can be conducted at different levels. In this study, we chose to analyze at the national level. The country-level political economy analysis is used to study the broad political and economic environment and to plan the country's strategic directions. It is important to study institutions, including structures (mainly long-term contextual factors such as economic and social structures, geostrategic position, natural resource availability, demographic changes, climate change, and technological progress), formal institutions (law, elections, power distribution), and informal institutions (religion, culture, traditions), and agents (political leaders, public officials, political parties, business associations, and foreign actors).

The representatives of the Neorealist School of international relations (Waltz, 1979 [5]; Daniel Yergin, 1990 [6]; Michael T. Klare, 2001 [7]; Jeff D. Colgan, 2013 [8]; David G. Victor, 2017 [9]; Thijs Van de Graaf, 2013 [10] and others), focus on the issues of the state's energy policy and the functioning of world energy markets in the context of the state's national interests and national security, military confrontation and regional conflicts. According to this approach, guaranteed access to external sources of energy,

even through the use of military force, is paramount for importing countries. In the case of exporting countries, in addition to economic benefits, it is very important to use energy resources as a political tool.

The theoretical foundations of the research are based on Georgian energy policy documents [11, 12, 13], projects [14, 15], national energy policy [16], as well as general directives and reports of the European Union [16, 17, 18, 19] because they determine the energy policy priorities such as sustainable energy development, energy efficiency and use of renewable energy sources. The analysis at the country level is based on published resources, while in the analysis of the sector it is difficult to obtain reliable information about informal relations, which can be considered as a limitation of the study.

During the research process, the discussion of the issue was organized at the international scientific practical conference and at the presentation of faculty grant projects, which were held in 2023 by the Faculty of Economics and Business of TSU.

RESULTS

Based on the political-economic analysis of the challenges of Georgia's energy policy in the process of integration with the EU, it was found that Georgia has fragile democracy, leading to unequal participation of interest groups in the decision-making process. The capacity of institutions is not highly effective. Georgia due to its' geophysical location, connecting East-West and North-South, is seen as a significant transit hub. Georgia's economy is growing, but it is an electricity importer due to the lack of fossil fuel reserves. Hydropower dominates electricity generation, while other renewable sources are underutilized. Russian state-owned companies control strategic energy assets in Georgia, and decisions on approving and implementing energy investment projects are not transparent or open to public scrutiny. The government's energy policies are often manipulated under the guise of moving towards European integration.

There is a high level of migration flows, and gender imbalances exist in decision-making positions and high-value-added jobs. Females' participation in economic activities needs encouragement. Over the last five years, demographic growth has been negative, with over 16% of the population over the age of 65.

In terms of integration with the global market, Georgia holds a marginal position. Its positioning relative to the European Union's market is also weak. The share of medium and high-technology activities in the manufacturing industry's exports is low. These findings suggest that deindustrialization continues in Georgia. [20]

Court systems face governmental and clan influences. The 2020 elections were protested by the opposition parties due to rigging, although the foreign countries recognized the election results. The pre-election marathon of the 2024 parliamentary elections is taking place in unequal conditions, which is related to financing, mass media coverage, use of administrative resources and other issues. The pre-election battles reflect the issue of Russian and Western influences on Georgia. The results of the 2024 parliamentary elections will provide detailed information on the issue of power distribution inside country and show which external actors will strengthen their influence in Georgia.

Among informal institutions, religious institutions have a strong ranking, although cases of intolerant attitudes towards other religions are also provoked. In addition to Georgians, the population includes people from Azerbaijan, Armenians, Ukrainians, Kurds, Russians, etc. Along with the traditional Georgian culture, the forms of modern culture are developing and establishing themselves, however, in the election year, the government's propaganda focuses on the secularization of Georgian culture and explains it with a patriotic motive. The negative framework of traditions is shaken to some extent, however, in regions and other ethnic populations, their influence is still maintained.

The interests of government representatives and leaders of the "Georgian Dream" Party (https://tabula.ge/ge/news/603307-valeri-vavilovi-sakartveloshi-akhali-data) are leading in energy policy decisions, which is proven by the number of victories in tenders by corrupt and party-affiliated persons. Approval and implementation of investment projects are not public and transparent; The views of business associations are aligned with the interests of the government. The government of Georgia manipulates the topic of European integration and joining the Euro-Atlantic structures, its policy is an imitation of moving towards Europe. Although this strategy is written in the constitution. Starts active cooperation with Iran, Russia, Turkey, Azerbaijan, Hungary, which causes concern of strategic partners. The international community calls on the current government to return to the framework of multi-year cooperation, although the answer to this question will depend on the results of the 2024 parliamentary elections.

DISCUSSION

For the European Union, escaping Russia's energy influence is a critical issue. The EU is seeking alternative energy import sources, especially after the collapse of the Nabucco natural gas pipeline project, which aimed to transit gas from Turkey to the EU. Political factors, including conflicting interests, made the project incompatible. Amid the growing confrontation between the West and Russia, transporting natural gas from the United States to Europe has gained particular relevance, as this could reduce Europe's dependence on Russian oil and gas. The EU has also activated efforts to diversify energy imports and secure gas and oil supplies from the Caspian and Black Sea regions, where Georgia plays a critical transit role.

In particular, analysts agree that Europe is making significant efforts to replace Russian gas in the short term. In the medium to long term, Europe aims to accelerate the placement of pipelines from the Caspian region to Europe, bypassing Russia, and exploring new energy sources within Europe. Additionally, Europe is focusing on increasing efforts to create new internal energy resources and enhance the interconnection of European pipelines and power transmission lines.

The primary reason for the increased dependence on energy imports by the EU over the past decade is the halving of the EU's oil and gas production and reduction in coal production. Moreover, the energy structure of the EU member states varies, not only due to resource differences but also because of the diversity of national energy policies over the years.

On the other hand, Georgia’s energy policy includes the strategic priorities of the country’s energy sector, focusing on security and economic development. The Caspian region, with its significant natural gas reserves, is essential for Europe's energy security,

and Georgia is a key transit country in this regard. As a transit corridor connecting Europe and Asia, Georgia's role in strategic projects has the potential to increase, especially as a route for the Southern Gas Corridor, which aims to transport Azerbaijani gas to Europe.

Georgia's accession to the Energy Community has further solidified its political association with the EU, while also committing the country to transparency in energy governance and reducing the risk of monopolistic and corrupt influences on energy policies.

Energy security challenges identified in Georgia's energy policy documents include: Increasing demand for energy imports, particularly during the winter, and insufficient strategic reserves; The occupation of Georgian territories by Russia, where several strategic energy facilities are located; The ownership of key energy assets in Georgia by Russian state and commercial companies; An unreliable and outdated energy infrastructure; The effects of climate change.

Thus, recent studies show that Russia has turned energy issues into a political bargaining tool over the last few decades, further underscoring the need for energy diversification in European countries. As a strategic partner of the EU, Georgia needs policies that not only reduce energy risks but also take advantage of the opportunities arising from the country's geopolitical and geo-economic situation.

CONCLUSION

This research provides a diagnostic analysis of Georgia's energy policy using political-economic analysis in the context of EU integration. The study identified challenges and developed the following recommendations to overcome them:

1. The change in the government's geopolitical stance can be considered a major risk factor for Georgia's energy security and the implementation of an effective energy policy. Therefore, the government must align its political will and actions with the spirit of cooperation with the EU.
2. A deeper political-economic analysis of the energy sector at the sectoral level is necessary.
3. Constructive dialogue with international partners and the fulfillment of obligations under the Energy Community must be prioritized.
4. It is essential to improve energy governance institutions and methods to meet the EU's energy obligations.
5. Greater involvement of interest groups in the decision-making process is required to enhance the efficiency of energy policies.
6. Attention should be given to energy threats, such as insufficient energy supply, high prices, supply interruptions, seasonal difficulties, and deviations from quality standards.
7. Regular energy security studies should be conducted, and appropriate recommendations developed.
8. Priorities should be identified, and they should receive sufficient political support.
9. The government must ensure the continuity of energy policy implementation, particularly in alignment with EU integration.

10. Russian companies should be restricted from exerting influence over Georgia's energy assets until transparent and independent governance conditions are established.
11. Strong investment decisions are needed to address uncertainties, regulatory clarity, and infrastructure challenges.
12. To achieve net-zero emissions (NZE), policies must be accelerated to create demand for low-emission hydrogen and unlock investments that can scale up production and infrastructure.
13. Energy policy should be based on the tools and infrastructure for the production and consumption of green and sustainable energy, and directed toward stimulating green growth across the country.

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COMPARATIVE ANALYSIS OF A PHOTOVOLTAIC SYSTEM FOR AN EDUCATIONAL BUILDING USING PVSYST AND SIMULINK

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ABSTRACT

The present research explores the integration of a photovoltaic system for an educational building through a comparative analysis using the PVsyst and Simulink platforms. The building, intended for university education, is located in Cluj-Napoca, Romania. Considering the building's location and specific climate, the feasibility of installing a photovoltaic system was analyzed with the aim of reducing electricity consumption from the electrical grid. The study began with a PVsyst simulation, which indicated that a substantial amount of energy could be generated by the photovoltaic system, a result further validated by simulations using the Simulink model. The nearly identical results obtained from both methods confirm that this proposal is a reliable solution for the building in question. A detailed analysis was conducted for each month of the year, assessing the performance indicators of the proposed system in comparison to energy consumption and emphasizing the benefits of implementing such measures. Additionally, the use of two different programs allowed for the identification of both their advantages and the potential challenges encountered in their application.

Keywords: photovoltaic system, PVsyst, Simulink

INTRODUCTION

ENERGY, one of the most used words nowadays could be seen as a trend, and in some situations, it may appear to be used superficially. However, the smart and thoughtful consumption of energy should be a major concern for everyone.

Energy can take many forms, but this paper focuses on electricity and the possibility of producing it locally for an educational building. The proper functioning of any educational institution is entirely dependent on the continuity of the electricity supply. Lighting, internet, computers, laboratory equipment, air conditioning, and heating all require electricity and are vital for carrying out daily activities in educational buildings.

This paper investigates the feasibility of integrating a photovoltaic system into the Faculty of Building Services Engineering building in Cluj-Napoca, Romania. With an annual electricity consumption of approximately 100 MWh (e.g., 103.87 MWh in 2023, a significant increase from 82.38 MWh in 2012 [1]), the building currently relies entirely on the electrical grid for its energy needs.

The study aims to assess the potential benefits and challenges of generating on-site renewable electricity using two distinct software tools: one dedicated to photovoltaic systems and another applicable to a wide range of engineering applications [2]. The

results from both methods confirm and complement each other, demonstrating the effectiveness of the proposed solution for the building under study.

MATERIALS AND METHODS

A comparative analysis of the photovoltaic system was performed utilizing both PVsyst software and the Simulink platform. PVsyst, renowned for its user-friendly interface and comprehensive built-in libraries for photovoltaic (PV) component modeling, is a versatile tool suitable for engineers, professionals, and researchers seeking rapid system design and performance evaluation [3]. In contrast, Simulink offers unparalleled flexibility and customization capabilities through its model-based design environment, making it the preferred choice for researchers investigating complex system dynamics and control strategies [4-5].

A PVsyst simulation was conducted using building-specific parameters, including geographical location, meteorological data, shading analysis, available roof area, and photovoltaic module specifications. After completing the simulation, and obtaining a proper configuration for the PV panels, based on the PVsyst results, a detailed photovoltaic system model was developed and simulated on the Simulink platform for each month of the year [6]. Results from both programs were used to the development of a comprehensive month-by-month analysis, to demonstrate that this proposal can be a reliable solution for the target building.

RESULTS

Using the PVsyst software for the studied building, it revealed that a potential system capacity of 99.0 kWp achievable with 180 modules and two inverters, one of 46 kWac and one of 36 kWac can generate 109.5 MWh annually. These values were obtained with Canadian Solar Inc., model CS-6W-550-MS PV, modules having the unit nominal power of 550 Wp, disposed in 10 strings x 18 in series.

Results from the PVsyst simulation are presented in Table 1, which include the global irradiation value [kWh/m^2] and the produced energy [MWh] for each month of a year.

The irradiation value [W/m^2] has been calculated as follows:

$$Irradiation = \frac{Global\ Irradiation\ \cdot 1000}{no.of\ month\ days\ \cdot no.of\ daylight\ hours} \quad (1)$$

Table 1. Results from PVsyst simulations

Month of year	1	2	3	4	5	6	7	8	9	10	11	12
Global Irradiation [kWh/m²]	34.3	55.3	94.5	127.1	162	174	173.7	157	107.1	73.8	39.1	27.4
Energy [MWh]	3.36	5.38	8.92	11.43	14.14	14.96	14.79	13.6	9.64	6.92	3.75	2.66
Irradiation [W/m²]	110.7	179.6	254	309.6	332.2	362.5	348.2	338.9	297.5	216.4	130.3	98.21

Getting the irradiation value expressed in W/m^2 is mandatory to make the transition between PVsyst and Simulink, this parameter being essential for setting the parameters of photovoltaic panels.

Simulink model used to verify the values obtained from PVsyst software can be observed in Figure 1, which simulates a PV array connected to a grid through a DC-DC (direct current) boost converter and a three-phase three-level voltage source converter [7-8].

This model can simulate a functioning real system based on the input data as: the PV modules parameters, PV array data, sun irradiance, cell temperature and returns values for power, current and current-voltage (I-V) and power-voltage (P-V) characteristics.

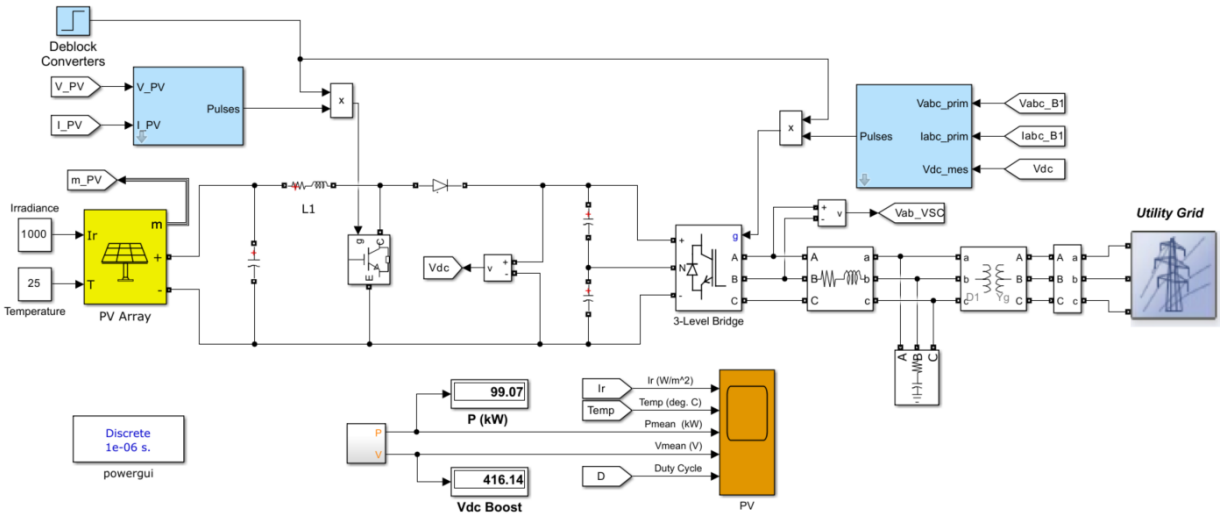


Fig. 1. Simulink model of a PV system [6]

Current–voltage and power–voltage characteristics of PV panels indicate electrical performance of a panel in a graphical representation according to a specified value of irradiation and cell temperature [9-10].

Parameters observed on I-V and P-V characteristics: open-circuit voltage, short-circuit current, maximum power point voltage, maximum power point current and maximum power are depicted in Figure 2.a.

In Figure 2. b,c,d are represented the I-V and P-V characteristics for every month of a year. The red line represents the standard test conditions simulation, which implies a temperature of 25°C and irradiation of 1000 W/m^2. At these conditions the maximum power output is 99.07 kW. The other curves coloured in blue, green, purple and orange represent a month at a time, as can be seen in every legend beside the graphical representation.

Starting from obtained values for irradiation from Table 1, were performed repeated simulations of Simulink model for each month. On I-V and P-V curves (Figure 2. b,c,d) it can be observed the significant impact of the irradiation to the PV panels performance [11-12]. While at standard test conditions the maximum power is 99.07 kW, in the most productive month (June), the output power outcomes to 35.68 kW, for 362.5 W/m^2 irradiation value. For geographic positioning of the building, the sun irradiation values are from approximately 100 W/m^2 in winter months to 350 W/m^2 in summer months [13-14], in these conditions the output power of the PV system is between 10 kW to 35 kW per month.

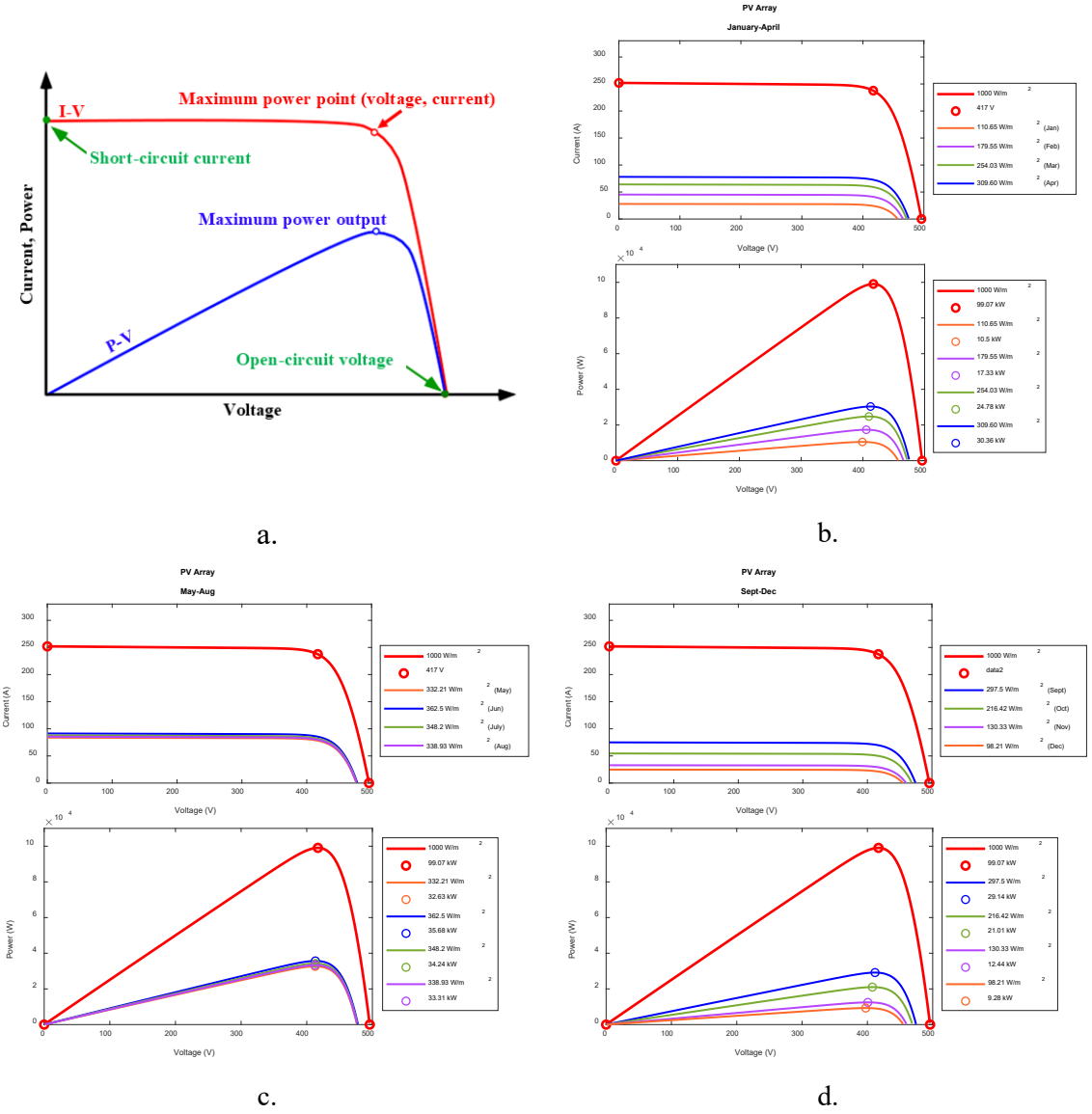


Fig. 2. Current–voltage and power–voltage characteristics of PV panels: a. explanations; from Simulink model for each month: b. January–April; c: May–August; d. September–December

Starting from the power values obtained from the simulations of Simulink model, the total electrical energy [15] has been calculated for every month (equation 2), and the results are summarized in Table 2.

$$Energy = Power \cdot no.of\ month\ days \cdot no.of\ daylight\ hours \quad (2)$$

For each month have been considered the number of month days and the daylight hours. The electrical energy has been expressed in MWh in order to compare these values with the monthly consumption of energy and with values provided by PVsyst software.

Table 2. Results from Simulink simulations

Month of year	1	2	3	4	5	6	7	8	9	10	11	12
Irradiation [W/m²]	110.7	179.6	254	309.6	332.2	362.5	348.2	338.9	297.5	216.4	130.3	98.21
Power [kW]	10.5	17.33	24.78	30.36	32.63	35.68	34.24	33.31	29.14	21.01	12.44	9.28
Energy [MWh]	3.26	5.34	9.22	11.84	14.16	15.05	14.86	13.42	10.49	7.16	3.73	2.59

The comparison of Simulink model simulations results and PVsyst results is presented in Figure 3. The slight differences of the values demonstrate that both programs offer the same overview of the studied case, in particular Simulink providing a much more detailed analysis of the PV system.

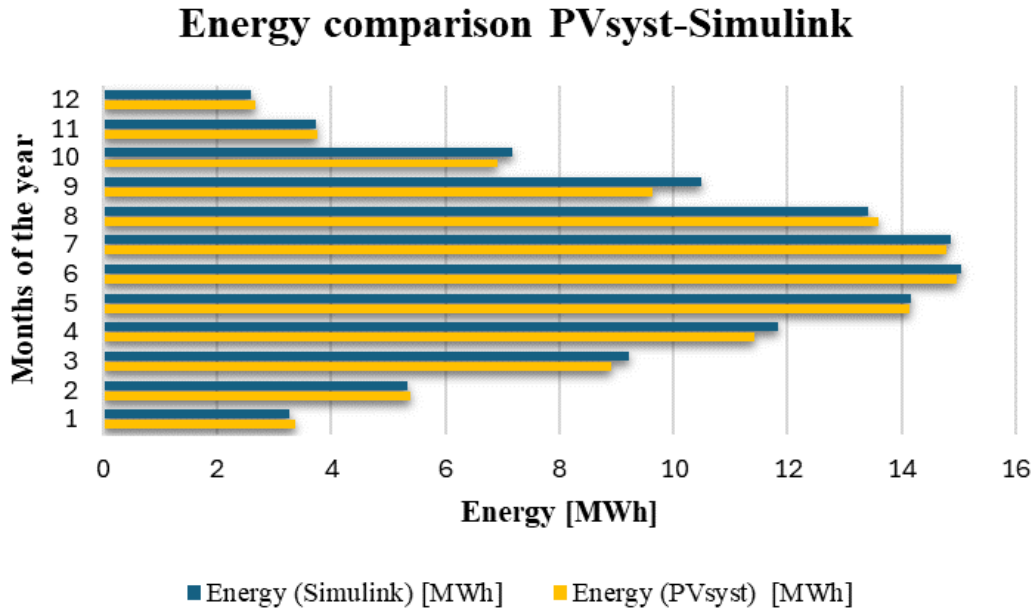


Fig. 3. Energy comparison between PVsyst and Simulink results

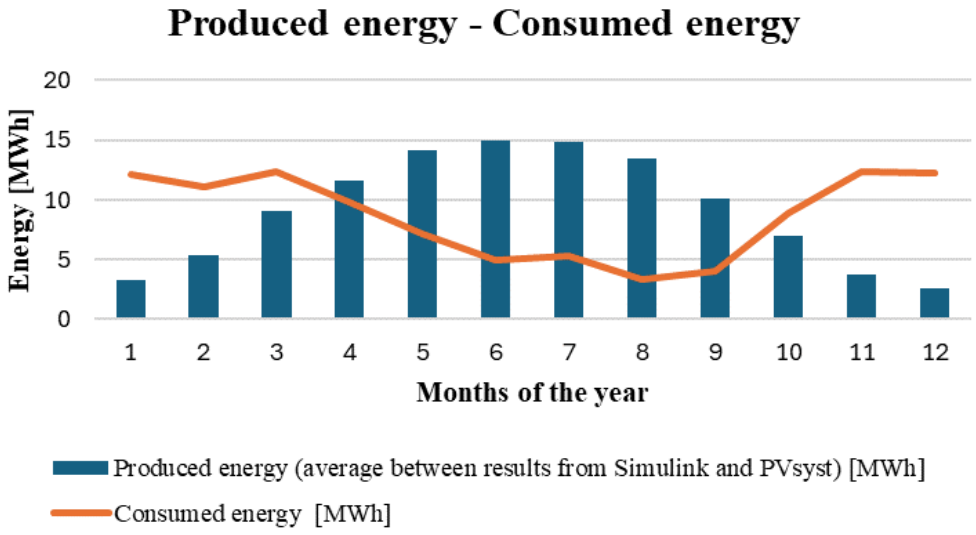


Fig. 4. Produced energy and consumed energy comparison (for 2023 year)

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Total electrical energy production established by PVsyst is 109.55 MWh, while values based on Simulink model determine a total electrical energy of 111.12 MWh for a year. The minor difference of 1.41 % between the used programs shows the relevance and the usefulness of both programs.

Knowing the annual energy consumption of the building in question, a comparison was made between the produced energy by PV system and the energy consumption for each month of a year, as in Figure 4.

Blue columns represent the produced energy (average between results from Simulink and PVsyst) and orange line the consumed energy (values for 2023 year) for each month.

DISCUSSION

Due to the geographic position and climate specificity for Transylvanian region, the required electrical energy for winter months is higher than the possible produced energy by the PV system. This situation is a predictable one, especially to the specific of building, being an educational building, and academic year starting from October till July, implies an intensive activity in cold season.

On the other hand, summarizing the electrical energy consumption for 2023 year, has determined a total of 103.87 MWh, while the proposed solution can generate 109.5 MWh annually in the considered conditions. This indicates that the annual energy consumption can be supported by the proposed PV system, and with a good electricity supply contract the amount of the electricity bill can be significantly reduced.

The comparative analysis of a photovoltaic system for the Faculty of Building Services Engineering in Cluj-Napoca, conducted using PVsyst and Simulink, revealed that the annual energy yield from both software platforms is highly consistent, suggesting a reliable solution for the studied building.

The utility of both programs is indisputable, each having its strengths and weaknesses, but they remain valuable references for making decisions regarding PV systems.

CONCLUSION

The comparative study unequivocally demonstrates the feasibility of a photovoltaic system for the target building. By offsetting a substantial portion of the building's electricity consumption, the system is poised to deliver significant reductions in grid dependency and associated energy costs and bring the building one step closer to energy independence. Additionally, the planned installation of air conditioning units in the near future will help reduce the gap between energy production and consumption during the summer.

It can be concluded that the PVsyst software benefits from a user-friendly interface, making the interaction a pleasant experience and encouraging not only engineers but also others to use this product with confidence.

For a more detailed analysis of a PV system, the use of Simulink is recommended, although it requires a thorough understanding of the program, more specialized expertise and implicitly a longer working time. This platform being an ideal environment for researchers.

Future work will involve analyzing and developing additional solutions to reduce energy consumption in various educational buildings and beyond.

ACKNOWLEDGEMENTS

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OPTIONS OF EXPORTING HYDROGEN FROM UKRAINE TO THE EU

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ABSTRACT

In light of the pressing need to achieve climate neutrality in the energy sector, the European Union seeks to identify strategies that will enhance and diversify its green energy supplies. As a renewable energy source, green hydrogen promises to offer a viable alternative to fossil fuels where green electricity may be insufficient or inaccessible. This is why the production and supply of this innovative energy carrier is becoming a significant focus in EU politics and research. This article examines and compares promising opportunities for supplying green hydrogen to the EU, particularly to countries such as Germany and Austria, which may face energy shortages in the absence of green hydrogen imports in the future. A comparative analysis was conducted to evaluate the production and supply costs of green hydrogen in various potential partner countries.

It can be assumed that the cost of renewable electricity production in Ukraine may prove to be lower than in the other countries under consideration. Consequently, the competitiveness of green hydrogen supply could be mainly determined by technology and transportation distance.

The results of the comparative analysis indicate that, given its geographical proximity and existing, well-developed network of gas pipelines, in addition to favorable natural conditions for the production of green electricity, Ukraine could offer considerable economic advantages for the supply of Germany and Austria, as well as for the EU as a whole. A series of potential scenarios for utilizing Ukraine's transport infrastructure to facilitate the supply of green hydrogen to the EU were subjected to analysis for this purpose. A fundamental condition precedent to this end is that the energy sector in Ukraine must achieve stability and recover from the consequences of war.

Keywords: hydrogen export, hydrogen supply, renewable energy sources, pipelines, diversification of energy sources.

INTRODUCTION

In view of the current energy crisis, the import of renewably produced hydrogen has gained importance in the EU, in addition to renewable electricity supplies from abroad. Hydrogen is a stable energy source that could balance electricity consumption with fluctuating electricity generation from other renewable energy sources.

It seems highly unlikely that the EU will be able to produce sufficient quantities of hydrogen internally, given the current lack of green electricity generation. It thus follows that the EU will be required to import a significant quantity of hydrogen produced in an environmentally friendly manner. The share of hydrogen in the EU energy mix is estimated to increase from less than 2% currently to 13-14% in 2050 [1].

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One of the most significant challenges to the utilisation of hydrogen as a source of energy is the identification of suitable transportation solutions for this energy carrier. The long distances between production and consumption sites have a significant impact on the overall efficiency and cost of energy production from hydrogen. Hydrogen can be transported by truck, rail, ship or pipeline. In terms of transport costs, the pipeline currently seems to be the cheapest alternative [2]. It is possible to utilise existing oil and natural gas pipelines for the delivery of hydrogen without the necessity for technically challenging conversions. This spans from the long-distance pipelines to the distribution networks and storage facilities. With a relatively modest financial input, it could be feasible to adapt the existing natural gas pipelines for the transportation of hydrogen.

The principal objective of this study therefore is to examine the potential avenues for the European Union (EU) to procure green hydrogen from Ukraine and to evaluate the associated costs, including those pertaining to transportation, in comparison to the costs of importing hydrogen from other regions.

Premise: All results presented in the article for the Ukraine are based on assessments of the capacities and existing potential for the production of renewable energies that were expanded in Ukraine before February 24, 2022. The actual possible quantities of hydrogen supplies will be constrained by the extent to which Ukraine is able to restore its territorial sovereignty and the level of investment made to rebuild the energy sector. According to preliminary estimates, [3], over 80% of wind turbines and 13% of PV - Facilities in Ukraine are occupied or destroyed.

MATERIALS AND METHODS

The study employed a comparative methodology to ascertain the viability of hydrogen supplies from Ukraine to the EU in relation to three key factors: a) delivery distances, b) transport modes and c) electricity production costs from solar and wind energy, in comparison to other potential suppliers. These three factors are of significant influence on the overall costs of hydrogen deliveries. The feasibility of supplying hydrogen from Ukraine was assessed with a focus on Austria and Germany, which are centrally located in Europe and have a growing need for hydrogen, thus representing major consumer countries. Other considered countries with the potential to supply this energy source, included Spain, Tunisia, the United Arab Emirates (UAE), Romania, and Chile.

In addition to the analysis of statistical data, the assessment also took into account political considerations. One such consideration was the diversification of Europe's hydrogen imports. It was posited that a neighbouring and EU-associated country, acting as a hydrogen trading partner, may offer a more reliable source of supply in comparison to partner countries on other continents.

In order to facilitate comparison, the distances involved in the transportation of hydrogen were determined from the border of the supplier country to the nearest border point of Austria, which is the importing country. The specific distances between the two extreme points of the transportation distance were calculated using Google Maps, with consideration given to the availability of the appropriate transport infrastructure. The cost estimate for the production of hydrogen by the electrolysis method took into account the decrease in the cost of technologies in 2030 and 2040. It was assumed that the costs associated with the electrolysis of hydrogen and subsequent conversion of hydrogen into electricity would remain constant across all countries under

consideration. Those were thus not included in the comparative analysis. The comparison was limited to the costs of electricity generation and hydrogen delivery.

The paper additionally presents an analysis of the prospective hydrogen supply capabilities from disparate regions of Ukraine to Austria and Germany, contingent upon Ukraine's capacity to reclaim its territory.

RESULTS

The demand for hydrogen in Germany is projected to increase significantly: In its national hydrogen strategy, the German government has projected that the nation's hydrogen consumption in 2030 will reach a level that is estimated to be as high as 95–130 TWh. In alignment with the aforementioned figures, the objective is to construct an electrolyser capacity of between 5 and 10 GW by 2030 [4]. Green hydrogen is an important basis for achieving climate neutrality in Austria as well. According to calculations of Austrias environmental agency Austria's demand for hydrogen might amount to approx. 15 TWh to 29 TWh in 2040 [5].

The cost of hydrogen is falling just as fast as the cost of generating clean energy from solar and wind power plants: In Austria total installed costs for producing renewable energy fell by 55% between 2013 and 2020 [6].

In addition to the costs associated with the production of hydrogen, the transportation costs represent a significant financial consideration. The construction of new pipelines is estimated to increase the cost of hydrogen transportation to approximately €20/MWh over a distance of 3,000 km. In contrast, the utilisation of repurposed pipelines could potentially reduce this cost to approximately half [7]. From this distance, the transportation costs (including liquefaction) would increase fivefold in comparison to a converted pipeline. The total costs of importing hydrogen in a liquid form by ship would then be approximately 50-125% higher than the total costs of transporting hydrogen via pipeline (see Table 1).

Table 1: Costs of H2 logistics for different modes of transport. Source: [8]

Distance, km	Pipeline (gaseous) conversion, €/MWh	pipeline New building (gaseous), €/MWh	Ship (Ammonia), €/MWh	Rail (gaseous), €/MWh	Truck (gaseous), 500 bar MEGC, €/MWh	Truck (gaseous), 300 bar MEGC, €/MWh
1000	3,5	5	37	18,5	13,9	16,5
2000	7	9,5	38	37,08	27,8	33,1
3000	9	18	39	55,6	44,75	49,7
5000	17,25	23	41	92,66	69,5	82,9
10000	29	42	44	185	139	165

It may be feasible to utilise the existing gas pipeline infrastructure for the transportation of hydrogen, provided that the necessary retrofitting is undertaken. It is estimated that the additional costs of transporting hydrogen through reused pipelines would be approximately €3.50/MWh. The construction of new pipelines will increase costs to approximately €5/MWh for a distance of 1000 km. The total cost of hydrogen produced in Ukraine is therefore competitive when compared to the costs of producing it in

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Germany or Austria. For example, it is expected that the costs of electricity production in Germany in 2040 from wind energy (onshore wind energy) will amount to 36 bis 65 Euro/MWh, from solar energy (open-space photovoltaics) will be equal to 19 bis 35 Euro/MWh [9]. The corresponding costs for Ukraine are shown in the Table 2. and will amount to 16,8 Euro/MWh for onshore wind energy and 26,5 Euro/MWh for open-space photovoltaics.

In comparison to the transportation of hydrogen by truck, the pipeline is the more economical method for the conveyance of significant quantities of hydrogen over extended distances. The cost advantage of trucks is limited to short-haul transportation distances of up to 300 km [10].

A broad network with partners in different regions of the world could contribute to a diversified hydrogen supply. North and South American states such as the USA, Canada, Chile, Brazil, Argentina, some African states such as South Africa, Algeria Morocco, Egypt and Namibia, as well as certain Asian countries, could be considered. Nevertheless, at this time it is challenging to anticipate how substantial quantities of hydrogen can be transported to Europe in a cost-effective manner over extended distances [7]. Both the electricity production cost as well as the transport costs have to be considered when comparing Ukraine with other possible hydrogen suppliers.

Based on the above analysis, hydrogen from Ukraine to borders of Austria (route Chop-Vienna) could be cheaper than from North Africa to Austria (route Tunis-Villach via Italy), because hydrogen transport distances from Ukraine are 4 times shorter than from Tunisia (approx. 550 km versus approx. 2000 km). Transporting hydrogen to Austria from Algeria, Niger and Nigeria via Italy only increases this distance difference.

In North Africa, much higher amounts of investment would be required to expand the pipeline networks for hydrogen transport compared to retrofitting the Ukrainian part of the EU-oriented pipeline network (see Figure 1).

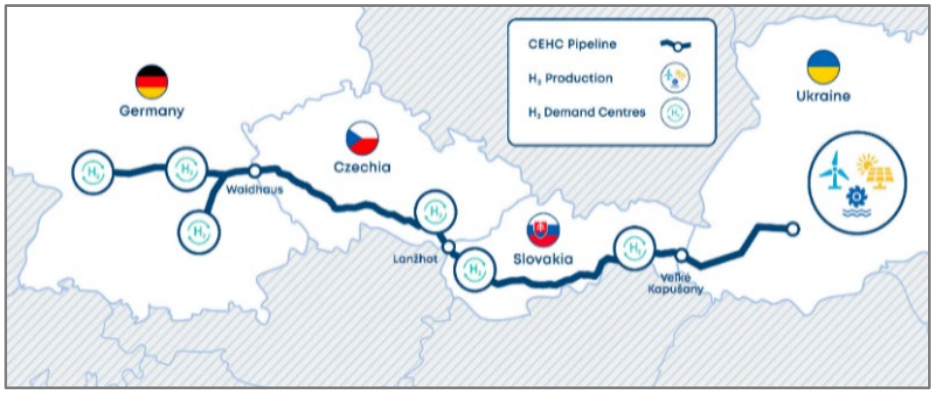


Figure 1: Pipeline networks for hydrogen deliveries from Ukraine to Europe. Source: [11].

In September 2021, four leading European companies in the energy sector - EUSTREAM gas transport infrastructure (Slovakia), operator GTS of Ukraine, NET4GAS (the Czech GTS operating company) and OGE (German GTS operating company) announced plans to lay a joint hydrogen pipeline from Ukraine to Germany via Central Europe. This hydrogen pipeline could deliver up to 120 GWh of energy per day (43.800 GWh or 43,8 TWh per year). This would be possible because of the conversion of the already existing natural gas pipeline in combination with targeted investments in new specialized hydrogen pipelines and compressor stations [11].

Climate-neutral and thus green hydrogen produced from sun and wind in Ukraine could then be used for seasonal structuring of the domestic and European energy supply in line with demand.

The European Hydrogen Backbone initiative (EHB) aims to deploy a hydrogen network with a length of almost 40,000 km by 2040, connecting 21 European countries. 75% of this hydrogen network is planned to be composed of existing (retrofitted) gas infrastructure. The remaining 25% of the gas pipelines will be newly built [12].

Naftogaz JSC and Ukrtransgaz, the gas storage operator of Ukraine, joined the H2EU+Store project, which aims to produce hydrogen in Ukraine and export it to Germany, including existing pipelines. In addition, the creation of a hydrogen corridor "Ukraine-Europe" is envisaged [13].

The green hydrogen produced in Ukraine is planned to be fed into the international gas transport network of western Ukraine by 2030 and transported to RAG Austria's energy storage facilities via the gas pipeline systems of Slovakia and Austria (Figure 1).

The delivery of hydrogen from Ukraine could take place from Transcarpathia to Vienna through the Slovak part of the Druzba pipeline. The electricity production costs and transport distances of respective variants of hydrogen deliveries in the EU are shown in Table 2.

Table 2: Electricity production costs from renewable energy sources by country, euros/ MWh. Source: own calculations using [8], [14]

Country	Spain	Tunisia	Romania	Chile	UAE	Ukraine		
Electricity production costs, euros/ MHw (WACC 6%)								
PV 2030	28	29	34	39	25	32		
PV2040	24	24,5	27	32	20,5	26,5		
Wind 2030	27	33	33,5	19	32	21,5		
Wind 2040	22	25,5	26	15	25	16,8		
Transportation costs, euros/ MHw								
Transport distance, km (to the nearest border of Austria)	2000	1650	1650	13800	7800	550* (Austria) 822** (Germany)		
Preferred mode of transport	Pipeline (New building)	Pipeline (New building)	Inland waterway transport	Ship (LH2, ammonia, LOHC)	Ship (LH2, ammonia, LOHC)	Pipeline		
						A***	B	C
Transportation costs, euros/ MHw	9,5	7,83	37,82	47,599	42,799	1,44/ 2,14	1,92/ 2,87	2,75/ 4,11
Total costs for hydrogen deliveries, euros/ MHw*								
PV 2030	37,5	36,83	71,825	83,599	67,799	33,44/ 34,14	33,92/ 34,87	34,75/ 36,11
PV2040	33,5	32,33	64,82	79,599	63,299	27,94/ 28,64	28,42/ 29,37	29,25/ 30,61
Wind 2030	36,5	40,83	71,32	66,599	74,799	22,94/ 23,64	23,42/ 24,37	24,25/ 25,61
Wind 2040	31,5	33,337	63,825	62,599	67,79	18,24/ 18,94	18,72/ 19,7	19,55/ 20,91

** Pipeline (Chop-Vienna route) - section; ** Pipeline (Chop-Waidhaus route)-entire route oriented towards Germany, the main EU consumer of Hydrogen. The transport distances were determined using Google Maps, taking into account the route of each pipeline branch (if such*

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*exists or is planned). ***a) Hydrogen admixture to natural gas b) Rededication of the natural gas pipelines c) New building*

If the hydrogen is transported from Ukraine to Austria or Germany (to the nearest border point of this countries), the transport distance via pipelines will not exceed 2.000 km - depending on which area of Ukraine the hydrogen will be delivered from. A key role in the development of transport options for hydrogen to the EU lies in converting natural gas pipelines.

Should the hydrogen production capacities in Ukraine be expanded in accordance with the National Hydrogen Strategy, Ukraine could emerge as a significant exporter of hydrogen and a key player in the European Union's hydrogen market (see Table 3). Overall Ukraine has a significant potential for the production of green hydrogen (337-505 TWh/year) [13].

Table 3: Hydrogen demand in Germany and Austria until 2050, TWh. Sources: own calculations using [5], [11]

Year	Germany	Austria	Ukraine
2030			
Production	19	4,35	4,5
Requirement	110	12	0,81
Net import	91	7,65	Export-3,69
2040			
Production	40	27	43,8
Requirement	225	47	10,95
Net import	185	20	Export-32,85
2050			
Production	215	40	126,58
Requirement	380	59	34,97
Net import	165	19	Export-88,6

The average transport distance of hydrogen from North Africa (pipeline across the territory of Nigeria, Niger, Algeria, Tunisia) to Italy exceeds 3.500 km**,** to countries in Central Europe (e.g. Austria, Poland, Slovakia, Slovenia, the Czech Republic, Hungary and parts of Germany) the delivery distance would be higher than 5,000 km.

DISCUSSION

The analyzed options for transporting hydrogen to Austria and Germany are not exhaustive and, of course, leave room for discussion. Much will still depend on political will and the search for investors. In addition, not only the costs of production and transportation of hydrogen should be taken into account, but also the total potential of its production and transportation.

The potential of the Ukrainian pipeline infrastructure after the upcoming retrofit could amount to a hydrogen export of 43.8 TWh per year towards Germany in 2030 [15]. As the diversification of supply sources is an important goal for EU countries, parts of these amounts of hydrogen could also be fed into Austrian power grids. Austria's central location in Europe may open up opportunities for cooperation in the expansion of grid networks. The possibility of importing gas via the Ukrainian pipeline could work most effectively if hydrogen and natural gas are supplied in a mixture. Therefore, the share of

hydrogen should not be less than 10 %. An admixture of 20% hydrogen by volume does not have any particular effect on the components of the natural gas network. A maximum of 70% by volume blending has been investigated and found to be potentially suitable [16]. As a result, Austria could import hydrogen-blended natural gas until 2040 in order to meet its climate neutrality targets.

Kathan et al. [14] also consider Spain, Romania, Chile, Tunisia and United Arab Emirates (UAE) as potential hydrogen suppliers for Austria. Spain, UAE and Tunisia have better conditions for electricity generation from PV plants, whereas Romania and Chile are cheaper countries for electricity generation from wind energy.

Transporting hydrogen from Chile to Austria could be done by ship using a large Hydrogen Hub located in the Port of Rotterdam. From Tunisia to Austria it could be done via an offshore hydrogen pipeline and the European hydrogen backbone in Italy. For transport from Romania to Austria, an inland waterway route via the Danube to Vienna would be suitable. Unlike the other transport routes, this would not require a pipeline. With the help of the LOHC-technology (Liquid Organic Hydrogen Carrier) developed by the company Hydrogenous, green hydrogen can be stored and transported safely and efficiently: The highly flammable gas therefore gets bound to oil and can later be released again [17]. This way the hydrogen (in the form of a liquid-organic hydrogen carrier) could be transported directly to Vienna, nevertheless this would require an import hub (with appropriate infrastructure) within Austria. Transport from Spain would take place exclusively via a hydrogen pipeline. For transport from the UAE to Austria, a shipping route across the Red Sea and the Mediterranean to northern Italy could be used [14].

Nevertheless, the primary challenge associated with the supply of hydrogen from Spain to Central European countries is the necessity for an expansion of the existing gas pipeline networks, a process that is projected to be completed by 2027. At that point, full integration to Germany's power grid will be achieved. So far, there are only two smaller pipelines across the Pyrenees to Francey. Generally, hydrogen supplies from Spain are not likely to solve the problem of meeting the growing demand for hydrogen in the EU in the short term. It is only one of the options to expand the renewable energy market in the EU.

The weighted arithmetic mean of the distances from production sites in Ukraine to entry sites in Slovakia is 977,29 km. Such a distance allows for lower H2 logistics costs compared to H2 delivery from North Africa (route Nigeria-Tunisia) to Austria via Italy.

The higher solar activity levels in North African countries like Tunisia, provide an advantage when it comes to the efficiency of solar systems. This is due to the fact that North African countries receive more solar radiation than countries like Ukraine. In contrast, Ukraine has better natural conditions for generating wind energy (in the south-east of the country and in offshore areas) [13].

Considering transport distances, the length of existing natural gas pipelines and the costs of electricity generation from renewable energy sources, Ukraine has sufficient competitiveness to export hydrogen to Austria, Germany and the EU as a whole.

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CONCLUSION

Ukraine is well positioned to become a competitive supplier of hydrogen to the European Union (EU). Its proximity to Austria and Germany offers a geographical advantage, while favorable climatic conditions for the generation of green electricity and a developed pipeline network provide logistical benefits. Furthermore, due to the political implications, an EU-associated country can be regarded as a more dependable partner in the development of the pan-European energy system. It is reasonable to conclude that Ukraine will be capable of exporting 88 TWh of hydrogen by the year 2050.

The existing pipelines have the potential to be rebuilt to allow for an increase in the proportion of hydrogen in the mixture with natural gas. The potential of transporting hydrogen through pipelines with a hydrogen content exceeding 70% in order to diminish the consumption of natural gas is a particularly salient area of research. The European gas pipeline network is in a state of active expansion, thereby enhancing the potential for the supply of green hydrogen from Ukraine.

In order to implement the energy transition and achieve climate neutrality in 2040, the use of hydrogen must be seen in the context of a holistic energy policy - together with measures to make the energy system more flexible, progressive digitization and the expansion of renewable energies, as well as increasing energy efficiency.

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PARTICULARITIES OF HYDROGEN COMBUSTION IN A NON-PREMIXED DIFFUSIVE REGIME WITH ACCOMPANYING AIR JETS, EITHER COAXIAL OR PARALLEL

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ABSTRACT

Hydrogen-based energy production involves the use of fuel cells or the direct combustion of hydrogen (a particular case being hydrogen combustion in internal combustion engines). Direct hydrogen combustion is still in the testing phase, with challenges arising from its energetic properties, which continue to be a difficult factor. For instance, hydrogen has a low calorific value (about three times lower than methane) in its gaseous phase, which is the phase where combustion occurs, a very high combustion speed (about eight times faster than methane), and wide concentration limits in air for ignition (explosion). From a thermodynamic perspective, the adiabatic combustion temperature is very close to that of methane, while the ignition energy is very low. When hydrogen is mixed with methane in proportions of up to 15%, it has been noted that all combustion systems designed for methane, particularly those using kinetic combustion technology (with air-gas premixing), can still operate effectively. However, transitioning to higher hydrogen proportions, up to 100%, and increasing the thermal power of burners present significant challenges that must be addressed through the use of diffusive combustion with separate fuel-air jets. This becomes essential to prevent flashback and ensure high flame stability. The paper presents an approach to diffusive combustion of pure hydrogen or hydrogen mixed with gaseous hydrocarbons, along with a detailed analysis of optimization using jet gas dynamics. The paper also presents a prototype burner with separate jets and preliminary results regarding its performance.
Keywords: hydrogen; diffusive combustion; prototype burner; methane; hydrocarbon

INTRODUCTION

Regarding the combustion of a gaseous fuel, it is specified that two completely different technologies can be used, namely, [1]:

- the combustion of an air-gaseous fuel mixture, known in physics as kinetic combustion;
- combustion with separate jets of air and gaseous fuel, known as diffusive combustion, because the processes are governed by the diffusion of one gas into the other.
- diffusive combustion can be achieved in most cases through the presence of concentric coaxial gas-air jets or through the presence of accompanying lateral jets.

Figure 1 shows a schematic of the construction and operation of burners for the two types.

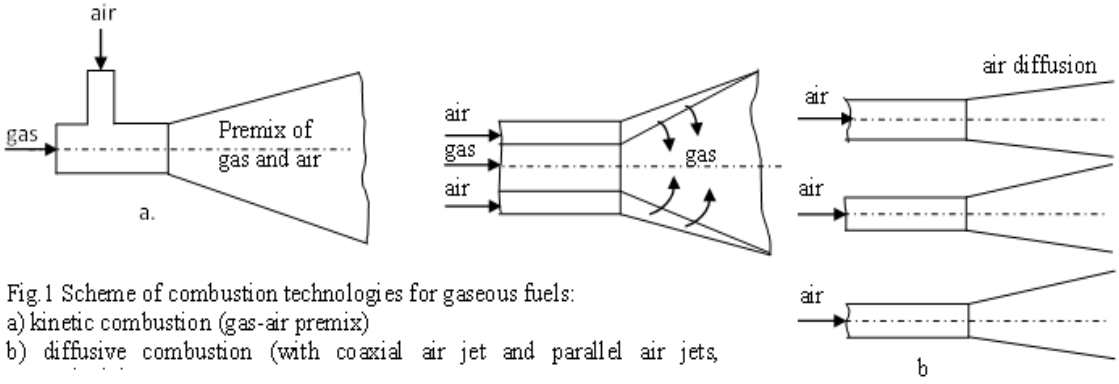


Fig.1 Scheme of combustion technologies for gaseous fuels:
a) kinetic combustion (gas-air premix)
b) diffusive combustion (with coaxial air jet and parallel air jets,

The stability of gas-air combustion is achieved when the flow speed "u" is equal to the burning speed u_a (the burning speed is opposite to the flow and perpendicular to the flame front):

$$u = u_a\ [m/s] \tag{1}$$

The burning speed depends on the dynamic flow regime, distinguishing:

- laminar burning velocity $u_L\ [m/s]$;
- turbulent flow velocity $u_T\ [m/s]$.

The existence of the air-fuel premix, for the case of the flow speed below the combustion speed, leads to the return of the flame to the burner body, a very dangerous process. Otherwise, the flame is extinguished by ejecting it from the jet. These aspects lead to the characterization of the air-gas mixture flame with reduced stability.

The burning speed is maximum for a stoichiometric gas-air mixture, and it decreases with the decrease or increase of excess air, which also explains the existence of flame extinguishing (explosion) concentration limits. For diffusive combustion, the penetration of air into the combustible gas jet defines the appearance of the surface that characterizes the stoichiometric concentration - fig 2.

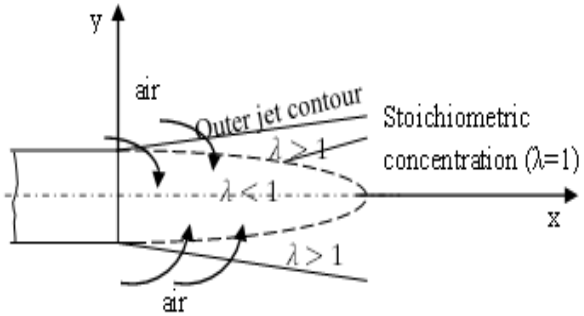


Fig 2. Diffusion of air in the gas jet and definition of the stoichiometric concentration surface (unit air excess, λ=1).

Combustion stability in an axial x and radial y coordinate process implies the equality between the flow speed and the combustion speed - fig 3.

For a jet, the flow velocity at a point x, y is defined by the relation:

$$u_{x,y} = u_0 \frac{1}{\bar{x}} e^{-(y^2/x^2)} \quad [m/s] \tag{2}$$

where u_0 is the speed at the exit from the embrasure, and $\bar{x}$ the relative axial distance ($\bar{x} = x/r_0$).

The geometry shown in figure 3 indicates the existence for any x coordinate and flow velocities of the stability point. When traveling the flow distance x, a stability curve results, which for the cylindrical aspect of the jet leads to a cylindrical combustion stability surface.

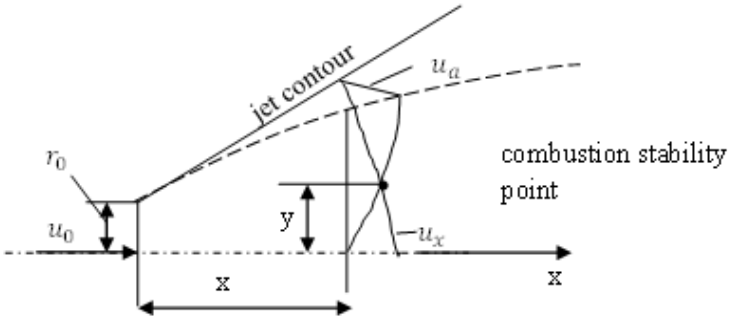


Fig 3. Combustion stability in the case of diffusive jets

Hence the conclusion that kinetic combustion is very stable. The turbulent burning speed depends on the temperature and the criterion R_e for the flow,[2]:

$$u_T = f(u_L, T, R_e) \tag{3}$$

1. Particular aspects of hydrogen combustion

Hydrogen is a difficult gaseous fuel because:

- the density is very low: $0.09\ kg/m^3$;
- very low calorific value: $H_i = 10.8\ MJ/m_N^3$ (H_i being the lower calorific value);
- very low laminar burning speed: $u_L = 3.1\ m/s$

By comparison, methane has $\rho = 0.716\ Kg/m_N^3$, $H_i = 35.7\ KJ/m_N^3$ and $u_L = 0.4\ m/s$.

The calculation of the combustion adiabatic temperature T_ad shows very close values between hydrogen and methane [3]:

- methane; $T_{ad} = 1946^0C$;
- hydrogen; $T_{ad} = 2101^0C$.

As the emission of NO_x depends on the combustion of a gaseous fuel on the value of the combustion adiabatic temperature,

$$NO_x \sim T_{ad}\ [mg/m_N^3] \tag{4}$$

results in an insignificant increase of it when using hydrogen, [4].

Most technical applications use a $CH_4 - H_2$ mixture, with the proportion of hydrogen up to 30% (usually 5 – 15%).

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These burner applications depend on the value of the Wobbe criterion (W_o). Its reduction compared to methane requires interventions on the burner nozzle. Figure 4 shows the change in the W_o criterion when the methane-hydrogen mixing increases (for methane, the unit value was considered).

$$W_o = \frac{\sqrt{p}\, H_i}{\sqrt{\rho}} \tag{5}$$

where: p is the gas pressure at the burner level, in bar;
H_i – lower calorific value, $[KJ/m_N^3]$;
ρ – gas density at the burner level, kg/m_N^3.

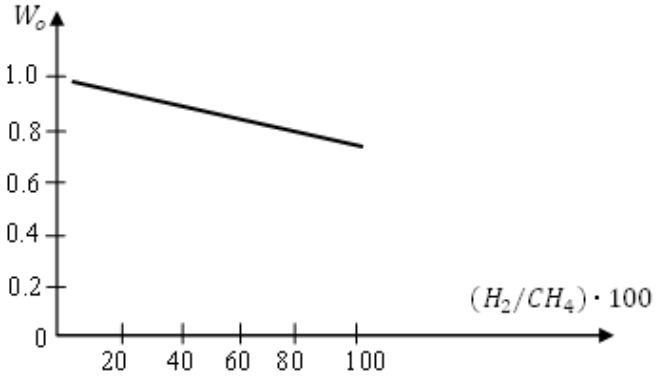


Fig 4. Variation of the W_o criterion according to the mix

Analyzing the value of the figure W_o, it follows that for $CH_4 - H_2$ mixtures of up to 15% H_2, no problem arises requiring changes to the CH_4 burners. This is important, for residential applications when injecting H_2 into the network of CH_4, at the pressure p already existing in the whole network [5], [6], [7].
The high turbulent speed of strong combustion for pure hydrogen, or in a mixture of more than 70% with methane, requires the use of high speeds, in correlation with its decrease along the axial direction, in order to be able to achieve the condition of combustion stability (relation 1).
Research on the flow, carried out by the authors, led to the recommendation for the speed of the jet at the exit of the nozzle to respect the condition:

$$u_0 = 10 S_T \tag{6}$$

Bollinger's relationship for the turbulence velocity starting from the laminar one S_L introduces the R_e criterion for temperatures and the flow regime [3]:

$$S_T = 0.1\, S_L d_o^{0,26} R_e^{0.24}\ [m/s] \tag{7}$$

2. Results of the modeling of thermochemical percentages from the jets for H_2

The numerical modeling was carried out with the help of the AMSYS – RLUENT program V.14.0 , [8], [9], [10]. Figure 5 shows the dimensions of the burner and the calculation domain. The speed in the exit sections of the burner was adopted at 120 m/s, and of the air at the same value of 120 m/s (air accompanying jet speed/jet speed ratio of H_2, $\Phi = 1$). For these conditions, the evolution of the combustion was very efficient, the maximum temperature being reached at a distance $x = 150\ mm$. The

decrease of the air speed to 36m/s ($\Phi = 0.3$) led to the length of the flame, the maximum being around 300 mm.

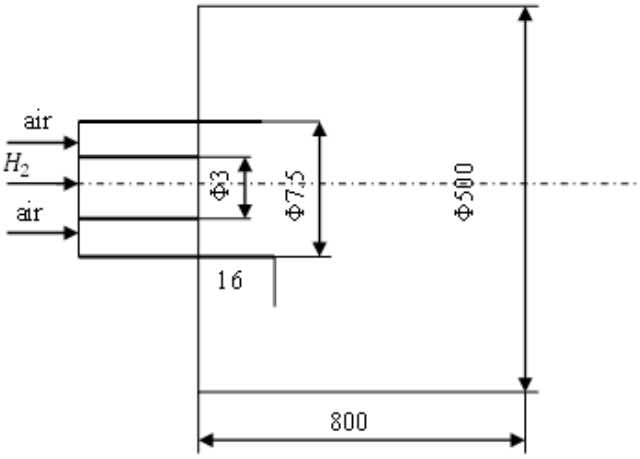


Fig.5. Modeling domain for H_2 and CH_4 combustion

Figure 6 summarizes the data regarding the evolution of the flame regarding the evolution of the thermal field. The same conclusion, regarding the length of the flame as the accompanying air velocity decreases, also results for methane, as stated in fig. 6.

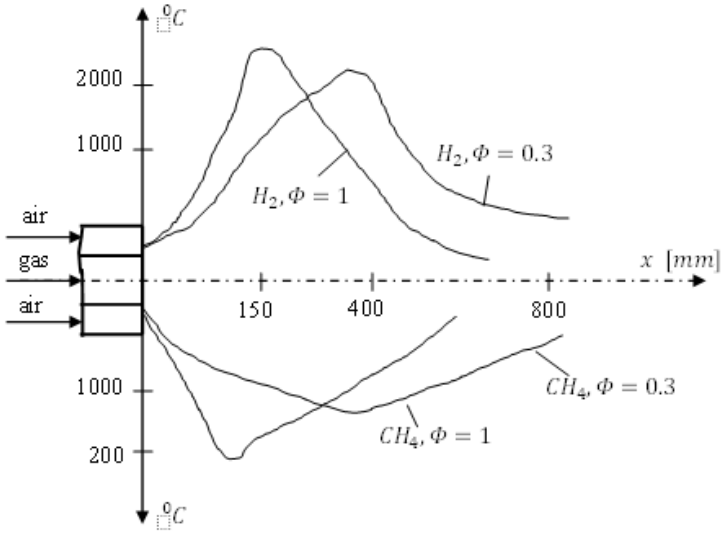


Fig.6. Temperature evolution for the analyzed model

Research has highlighted the importance of using an air velocity as close as possible to that of the gaseous fuel. For aerodynamic, but also economic reasons, the reduction of the accompanying air speed up to $\Phi = 0.3$ (a third of that of the gas) was studied, [11], [12]. The non-mixed combustion of hydrogen still creates a problem regarding the ignition phase and the evolution of the combustion process along the jet, [13], [14].

3. Combustion experiments of H_2 combustion pure or mixed with hydrocarbons

The experiments were carried out with the help of a diffusive pilot burner, which includes three combustion modules, each module having a combustible gas jet enclosed by five air jets - fig.7. The burner was designed to achieve a thermal output

of 25 KW, when operating with H_2; CH_4; $0.9\,CH_4 + 0.1H_2$; $0.3\,C_3H_8 + 0.7\,C_5H_2$; $0.3\,C_3H_8 + 0.65\,C_5H_2 + 0.05H_2$.

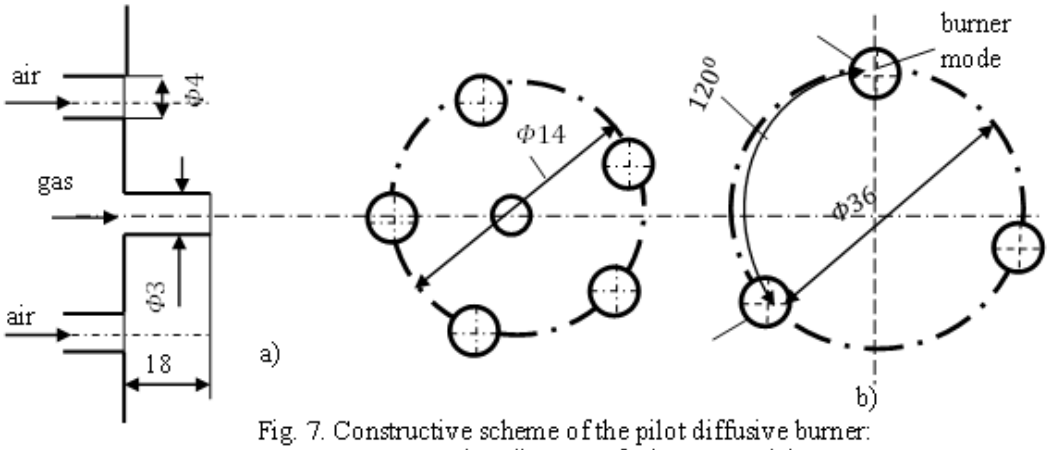


Fig. 7. Constructive scheme of the pilot diffusive burner:
a – construction diagram of a burner model;
b – placement of the modules at the burner shaft

The developed combustion system can be extended and adapted also for gas turbine combustion chambers [15]. The gas-dynamic parameters of the burner in the embrasure (output of gas and air jets) are presented in table no.1.

Burner nominal data (excess air $\lambda = 1.05$) Table no. 1

Fuel gas	Gas flow $[m_N^3/h]$	Gas speed, $[m/s]$	Air flow, $[m_N^3/h]$	Air speed, $[m/s]$	Speed ratio coefficient $[\Phi]$
H_2	7.5	100.0	19.0	30.0	0.3
CH_4	2.4	33.0	24.2	36.0	1.0
$0.9\,CH_4 + 0.1H_2$	2.5	35.0	23.0	36.0	1.0
$0.3\,C_3H_8 + 0.65\,C_5H_2 + 0.05H_2$	1.0	13.5	11.5	12.9	1.0

The constructive data allow experimenting with the mixture of hydrogen with gaseous hydrocarbons for high air speeds, characterized by the coefficient $\Phi = 1$. For the fuel gas jet, the recommendation was followed that its speed in the exit section should be over 10 times the value of the combustion speed (which has a value of 3.1 m/s for hydrogen, 0.4 m/s for methane and about 0.9 for the mixture of butane, propane and hydrogen.

Preliminary tests have shown good combustion stability, with flames forming at the base of the exit section of the jets. Figure 8 shows images of the flames. The lateral air intake allowed a reduction in the length of the flames, which usually did not exceed 400mm. It is necessary to continue the research, for a better monitoring of the

geometry of the flame, the temperature field and the pollutant emissions, aspects that are part of the future research.



Fig. 8. Aspects of the combustion process

CONCLUSIONS

The work addressed the difficult aspects, in the process of being solved, regarding the combustion of pure hydrogen or partially mixed with hydrocarbons in the technology of non-mixing with air.

The basis of the approach was the achievement of the agreement between the gas dynamics of the fuel and air jets with the burning speed, in order to achieve a stable combustion. This requires the observance of strict limits regarding the speed of the jets at the level of the exit from the respective nozzles.

The combustion of pure hydrogen was studied by numerical simulation. A new combustion predictability criterion, Φ, was introduced, defined as the ratio between the air and fuel velocity at the exit of the burner nozzle.

The paper concludes with a presentation of a 25KW pilot burner, and preliminary data from its testing.

ACKNOWLEDGEMENTS

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POPLAR BIOMASS PRODUCTION IN TEMPERATE-CONTINENTAL PLAIN CONDITIONS

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ABSTRACT

Biomass is the first form of energy used by man at the same time with the discovery of fire, means all the products of animal and vegetable origin used in present in the production of energy. Actually, the biomass approximately half (44-65 %) of the total renewable energy sources used in the EU, and occupies a third place as a primary energy source in the world, after coal and oil. At the same time represents a sustainable alternative to reduce carbon emissions.

The experimental territory is located in the middle of the low plain area of the Western Plain in Romania at an altitude of 80-90 meters. The climate is temperate-continental, with Mediterranean and oceanic influences, the average annual temperatures are 10-11 degrees Celsius. Precipitation shows some particularities, but on average the average annual amounts recorded are 500-600 mm.

The purpose of the present study, the production potential of a poplar energy crop located in the low plain in Romania. A pure culture was analyzed in terms of biomass production over a 6-year production cycle under optimal culture conditions. Development parameters such as survival rate and plant height were analyzed, as well as production parameters such as dry matter content and biomass production. Also, a culture technology characterized by low energy consumption was used, i.e. without the application of irrigation, or fertilization.

Finally, the study wants to convince that the energy poplar culture is particularly productive in a 6-year production cycle and also constitutes a very good alternative to using agricultural land unsuitable for other crops.

Keywords: biomass, poplar production, renewable energy

INTRODUCTION

Renewable energy is that energy produced from renewable resources replenished naturally on a human scale, these include sources such as: sunlight, wind, rain, tides, waves, geothermal heat, etc. [1]. It is considered that the largest source of energy from renewable sources is biomass. As the development of society is done with equal energy consumption, man decides that he needs more energy from renewable sources, which is why the importance of biomass also increases.

Initially, biomass was seen as a use of agricultural or forestry waste [1; 2]. Starting from the consideration that biomass is the most abundant renewable resource on the planet,

we include in this category all the organic matter produced by the metabolic processes of living organisms. Biomass is the first form of energy used by man, with the discovery of fire.

An increase in energy production from renewable energy sources in Europe is absolutely necessary to reduce emissions but also to meet other objectives, such as those related to the security of energy supply [3; 4]. The European Union through legislative and financial instruments supports the transition towards obtaining energy with low carbon emissions, in this regard, fast-growing trees play a particularly important role as renewable raw materials in different land use systems, but at the same time they also contribute to mitigating climate change [5].

Nowadays, obtaining biomass from short-term energy poplar crops is also associated with related benefits such as: phytoremediation, carbon capture from the soil, reduction of sediment runoff, improvement of soil quality and wildlife habitat [6; 7]. In other words, poplar grown for the purpose of obtaining bioenergy can be an important component of solving the economic and environmental problems of the 21st century, as both the human population and greenhouse gases increase [8].

It is known that the poplar is a species used since ancient times due primarily to the ease with which it can propagate vegetatively. Thus, at the end of the 18th century, the American black poplar (*Populus deltoides* Marsh.) and the European black poplar (*Populus nigra* L.) were introduced to Europe, naturally resulting in hybrids of these species, with very fast growth at young ages, revolutionizing the cultivation methods of these species and the creation of specialized plantations.

In Romania, hybrid poplars were planted in parks or as ornamental trees and then, between 1915 - 1950, in specialized plantations providing raw material for pulp and paper factories.

Poplar is also one of the woody species cultivated in a short rotation (SRWC). Short rotation is represented by a harvest period every two to five years [9]. The poplar crop is much more suitable for producing biofuels than many other woody crops due to its rapid growth, the ability to produce a significant amount of biomass in a short period of time, and its high cellulose and low lignin content. In addition, the development of high-yielding genotypes associated with increased adaptability and easy vegetative propagation has made poplar a commercially valuable energy crop [10; 11].

MATERIALS AND METHODS

Experimental conditions

The experimental territory was located in the middle of a low plain area, its altitude, 80-90 meters, is lower than that of the adjacent plains. The climate is temperate-continental, with Mediterranean and oceanic influences, because it is sheltered by the Carpathian chain that stops cold air masses from the north and northeast and allows the penetration of maritime ones from the west and southwest.

Average annual temperatures are 10-11 degrees Celsius, winters are mild, with average temperatures of -2 degrees Celsius, springs are early, short and with large temperature variations, summers are hot and long, with average July temperatures of 22- 24 degrees Celsius. The precipitation shows some particularities compared to other plain areas in the country.

The average annual amounts recorded are 500-600 mm, the most abundant being at the end of spring and the beginning of summer, in June (65-90 mm), and the lowest in February (25-35 mm)

The purpose of the study

The purpose of this study is to record and compare the major growth parameters of a poplar crop over a period of six years, including two harvests under real production conditions. Development parameters such as survival rate and plant height were analyzed, but also production parameters such as dry matter content and biomass production. The culture technology represented also an important part of the research.

RESULT

The technology applied in the energy poplar plantation

The energetic poplar cultivated in short rotations has high requirements regarding climatic conditions, soil and water. For high productivity, it requires a growing season of at least 180 days and high temperatures, especially from June to September, when the average temperature should be 17 °C. For these reasons, a land was selected that would satisfy the requirements of the poplar, namely in the low plain area, its altitude, 80-90 meters, with a drainage slope is very slow and the low depth at which the groundwater.

The planting material came from Italy and it is a hybrid coded HPI-1, the shoot length was between 20-22 cm with two buds with a diameter of 1.5-3.0 cm, so that the second bud should be at ground level. The preparation of the land consisted of carrying out a basic mobilization of it carried out with the help of disks, then a deep plowing at 35 cm to ensure a good rooting of the planted cuttings. Planting was done at a depth of 3-5 cm from the soil surface, with freshly cut cuttings that were immediately planted. The optimal period of (October-November) was respected and the diseased plants were removed.

In the autumn after the first year of vegetation, 48 kg N, 144 P and 144 kg K were incorporated to each hectare, after each biomass harvest nitrogen was applied in the amount of 80–120 kg/ha.

Harvesting and production quality

The harvesting of poplar wood mass was carried out after the fall of the leaves and was carried out until almost the end of March.

DISCUSSION

The practices of using lands occupied with energy crops often start from the premise of capitalizing on agricultural lands that are affected by degradation phenomena at different stages, with a production capacity affected by limiting factors when they are intended for agricultural uses traditional.

The hybrid genotype of Italian origin HPI-1 showed a production potential compared to other studies in the field under conditions of maximum density of 6.6 thousand pieces of cuttings planted per hectare with a distance between rows of 3.5 m, and the distance between the plants in a row of 0.6 m. thus, under these conditions, a statistically significant constant growth was recorded starting with the 3rd year of growth of 41.2 kg, which corresponds to a production of 70-80 mc/ha/final cycle of 6 years.

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Poplar -first year of vegetation



Poplar -the third year of vegetation



Poplar -the fourth year of vegetation



Poplar -the sixth year of vegetation

Figure 1. Stages of exploitation and experimentation of the energetic *Populus alba* culture, source: [1], photo Vlad Cândea

According to several researches in the field [12; 13; 14] the production potential of the energy poplar agricultural crop with a short production cycle was evaluated based on plot averages. According to these researchers, biomass production is influenced by the genotype of the poplar variety. The superior yields were obtained in the genotypes Fritzi Pauley" (44.3 kg) and "NE-42" (42.4 kg), which corresponds to an annual dry mass production by "NE-42" and "Fritzi Pauley ” of 8Mgha−1. The calorific value guarantees as a safe and non-polluting source of energy a value of 17,000 - 18,000 kJ/kg), without excessive emission of carbon dioxide.

Another series of research highlights the importance of planting density, densities ranging from 400 to 80,000 plants/ha were used, where productions between 327 m^3/ha and 485 m^3/ha were recorded, or an annual average of 41.0 to 53.9 m^3/ha, obtained in a production process lasting from 8 to 10 years.

CONCLUSION

Finally, the study wants to convince that the energy poplar culture is particularly productive in a production cycle of 5 or 6 years and also constitutes a very good alternative to using agricultural land unsuitable for other crop plants. The energetic poplar plantation where the current study was carried out belongs to the category of plantations with a short rotation period, which have a fast growth, this energy culture has demonstrated that the finished product has a caloric power/kg of 4.95 kWh, in time that the calorific value of a kilogram of deciduous wood is 3.1-4.2 kWh.

The study also demonstrates that the cultivation of energy poplars in the Western Plain region of Romania (Banat Plain) represents a promising balance between renewable energy production and environmental sustainability [15].

It is thus scientifically proven that the energy poplar culture protects the forests from continuous deforestation caused by the rush for cheap firewood that makes good use of land unsuitable for other crops, such as, for example, floodplains, around sewage treatment plants, etc.

At the level of 2024, Romania has planted energy poplar crops only on an area of approximately 2,000 hectares, which can be harvested once every five or six years, because their root remains in the ground and regenerates.

The study of specialized literature shows that the use of energy crops to produce biomass contributes to maintaining or restoring the hydrological balance, improving some physical and chemical properties of the soil, reducing soil and deep-water pollution, maintaining a high biodiversity by supporting natural trophic cycles, etc.

ACKNOWLEDGEMENTS

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RISK ASSESSMENTS IN TERMS OF OCCUPATIONAL HEALTH AND SAFETY FOR 220 kV TIMIȘOARA POWER SUBSTATION

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ABSTRACT

Based on the principles of prevention, the employer must seek to eliminate risk at source and, in order of priority, to replace hazards through non-dangers, to separate or isolate areas where there are hazards, ensuring adequate collective and individual protection. However, workers from high and very high voltage power substations continue to be exposed to occupational hazards, suffering accidents at work and occupational diseases with significant repercussions on their health, on colleagues or National Power System. Accidents at work and occupational diseases are the unseen face of wage labor, industrialization and economic development. Unfortunately, they are most often the general concern of society when tragedies occur, as was the case with explosions, of collective accidents with many victims or of particularly dangerous incidents that could have had dramatic consequences. According to the Law on Occupational Health and Safety no. 319/2006, the event means the accident that caused the death or injuries of the body, produced during the work process or in the performance of duties, the situation of missing person or the accident of route or traffic, under the conditions in which employed persons were involved, the dangerous incident, as well as the case susceptible to occupational or occupational disease.

Keywords: Risk assessment, Occupational Health and Safety, Power substation

WORK ACCIDENT PREVENTION NOTIONS

In accordance with the provisions of art. 5, letter e of the Law on Occupational Health and Safety, no. 319/2006, prevention is all security and safety measures taken by the employer and the employee to secure all place of works within an entity, that the working personnel carry out their work safely without jeopardizing their personal integrity. Prevention depends on several aspects: legislative domain, size or structure of the entity, number of hours worked, work procedure and quality prevention personnel. [1, 2]

Labor and those produced in the following circumstances shall also be considered as accidents: [3, 4]

- the accident suffered by persons visiting the enterprise and / or unit with the permission of the employer;

- the accident suffered by persons performing state or public interest tasks, including in cultural, sports activities, in the country or abroad, during and due to the performance of these tasks;
- the accident occurred within the organized cultural-sports activities, during and due to the fulfillment of these activities;
- the accident suffered by any person as a result of an action taken on their own initiative to save lives;
- the accident suffered by any person, as a result of an action taken on their own initiative to prevent or eliminate a danger that threatens public and private property;
- the accident caused by activities unrelated to the labor process, if it occurs at the legal entity's premises or at the address of the natural person, as an employer, or in another job organized by them, during the work schedule and is not due to the exclusive fault of the injured party;
- the route accident, if the trip was made during and on the normal route from the worker's home to the workplace organized by the employer and vice versa;
- the accident suffered during the trip from the legal entity's premises or from the natural person to the workplace or from one workplace to another, for the performance of a work task;
- the accident suffered during the trip from the legal entity's premises or from the natural person to whom the victim is employed, or from any other workplace organized by them, to another legal or natural person, for the performance of work tasks, during the normal period of travel;
- the accident suffered before or after the cessation of work, if the victim takes over or teaches the work tools, work, machinery or materials, if he changes his personal clothing, personal protective equipment or any other equipment provided by the employer, if he was in the bathroom or in the laundry or if he was moving from work to leaving the company or unit and vice versa;
- the accident suffered during the regulatory breaks, if it took place in places organized by the employer, as well as during and on the normal route to and from these places;
- the accident suffered by workers of romanian employers or by romanian individuals, delegated for the performance of service duties outside the country, during and during the route provided in the travel document;
- the accident suffered by romanian personnel performing works and services on the territory of other countries, based on contracts, conventions or other conditions provided by law, concluded by romanian legal entities with foreign partners, during and due to the performance of service duties;
- the accident suffered by those taking qualification, retraining or improvement of professional training courses, during and due to the performance of activities related to the internship;

- accident caused by natural phenomena or calamities, such as storm, blizzard, earthquake, flood, landslides, lightning, if the victim was in the process of working or in the performance of duties;
- disappearance of a person, in the conditions of an accident at work and in circumstances that justify the assumption of his death;
- the accident suffered by a person in the performance of his duties, as a result of an aggression.

The formula for calculating the *global risk level* – N_r is the following:

$$N_r = \frac{\sum_{i=1}^{n} r_i \cdot R_i}{\sum_{i=1}^{n} r_i} \quad (1)$$

where:

N_r - the level of global risk in the workplace;

r_i - risk factor ranking „i";

R_i - level of risk for the risk factor „i";

n - number of risk factors identified at the workplace.

The level of security (Ng) at workplace is identified on the risk/security level mapping scale, built on the opposite proportionality of risk and security levels. Both the global risk level and the safety level are recorded in the workplace sheet. In the case of macro-systems assessment (sector, section, company), the weighted mean of the average safety levels determined for each workplace analysed in the macro-system component (similar workplace are considered as a single workplace) has to be calculated so that to obtain the *global level of safety at work* for the workshop/section/sector or enterprise under investigation – Ng:

$$N_g = \frac{\sum_{p=1}^{n} r_p \cdot N_{rp}}{\sum_{p=1}^{n} r_p} \quad (2)$$

where:

Ng = the overall risk level of the power substation;

rp = workplace rank p, equal to the risk level of the workplace;

n = number of workplaces;

Nrp = is the level of overall workplace risk.

WORK ACCIDENT ASSESSMENT AT A 220 kV TIMISOARA POWER SUBSTATION WITHIN NATIONAL POWER SYSTEM

A. Program for assessing conformity with legal and other provisions in force

220 kV Timisoara power substation is located in Timis county, belonging to the Center for the Exploitation of Electricity Transmission Networks – Timisoara Electricity Transport Unit, *according to fig. 1*.

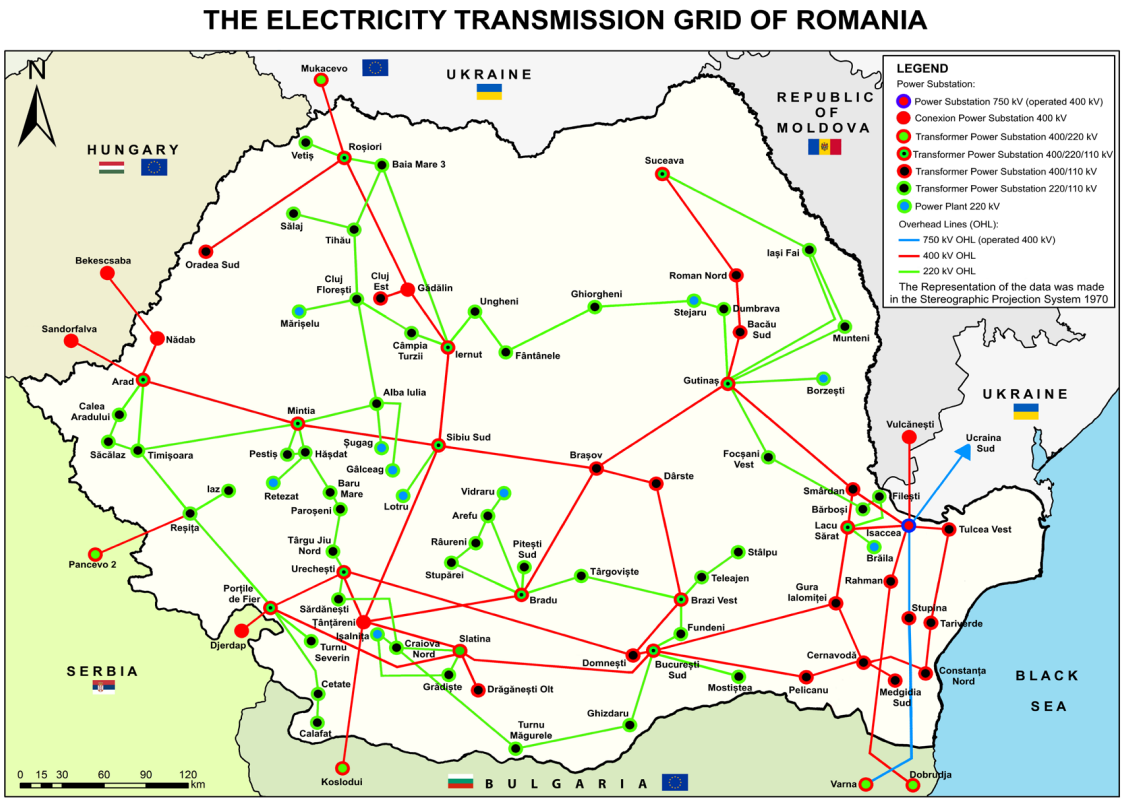


Fig. 1. Positioning of the 220 kV Timisoara power substation (west zone)
(source:www.transelectrica.ro and www.entsoe.eu)

Within the 220 kV Timișoara power substation exist the followings workplaces: *a) 220 kV Operational Service; b) 20 kV Operational Service; c) 220 kV Primary Circuit Maintenance; d) 20 kV Primary Circuit Maintenance; e) 20 kV Secondary Circuit Maintenance.* [5, 6, 7]

A. Risk level assessment for the activity: 220 kV Operational Service.

220 kV Power Substation: *busbars; OHL switchgears (Arad, Săcălaz, Mintia, Reșița); 220/20 kV auto transformers (AT) switchgears; coupling switchgears (transversal / longitudinal / longo-transversal); compensating coil switchgears; busbar measuring switchgears; discharge switchgears, etc.*

The global risk level at workplace: 220 kV Operational Service

$$N_{220kV} = \frac{\sum_{i=1}^{7} R_i \cdot r_i}{\sum_{i=1}^{7} r_i} = \frac{2\cdot(1\cdot1)+2\cdot(3\cdot3)+3\cdot(4\cdot4)}{2\cdot1+2\cdot3+3\cdot4} = \frac{68}{20} = 3,4 \quad (3)$$

B. Risk level assessment for activity: 20 kV Operational Service

The global risk level at workplace: 20 kV Operational Service

$$N_{20\,kV} = \frac{\sum_{i=1}^{11} R_i \cdot r_i}{\sum_{i=1}^{11} r_i} = \frac{11 \cdot (3 \cdot 3)}{11 \cdot 3} = \frac{99}{33} = 3{,}00 \tag{4}$$

C. Risk level assessment for activity: 220 kV Primary Circuit Maintenance

The global risk level at workplace: 220 kV Primary Circuit Maintenance

$$N_{MENT.EP\ 220kV} = \frac{\sum_{i=1}^{14} R_I \cdot r_i}{\sum_{i=1}^{14} r_i} = \frac{1 \cdot (1 \cdot 1) + 3 \cdot (2 \cdot 2) + 8 \cdot (3 \cdot 3) + 2 \cdot (4 \cdot 4)}{1 \cdot 1 + 3 \cdot 2 + 8 \cdot 3 + 2 \cdot 4} = \frac{101}{39} = 2{,}58 \tag{5}$$

D. Risk level assessment for activity: 20 kV Primary Circuit Maintenance.

The global risk level at workplace: 20 kV Primary Circuit Maintenance

$$N_{MENT.EP20kV} = \frac{\sum_{i=1}^{16} R_I \cdot r_i}{\sum_{i=1}^{16} r_i} = \frac{3 \cdot (2 \cdot 2) + 2 \cdot (3 \cdot 3) + 2 \cdot (4 \cdot 4) + 4 \cdot (5 \cdot 5) + 5 \cdot (6 \cdot 6)}{3 \cdot 2 + 2 \cdot 3 + 2 \cdot 4 + 4 \cdot 5 + 5 \cdot 6} = \frac{342}{70} = 4{,}8 \tag{6}$$

E. Risk level assessment for activity: 20 kV Secondary Circuit Maintenance.

The global risk level at workplace: 20 kV Secondary Circuit Maintenance

$$N_{EP} = \frac{\sum_{i=1}^{17} R_I \cdot r_i}{\sum_{i=1}^{17} r_i} = \frac{13 \cdot (3 \cdot 3) + 3 \cdot (2 \cdot 2)}{13 \cdot 3 + 3 \cdot 2} = \frac{129}{45} = 2{,}87 \tag{7}$$

B. Global risk level assessment of the 220 kV Timișoara power substation

The risk levels, determined for each workplace in the 220 kV Timișoara power substation are generally the followings:

Table 1. Workplace from 400/220 kV power substation

No.	WORKPLACE	LEVEL RISK (N_{rp})
1	220 kV OPERATIONAL SERVICE	3,4
2	20 kV OPERATIONAL SERVICE	3
3	220 kV PRIMARY CIRCUIT MAINTENANCE	2,58
4	20 kV PRIMARY CIRCUIT MAINTENANCE	4,8
5	20 kV SECONDARY CIRCUIT MAINTENANCE	2,87

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The global risk level of the 220 kV power substation is:

$$N_{rg} = \frac{\sum_{p=1}^{n} r_p \cdot N_{rp}}{\sum_{p=1}^{n} r_p} = \frac{(3,4 \cdot 3,4) + (3 \cdot 3) + (2,58 \cdot 2,58) + (4,8 \cdot 4,8) + (2,87 \cdot 2,87)}{3,4 + 3 + 2,58 + 4,8 + 2,87} = \frac{49,48}{16,65} = 2,97 \quad (8)$$

$N_{rg\text{-power substation}} = 2,97$

CONCLUSIONS

The current paper approached the risk assessment in terms of OHS within a 220 kV power substation located in Timișoara, Timiș County, Romania, substation that is interconnected to the National and European grid, identified and assigned as European critical infrastructure. The assessment was carried out using the NRDIOS Bucharest method.

The assessment of the risks of injury and occupational disease was carried out for five activities that were highlighted at the power substation:

1) 220 kV Operational Service;
2) 20 kV Operational Service;
3) 220 kV Primary Circuit Maintenance;
4) 20 kV Primary Circuit Maintenance;
5) 20 kV Secondary Circuit Maintenance.

and are as follows (table 2).

Table 2. Risk factors / Risk levels per workplace / Global risk level of the

220 kV Operational Service	**20 kV Operational Service**	**220 kV Primary Circuit Maintenance**	**20 kV Primary Circuit Maintenance**	**20 kV Secondary Circuit Maintenance**
number risk factor → risk level	number risk factor → risk level	number risk factor → risk level	number risk factor → risk level	number risk factor → risk level
1 → 1	1 → 3	1 → 3	1 → 4	1 → 3
2 → 4	2 → 3	2 → 2	2 → 3	2 → 3
3 → 4	3 → 3	3 → 3	3 → 2	3 → 3
4 → 3	4 → 3	4 → 4	4 → 4	4 → 3
5 → 4	5 → 3	5 → 3	5 → 6	5 → 3
6 → 3	6 → 3	6 → 2	6 → 6	6 → 3
7 → 1	7 → 3	7 → 2	7 → 5	7 → 2
	8 → 3	8 → 3	8 → 3	8 → 2
	9 → 3	9 → 3	9 → 2	9 → 2
	10 → 3	10 → 4	10 → 6	10 → 3
	11 → 3	11 → 3	11 → 6	11 → 3
		12 → 3	12 → 6	12 → 3
		13 → 1	13 → 5	13 → 3
		14 → 3	14 → 5	14 → 3
			15 → 2	15 → 3
			16 → 5	16 → 3
Work environment 14%	Work environment 9%	Work environment 7%	Work environment 6%	Work environment 6%
Performer 29%	Performer 36%	Performer 50%	Performer 43%	Performer 43%
Mean of Production 57%	Mean of Production 55%	Mean of Production 29%	Mean of Production 38%	Mean of Production 8%
		Work load 14%	Work load 13%	Work load 13%
Risk level 3,4 Unacceptable	Risk level 3 Low	Risk level 2,58 Very Low	Nivel risk 4,8 Unacceptable	Nivel risk 2,87 Very low
GLOBAL LEVEL RISK 2,97 → RISC LEVEL LOW – VERY LOW				

https://doi.org/10.5593/sgem2024v/4.2/s16.07

These risk factors must be the focus of those who coordinate the activities of the 220 kV power substation, as they can always be manifested in an event that can result in human casualties. The conclusion is that those who lead and coordinate the work are not influenced by the global value of the level of risk (which is a weighted average of the risk levels and risk factors identified), but take account of these risk factors with the maximum possible consequence of DEATH for which existing preventive measures must be maintained and the adoption of additional preventive measures. Given the risk factors identified for each assessed activity, specific to the elements of the work system and taking into account the level of risk corresponding to each risk factor, a number of preventive measures have been proposed. After the analysis, it was concluded that the 220 kV Timișoara power substation should enter *full retechnologization*, for the following reasons:

- the age of apparatus and equipments in the primary circuits of the 220 kV and 20 kV power substations<
- the age of apparatus in the secondary circuits of the 220 kV and 20 kV power substations.

Due to these very old apparatus and equipment, the hazard of incidents is very great, which would endanger the good functioning of the National Power System. The risk of injury and occupational disease is particularly high in the 20 kV power substation, which is also a reason for the power substation to go into full retechnologization.

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STORAGE SYSTEM TOPOLOGIES FOR VARIOUS RENEWABLE ENERGY SOURCES

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ABSTRACT

Hybrid electricity storage systems are becoming essential for efficiently managing renewable energy sources and enhancing the stability of power grids. As the adoption of renewables expands, these systems are crucial for balancing supply and demand, mitigating intermittency issues, and ensuring grid reliability. This paper offers an in-depth review of different system configurations used in hybrid storage systems, emphasizing the significance of understanding and optimizing their intricate designs.

Recent technological advancements have paved the way for the development of innovative storage system topologies, including redox flow batteries, solid-state lithium-ion batteries, and supercapacitor-based systems. Each of these technologies presents distinct advantages: redox flow batteries are notable for their scalability and extended cycle life, solid-state lithium-ion batteries provide high energy density and enhanced safety, while supercapacitors excel in applications requiring fast charging and discharging. Nonetheless, these innovations also face challenges, such as the high costs and manufacturing complexities of solid-state lithium-ion batteries, as well as the lower energy density characteristic of supercapacitors.

Evaluating the advantages and limitations of these advanced topologies is critical for guiding future research and development. The strategic integration of these technologies can result in more resilient, efficient, and cost-effective hybrid storage systems. This evolution is essential for supporting the global shift towards sustainable energy, ensuring that hybrid systems not only meet current demands but also pave the way for future innovations in renewable energy management.

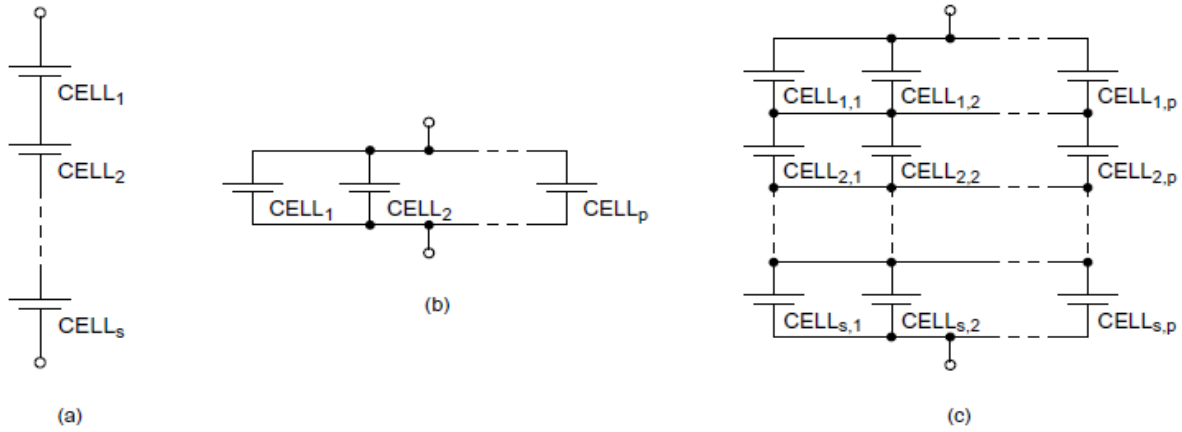
Keywords: Hybrid electricity storage systems, Renewable energy management, Power grid stability, Advanced storage topologies, Technological advancements.

INTRODUCTION

Battery electric vehicles (BEVs) are key to reducing CO2 emissions in personal transportation, but their broader adoption depends on improvements in range, acceleration, and energy recovery. Hybrid energy storage systems, which combine high power (HP) and high energy (HE) storage units, offer a promising solution. Traditionally, these systems have relied on DC/DC converters for integration. However, this paper examines reconfigurable topologies that could potentially eliminate the need for these converters [1].

The proposed approach introduces a new class of hybrid energy storage topologies using standardized energy storage modules (ESMs) that can be flexibly reconfigured through switching elements. This results in four distinct sub-topologies, enhancing the system's adaptability. Additionally, the paper discusses the impact of strict emission standards, such as the EU's 95 g/km CO2 limit, on the electrification of vehicle powertrains, particularly for larger vehicles. Current BEVs typically use uniform energy storage cells, with series and parallel interconnections boosting system performance [1].

Figure 1. Basic interconnection topologies. (a) series, (b) parallel, and (c) parallel-series



MATERIALS AND METHODS

Hybrid passive energy storage topology

A simple approach to hybridization is the direct connection of various types of energy storage cells, resulting in a hybrid passive energy storage topology (P-HEST). This configuration, illustrated in Fig. 2, integrates battery storage with electric double-layer capacitors (EDLCs) without requiring intermediate power electronic converters. In this setup, the battery voltage (VBATT1) and EDLC voltage (VEDLC1) align with the load voltage (Vpower train), making it well-suited for automotive applications where the drivetrain is the load [1], [2].

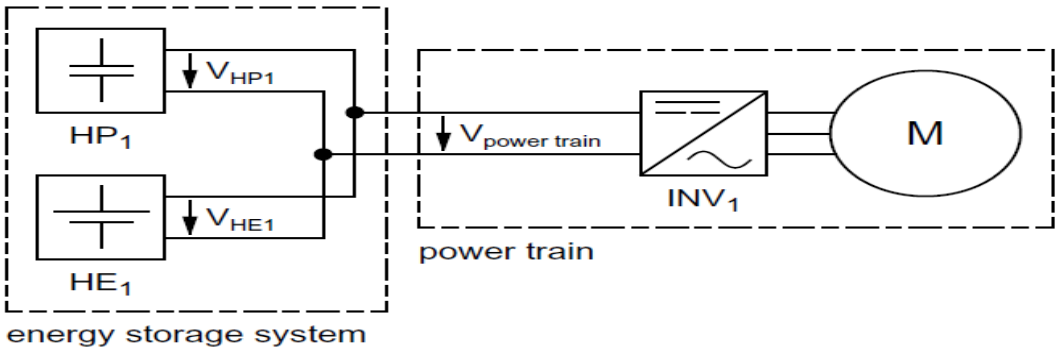


Figure 2. Hybrid passive energy storage topology [1].

This design provides benefits in terms of cost, space, and weight by removing the need for additional power electronics and simplifying the wiring. The power distribution between the storage systems is determined by their equilibrium voltages and internal resistances (Ri,BATT1 and Ri,EDLC1), underscoring the need for well-matched voltage windows for optimal performance [1], [2].

The internal resistance of hybrid energy storage systems is influenced by factors such as cell design, state of charge (SOC), temperature, and aging. In a direct parallel connection between batteries and EDLCs, power distribution is uncontrolled, yet this setup can deliver increased peak power and reduced losses. Hybrid systems, particularly those combining lithium-ion batteries and EDLCs, demonstrate longer lifetimes under dynamic discharge conditions and experience lower voltage drops due to the EDLCs' contribution to current flow. This configuration also reduces heating and internal losses in the battery, with the benefits influenced by pulse characteristics and EDLC performance [2].

Active Configuration of Hybrid Energy Storage Systems

The charge and discharge behaviors of energy storage devices differ depending on the technology used, as shown in the voltage profiles of Li-ion batteries and EDLCs in Fig. 3. To optimize the performance of each energy storage unit according to its unique characteristics, decoupling is necessary, a technique known as active hybrid energy storage topology (A-HEST). This method typically involves the use of a DC/DC converter for active separation. Depending on the degree of decoupling, the system can be classified as either semi-active (SA-HEST) or fully active (FA-HEST) [1].

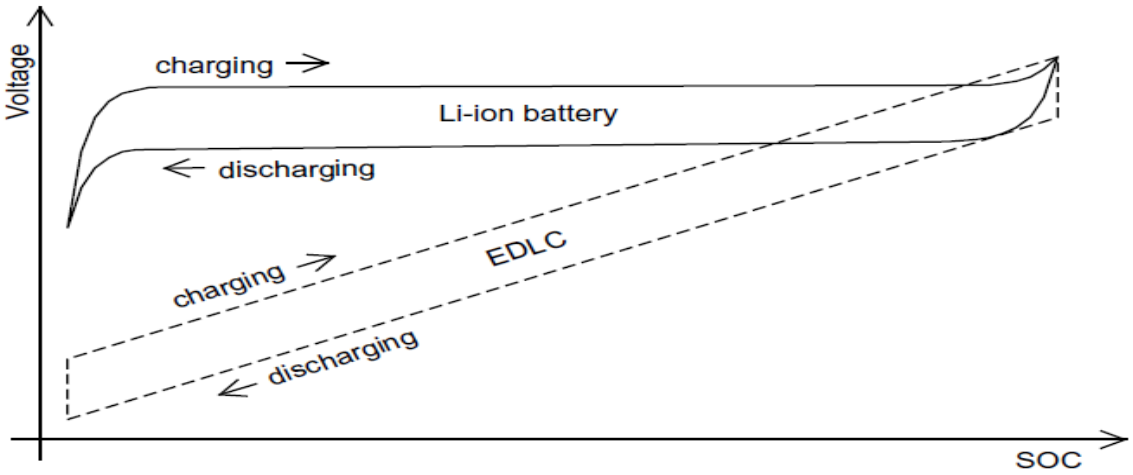


Figure 3. Example voltage profiles illustrating the charging and discharging behavior of Li-ion batteries and electric double-layer capacitors [1].

Electricity storage as a potential solution

Electricity storage (ES) technologies offer solutions to address the intermittency of renewable energy without significantly increasing carbon emissions compared to fossil fuels. These technologies convert electricity into stored energy, which can later be converted back into electricity, though some energy is lost in the process. ES technologies include options like pumped hydro, compressed air, various battery types, regenerative fuel cells, and hybrid electrochemical cells, each with unique characteristics that impact their economic viability. Evaluating their feasibility requires a deep understanding of both the technical aspects and market dynamics, including considerations such as storage capacity, efficiency, and costs [3].

Batteries with solid electrodes

Comparing the power-to-energy ratios of solid electrode batteries with the storage needs of wind and solar power highlights their limitations. Solid electrode batteries, such as

https://doi.org/10.5593/sgem2024v/4.2/s16.08

NiMH, lead-acid, and lithium-ion, have fixed ratios between power and energy capacity, with energy/power ratios ranging from 6 to 35 minutes. This means they store much less energy than needed for wind and solar storage when power capacities are equal. While not unfeasible, this results in very large storage systems. In contrast, flow batteries and regenerative fuel cells offer greater flexibility, allowing independent optimization of power and energy capacities [4][15].

RESULTS

The upcoming analysis will focus on comparing five different types of batteries:

- Lead-Acid Batteries
- Lithium-Ion Batteries
- Nickel-Cadmium (NiCd) Batteries
- Flow Batteries (e.g., Vanadium Redox)
- Solid-State Batteries.

Tabel 1: Storage battery parameters

Battery Type	Energy Density (Wh/kg)	Power Density (W/kg)	Efficiency (%)	Cycle Life (Cycles)	Cost ($/kWh)
Lead-Acid	40	180	75	750	125
Lithium-Ion	200	300	90	3000	300
Nickel-Cadmium	65	150	80	1750	400
Flow	35	120	75	10000	650
Solid-State	400	500	95	6000	600

We will now run a simulation to see how these battery types compare to the parameters above. This will give you a clear picture of which battery might be best suited for different renewable energy storage applications.

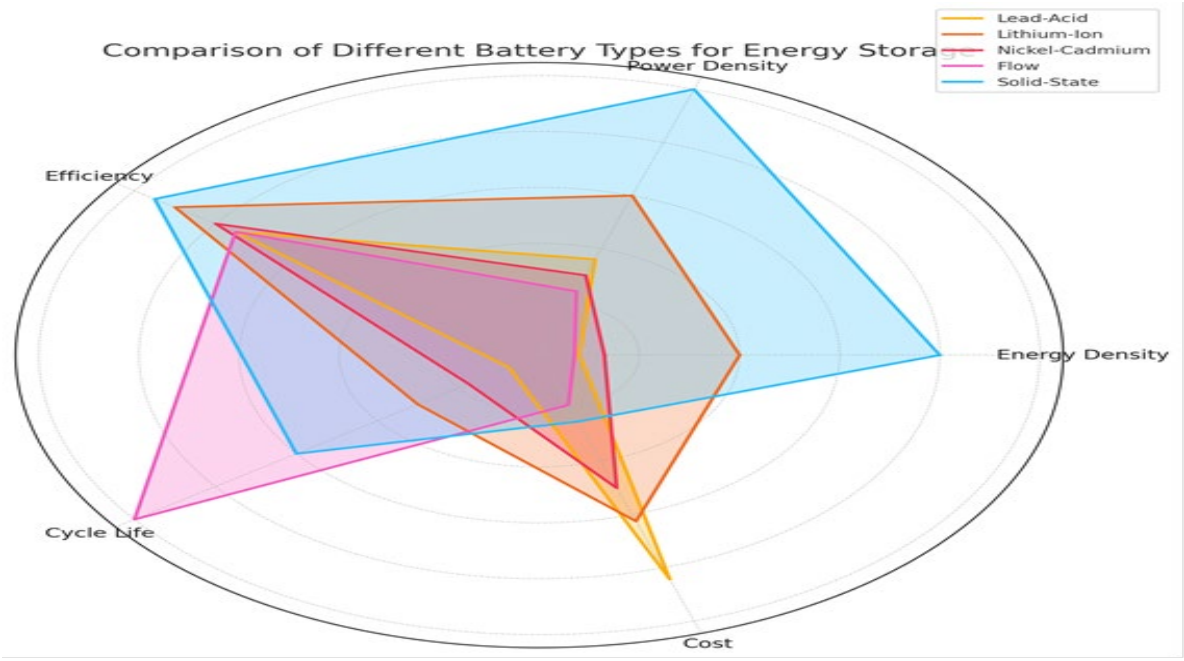


Figure 5: Comparing different types of batteries

Figura 5, the radar chart illustrates the comparative performance of different battery types for energy storage based on key parameters.

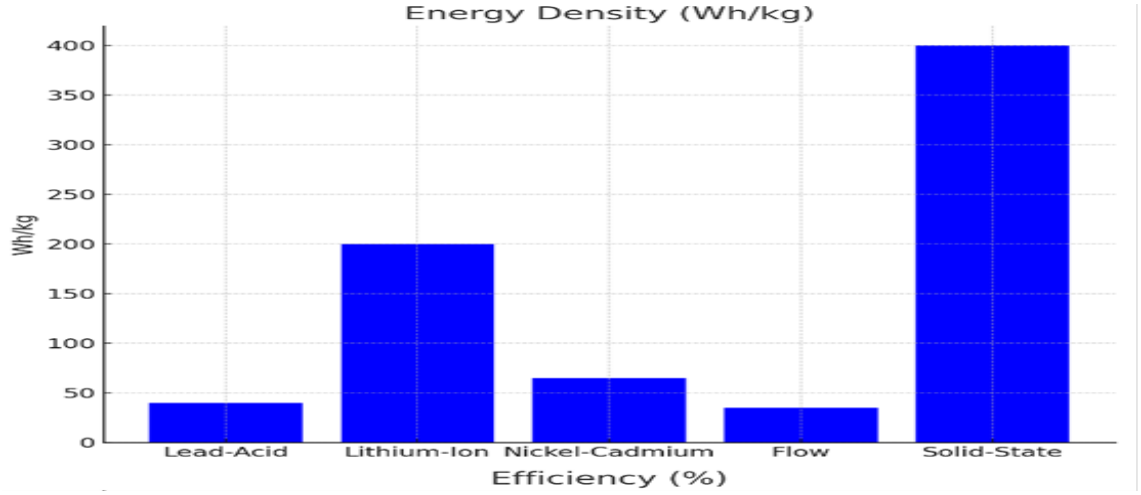


Figure 6: Energy density of different types of batteries

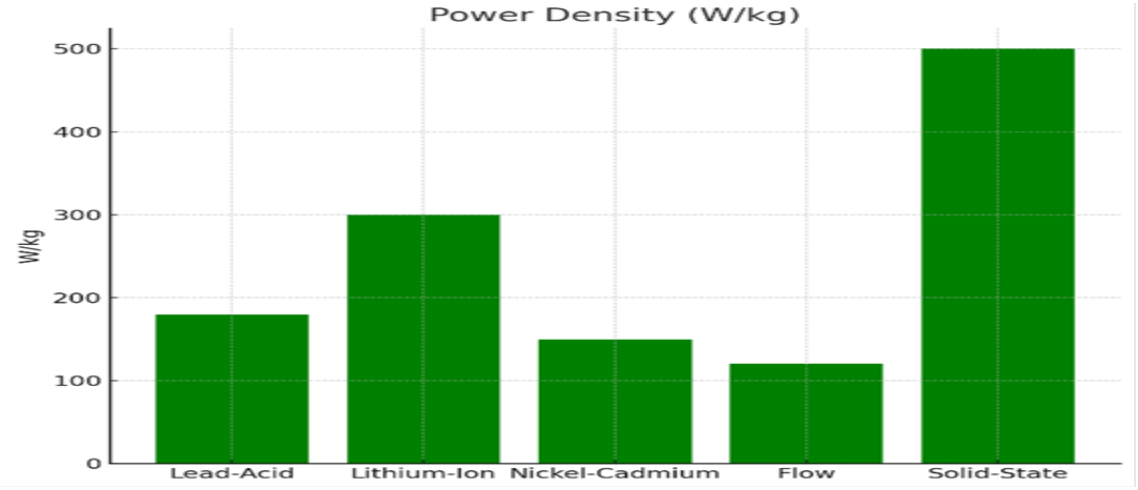


Figure 7: Power density of different types of batteries

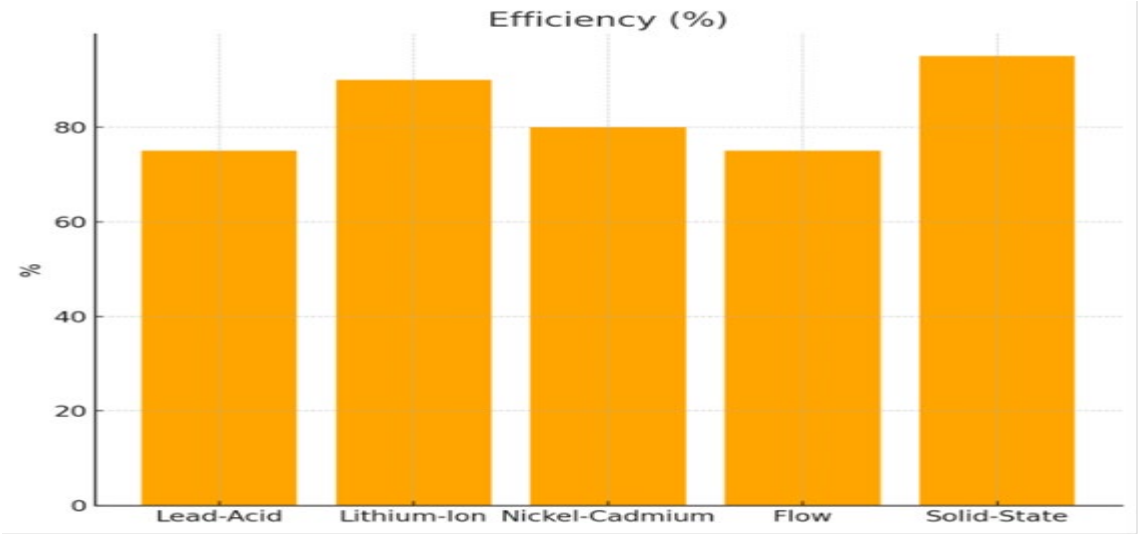


Figure 8: Efficiency of different types of batteries

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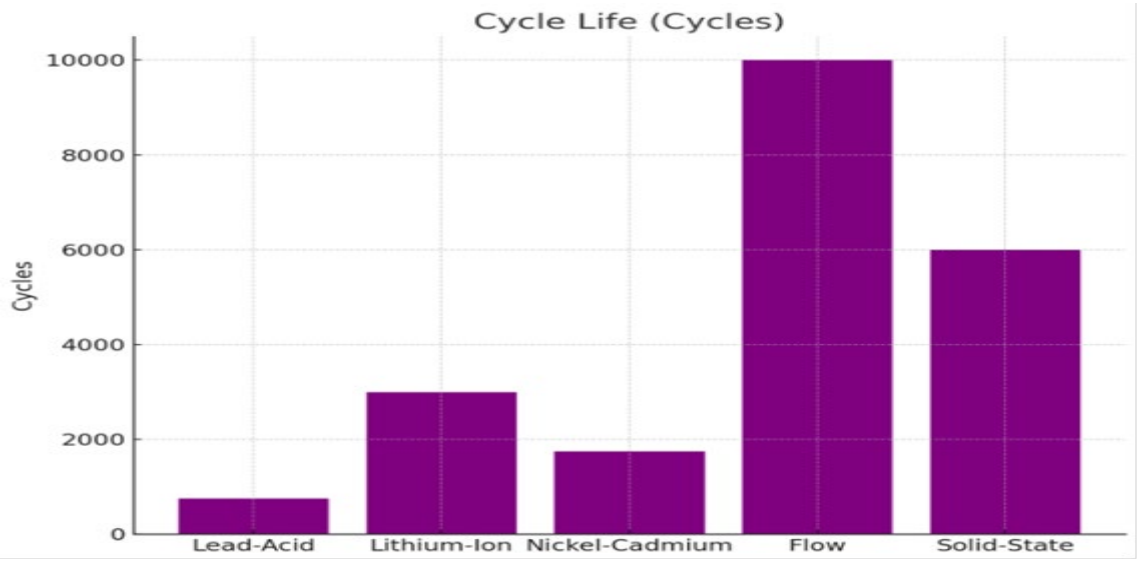


Figure 9: Cycle Life of different types of batteries

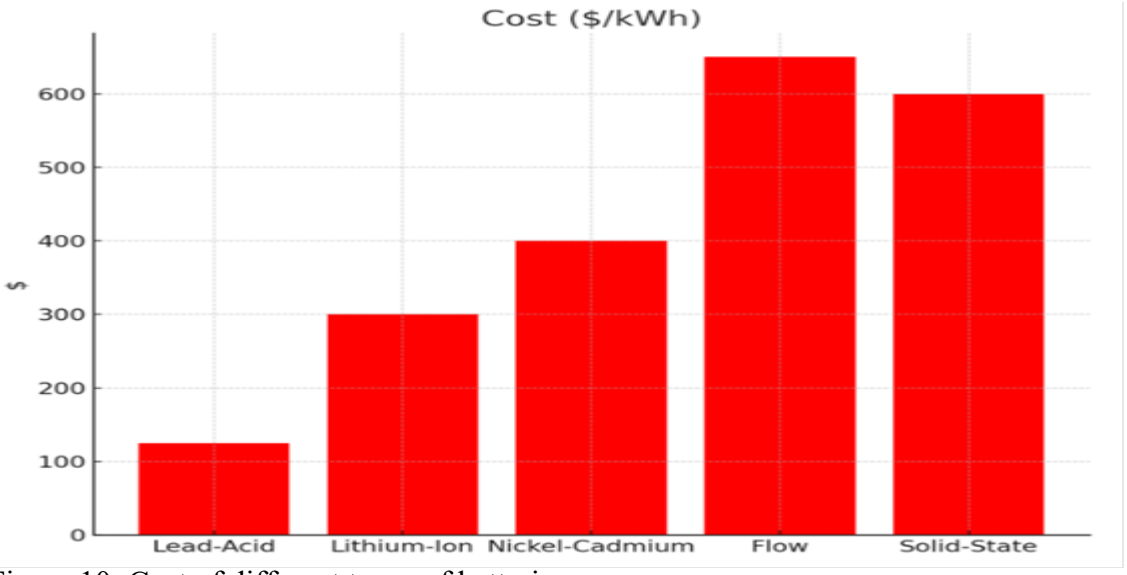


Figure 10: Cost of different types of batteries

DISCUSSION

Our simulations and data analysis demonstrate that advanced battery technologies, including Lithium-Ion and Solid-State batteries, surpass traditional options like Lead-Acid and Nickel-Cadmium in energy density, efficiency, and cycle life. These findings align with existing research, emphasizing the advantages of newer batteries for high-demand applications. Although advanced batteries are more expensive, their efficiency and longevity make them a sustainable choice. The higher cost of Flow Batteries, despite their long cycle life, is likely due to design and material costs specific to large-scale storage systems. Overall, the results underscore the need to select battery technology based on specific storage requirements [6], [7].

CONCLUSION

This project has effectively analyzed and compared different battery storage topologies for renewable energy systems, including Lead-Acid, Lithium-Ion, Nickel-Cadmium, Flow, and Solid-State batteries. The findings indicate that Lithium-Ion and Solid-State

batteries are the most efficient and well-suited for contemporary renewable energy storage requirements, providing high energy density, superior efficiency, and extended cycle life. However, these advantages come with a higher cost, which may be warranted in applications where reliability and long-term sustainability are crucial [8], [15].

Traditional batteries like Lead-Acid and Nickel-Cadmium, while more affordable, exhibit lower energy densities and shorter cycle lives, making them less ideal for high-performance applications but still viable in situations where cost is a significant constraint [9], [10].

Flow batteries, with their extensive cycle life, are well-suited for large-scale, stationary energy storage, although their initial costs and lower energy density limit their application in smaller, mobile setups [11], [12].

Overall, the project concludes that selecting the appropriate battery technology depends on the specific requirements of the energy storage application, balancing factors such as cost, efficiency, energy density, and lifecycle needs. The results align with industry trends, confirming the growing preference for advanced battery technologies in the renewable energy sector [13], [14].

ACKNOWLEDGEMENTS

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SWOT ANALYSIS OF ROMANIAN ENERGY RESOURCES OF HYDROCARBONS IN THE CONTEXT OF ENSURING ENERGY SECURITY

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ABSTRACT

The SWOT analysis of the energy resources of hydrocarbons comes in the context in which the possibility of a black-out is very likely, and the lack of energy resources can cause major damage through enormous financial losses, which through the domino effect can spread economic and national insecurity. In this context, the SWOT analysis energy resources become an essential issue of national security and makes this paper of real interest. The authors consider that the security supply with energy resources of hydrocarbons of Romania is a strictly national security issue because the lack of energy resources can cause enormous damage to the national and European industry and economy, which are almost entirely dependent on energy resources. Romania cannot develop its defense industry, which is becoming increasingly vulnerable, without energy resources from hydrocarbons.. Romania must be prepared in the event of a crisis indifferent to its nature and face all the challenges at any time. Paper contains essential information's regarding situation of hydrocarbons (natural gas and oil) from Black Sea in the context of energy security in Romania. The aim of the paper is to demonstrate that energy in all its forms can be a reason for cooperation and confrontation with connotations often military, generating wars that seriously damage all social environments and thus global welfare. The authors propose to suggest some actions for Romanian decision-makers of need to create energy stability factors in order to combat energy poverty, vulnerable consumers and ensure energy security.

Keywords: SWOT Analysis, Energy Resources, Hydrocarbons, Energy Security.

INTRODUCTION

In the new context of energy insecurity caused by the geopolitical positioning of Romania and military global instability, energy resources play among the most important roles in the position occupied by the Romania and its role in the system of international relations, in the context of ensuring national and European energy security.

Lack or precariousness of energy resources (hydrocarbons - natural gas and oil) of less energy and economically developed countries, they have led to the amplification of games on their side and have allowed some energy dependencies in terms of energy security control.

Under these conditions, energy security is no longer just an objective of foreign policy, but has become a solid and constant concern for the international energy community, in the context of ensuring national and European security. In order to prevent a collapse of the National Energy System, Romania must have energy security strategies and secure its energy resources or critical power infrastructures that facilitate the population's access to energy resources, important factor in European security.

The United Nation 21 Agenda 1992 stated that "Energy is Indispensable for Societal Development and the Improvement of Living Conditions of Life" The all-organization's Member countries reaffirm "the critical role that energy (in all its forms) plays in the development process, given that access to modern and sustainable energy services contributes to the eradication of poverty, saving lives, improving health and supporting the provision of basic needs of the individual". [1].

Natural resources, especially energy (hydrocarbons, uranium, coal, etc.) and electricity, have influenced the evolution and development of human society since ancient times, and the modern economic development of a state is dependent on energy resources, where the volume of energy (in all its forms) consumed per capita has become a significant indicator of the progress and modernization of a state. The national power of a state is the possession, control and rationalization of energy resources in order to maintain its energy independence and eliminate dependence on other states. The strategic importance of energy resources (hydrocarbons, natural gas, and oil) lies in their ability to ensure economic and security development and are influenced by political factors in the context of military development. To these can be added coal, non-ferrous metals (aluminum, tin, etc.), uranium ores and precious ores (gold) [2].

SWOT analysis is the most important technical and managerial analysis on understanding and knowing the strategic position of an organization, industry or national economy and has the following objectives: the detailed knowledge of threats, risks and vulnerabilities and the possibilities to counter them related to energy organizations, industry and the national economy; development opportunities of national energy organizations, industry and economy; the safety and security level of the national industry and economy; the real state of the national economy and economic security; the recommendation of strategies that ensure the best alignment between the internal and external environment and choosing the right strategy for adapting strengths to opportunities, minimizing risks and eliminating weaknesses. [3].

SWOT analysis on energy resources (hydrocarbons – natural gas and oil) becomes an extremely important and essential thing and shows the exact situation of the state of national energy security, how to supply other missing energy resources and ways forward in the event of an energy crisis. These energy security strategies are developed only by SWOT analysis for to know strengths, weaknesses, opportunities and threats of energy resources, which ensure stability and energy security. [8]

SWOT ANALYSIS OF ROMANIAN ENERGY RESOURCES (HYDROCARBONS – NATURAL GAS AND OIL)

Strengths

After the energy security analysis, the following strengths were identified: [4-8]

- Romania is a member state of the European Union and NATO, which gives us security, stability, credibility, economic relations and energy ties with all the countries of the world;
- Declaration of the Black Sea as an area of strategic energy interest by NATO (Summit Madrid 2022);
- Exit to the Black Sea (warm sea), through the port of Constanta, a decisive factor in energy relations and routes;
- The Danube's navigability (energy, trade or strategic transport on the Danube with EU and Serbia states);
- Connection to ENTSO-G – the main natural gas system in the European Union through the following cross-border gas pipelines: Arad – Szeged (Hungary); Mediesu Aurit – Tekovo (Ukraine via Russia); Iasi – Ungheni (Republic of Moldova); Isaccea – Orlovka 1,2,3 (Ukraine via Russia); Negru Voda – Kardam 1,2,3, (Bulgaria); Giurgiu – Ruse (Bulgaria);
- Romania has over 150 years of experience in the oil industry and over 100 years in the natural gas industry, in all specific sectors of activity: geology and geophysics; exploration of resources; well drilling and oil and gas exploitation; hydrocarbon processing (refining, petrochemicals, etc.); collection, transport, storage and distribution of crude oil, gas and petroleum products; scientific research, design, design, education and training of specialists;
- Safe and steady hydrocarbon production (2008 – 2012): 2008: oil production – 4.6 million tons; natural gas production – 11.8 billion cubic meters; 2009: oil production – 4.4 million tons; natural gas production – 11.3 billion cubic meters; 2010: oil production – 4.2 million tons; natural gas production – 11.14 billion cubic meters; 2011: oil production – 4.0 million tons; natural gas production – 11.16 billion cubic meters; 2012: oil production – 3.9 million tons; natural gas production – 11.09 billion cubic meters;
- Solid tradition of the energy sector that brought Romania several world premieres with energy independence;
- Romania is one of the oldest oil and gas producers in the world;
- Definite hydrocarbon resources in the Neptun Deep area estimated at 100 bcm, at depths ranging from 100 – 1700 meters (fig. 1);
- The energy companies OMV Petrom (the Romanian hydrocarbon company owned by OMV Austria) and Romgaz (the Romanian natural gas company owned by the Romanian state) have announced plans to develop the offshore hydrocarbon field Neptune Deep of Romania;
- Infrastructure development will start in 2024, and the first production is expected in early 2027, and Neptun Deep will produce between 7 bcm and 8 bcm per year, with potential revenues of over twenty-five billion dollars;
- The development of the resources is a good sign for the wider energy security of the Black Sea and has the potential to have a geopolitical and economic impact on the region, in particular by offering an alternative to Russian gas, thus weakening Moscow's influence;

- Romania has discovered significant offshore gas reserves in the exclusive economic zone and plans to exploit about 200 billion cubic meters and started doing so in 2023, producing 1 bcm at the Ana platform, a deposit developed by Black Sea Oil & Gas;
- Romania will become a regional natural gas exporter;
- Sustainable energy and quality of life;
- Approaching the Caspian energy resource basins;
- Oversized own infrastructure – network of oil pipelines and gas pipelines, owned by the following companies: Conpet – operator oil transport and Transgaz – operator natural gas transport;
- The largest refinery in the Black Sea – Midia Navodari;
- Oversized and largely unused capacity of the petrochemical industry;
- Permissive topographic surface, which does not imply special technical and economic difficulties of laying/installation of pipes;
- Pumping stations with the lowest costs in the area;
- The signing, on 13 July 2009, in Ankara, together with Turkey, Bulgaria, Hungary and Austria of the Intergovernmental Agreement on the construction of the Nabucco gas pipeline, was signed, which states that Romania will benefit from deliveries of 2.58 billion cubic meters of gas annually;
- Friendly relations with Azerbaijan, embodied in a strategic partnership, which will facilitate its access to Caspian energy resources and projects on their transport to Europe. Romania has succeeded in concluding a strategic partnership with the Republic of Azerbaijan, established by "The joint declaration on the agreement on the establishment of a strategic partnership between the Republic of Azerbaijan and Romania". Azerbaijan offered to deliver 7.3 billion cubic meters/year of gas to Romania, transportable through the Nabucco pipeline, which represents about 25% of the annual capacity of the pipeline. Romania's interest in Azerbaijani energy resources is absolutely natural for the following reasons:
    - first of all, the Romanian company Transgaz participates, as a representative of Romania, in the Nabucco project (fig. 2);
    - secondly, the implementation of the Constanta-Triste oil pipeline project involves certain advantages for Romania;
    - on the other hand, Azerbaijan, through the development of relations with Romania, also pursues, along with economic objectives, some of political ones, because Romania is one of the countries that, during the last years, has, it has supported and continues to support the position of the Azerbaijani state in relation to the Nagorno-Karabakh conflict, and this is of particular importance to Baku;
    - Azerbaijani state-owned company GNKAR will also be able to transport its energy resources on two routes:
        - ✓ the first will allow him to deal with the processing processes of energy resources already transported to processing plants in Romania in the framework of cooperation actions;
        - ✓ the second option requires GNKAR to make the transit through Constanta, obliging it to increase the storage capacities of crude oil from the Romanian port, then orienting it to Trieste.



Fig. 1. Neptun Deep area from Black Sea. (source: https://www.cotidianul.ro)



Fig. 2. Nabucco project (source: https://en.wikipedia.org/wiki/Nabucco_pipeline)

Weaknesses

After the energy security analysis, the following weaknesses were identified: [4-8]

- Partial dependence on Russian gas;
- Currently, the Black Sea provides only about 10% of Romania's natural gas demand;
- The current resources are nearing the end of the production period;
- Negative impact on the marine environment: Neptun Deep, the gas exploitation project planned by OMV Petrom and Romgaz, endangers dolphins in the Black Sea and destroys climate protection efforts (the project intersects with two protected natural areas, „Head Tuzla" (ROSCI 0273) and „Black Sea" (ROSPA 0076), where to release chemicals with negative impacts on the marine environment and massively increase climate-damaging emissions for another 20 years);
- Exodus abroad of specialists and experts from the energy environment.

Opportunity

After the energy security analysis, the following opportunity were identified: [4-8]

- Romania to become an energy security provider;
- Romania's exit from dependence on Russian gas and Russia's impossibility to use its energy as an energy weapon or political pressure tool for pursuing its interests;

- massive investments in exploring and extracting possible hydrocarbon resources (oil and natural gas) in the Black Sea;
- Romania's exit from the NATO periphery and its transformation into a regional hub of energy and regional security;
- The Black Sea has the potential to become a new North Sea in terms of hydrocarbon resources;
- the potential of resources within the Neptun Deep perimeter;
- Possibility to become the largest natural gas producer in the EU;
- Reaffirming the strategic position as energy producer for the country;
- It is estimated that the exploration and production sector of the Black Sea can attract cumulative investments of up to 16 billion dollars, this would lead to the creation or maintenance of up to 30 000 jobs, on average, per year, throughout the projects, a contribution of up to 71 billion dollars to the national production of goods and services and a contribution of up to 26 billion dollars to the state budget of Romania;
- Economic growth through the potential of the exploration and production sector of the Black Sea to have a major positive impact on the Romanian economy in the coming decades;
- Successful natural gas projects in the exploration and production sector would pave the way for the development of projects in related industries, from the transmission and distribution of natural gas to the chemical and petrochemical sector or the conversion of natural gas into electricity;
- Natural gas is a solution for Romania to reduce its carbon emissions and to support the country in achieving its environmental objectives, given the multiple possibilities of use, from heating and electricity to mobility;
- Positive impact can occur in many industrial fields as well as in our daily lives. 60% lower CO2-emissions natural gas power plants than coal is a solution to ensure electricity supply while meeting environmental challenges;
- Given the high level of risk in the Black Sea region, Romania must act to increase its attractiveness and competitiveness as a destination of capital, technology and know-how in the offshore sector, always taking into account the best practices in the field worldwide, as well as international and regional trends;
- Developing the institutional, administrative and know-how capacity of the Romanian Government for the proper management of the offshore hydrocarbon sector.

Threats

After the energy security analysis, the following threats were identified: [4-8]

- The extremely aggressive attitude of Russia towards the EU and implicitly Romania regarding the energy policy fueled by the economic development based on the export of energy;
- The dependence of the EU and implicitly of Romania on Russian gas, but which also has as reverse the dependence of Russia on the revenues obtained from gas sales on the European market;
- The Black Sea is a hot zone for the extended security of the world, because it is very rich in hydrocarbons (oil and natural gas) and delimits the border between NATO and the Russian Federation, as well as influences from China, a great

opponent of the two world superpowers. Since the Black Sea is of paramount importance in protecting NATO's eastern and southern flank, it represents the space of confrontation between the Russian Federation and NATO and the defense of strategic interests. For this reason, the Russian Federation can disrupt navigation, create problems for Romania in the perimeter of exclusive economic areas where strategic energy resources are;

- The use of gas by Russia as an energy weapon or a political pressure instrument in achieving the objectives;
- The development of major energy projects requires significant investment due to the exceptional depth of the Black Sea;
- Possible Black Sea investors that do not aim at the profitability of Romanian projects, but purely geopolitical interests;
- Non-operation in agreement and profitability (win – win – win) of triad state – society – investor;
- Geopolitical tensions and risks with military connotations caused by Russia in the context of access to hydrocarbons;

CONCLUSIONS

Because energy resources (hydrocarbons – natural gas and oil) are safety and security elements for those who own, control, exploit, distribute and/or use them, they can generate conflicts or energy wars, which is characterized by the use of energy instruments to compel the adversary to change his policy or behavior, or to undermine the capacity of that state to maintain normal relations with other states, in times of peace or war, which may be: customs barriers, embargoes, boycotts, royalties, blockades, takeovers and mergers, espionage, naval piracy, economic-energy terrorism, etc.

Without energy resources the entire economy can collapse, because almost all industry and the European economy depend on these indispensable elements, and any short circuit on the European energy market, it is a danger to energy security and therefore energy security is an important component of the European security and foreign policy strategy.

For this reason, energy resources are often used as instruments of political, economic and military pressure in order to gain some strategic advantages on the complex and dynamic stage of international relations, where some states or economic groups in power, use this energy weapon to set some strategic goals.

In this context, the SWOT analysis of the security supply with energy resources (hydrocarbons – natural gas and oil) becomes an essential issue of European security and makes this paper of real interest. The authors consider that the security supply with energy resources of European Union is a strictly national for every country and European security issue because the lack of energy resources can cause enormous damage to the European industry and economy, which are almost entirely dependent on energy resources.

To ensure energy security, Romanian decision-makers need to create energy stability factors in order to combat energy poverty, vulnerable consumers and ensure energy security through the following actions: reducing energy dependence by ensuring the minimum need for energy resources for underdeveloped or developing countries;

protection of national and European critical infrastructure for the transport of energy resources to ensure continuity of supply and prevent energy collapse; exploring new onshore and offshore energy sources; new critical energy infrastructures; development of renewable energy sources; introduction of clear and transparent energy efficiency measures; rationalization of energy use: electricity; natural gas; oil; fuel, etc. stopping the exodus abroad by energy specialists (ultra-qualified human resource); place major investments in the energy research and development segment; development of specialization courses for energy sector personnel; increase the salaries for the human resources in energy sector; improving working conditions.

All these actions must be carried out by the state through its mechanisms for ensuring a strong energy security, and in this context, national energy security is in fact European and regional security.

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SECTION RECYCLING, WASTE MANAGEMENT, AND CIRCULAR ECONOMY

A REVIEW ON THE USAGE OF BIOCHAR AS AN ALTERNATIVE REDUCTANT IN THE PYROMETALLURGICAL TREATMENT OF ORES

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ABSTRACT

Carbon emission has increasingly become a topic of the day. Carbothermic reduction processes and energy generating units have for years used generic carbonaceous materials contributing to high carbon pollution. Ongoing investigations are showing good prospects. This paper corroborates a comprehensive review on the potential of biochar as an innovative and sustainable alternative to traditional carbon sources in pyrometallurgical processes, addressing the environmental ithreats caused by fossil fuel use, such as greenhouse gas emissions and global warming, and the urgent need for greener reductants in metallurgical operations. Derived from various biomass sources through pyrolysis, biochar exhibits unique chemical and physical properties that make it a promising reductant in high-temperature metallurgical operations, particularly in ferroalloy production and metal recovery from slags. The review delves into the characterization of biochar, examining its chemical composition, functional groups, and physical attributes such as high surface area, porosity, and thermal stability. These properties contribute to biochar's enhanced reactivity and efficiency in reduction processes. Multiple studies have demonstrated biochar's superiority over conventional reductants like coke and coal in various applications, including ferrosilicon production, copper slag cleaning, and iron ore reduction. Biochar's porous structure facilitates better gas-solid interactions and diffusion of reducing gases, leading to more uniform and complete reduction reactions. Its higher reactivity, lower activation energy, and potential catalytic effects from inherent mineral matter further enhance its performance in pyrometallurgical processes. The review also highlights the environmental benefits of using biochar, a renewable resource, in reducing the carbon footprint of metallurgical operations. However, the effectiveness of biochar can vary depending on its source material and production conditions, necessitating careful selection and potential tailoring for specific applications. Overall, this review underscores the significant potential of biochar to revolutionize pyrometallurgical processes, offering improved efficiency, lower energy consumption, and environmental sustainability in the metallurgical industry. This paper review only wood and woody biomass as well as herbaceous biomass are reviewed and discussed.

Keywords: Biochar, reductant, replacement, review

INTRODUCTION

Today, the world mainly relies on energy from oil, coal, and natural gas. These fossil fuels make up about 80% of all the energy we use. To put this in perspective, in some countries where over 400 megajoules (MJ) of energy is used each year, and most of this

comes from these traditional sources [1]. The burning of fossil fuels like oil, coal, and natural gas releases carbon dioxide (CO_2) into the atmosphere, which is the primary cause of major environmental issues. Since the Industrial Revolution began, the amount of CO_2 in the air has risen dramatically, leading to an overall increase in global temperatures. As a result, our continued reliance on these fossil energy sources is directly contributing to global warming and climate change [2]. Biomass offers a promising alternative to fossil fuels in the fight against pollution and global warming. This renewable energy source comes from organic materials like plants, agricultural waste, and wood products. When used for energy production, biomass can help reduce greenhouse gas emissions since the CO_2 released during combustion is offset by the carbon absorbed during the growth of the organic matter. Unlike fossil fuels, biomass is part of a short-term carbon cycle, making it nearly carbon neutral. Additionally, using biomass for energy can help manage waste, support rural economies, and decrease dependence on non-renewable resources. While challenges in production and efficiency exist, ongoing research and technological advancements are making biomass an increasingly viable option in the transition to cleaner energy sources. As a result, while biomass plays a crucial role in household energy consumption, its impact on industrial energy production is limited, albeit noteworthy. For instance, the sugar industry harnesses bagasse, a sugar production byproduct, to generate about 245 megawatts of power. Similarly, the pulp industry utilizes sawdust to produce 170 megawatts of energy. These examples highlight the potential of biomass in specific industrial sectors, despite its overall minor contribution to industrial energy production [3].

I. SOURCES OF BIOMASS

Biomass encompasses a wide range of organic materials that can be used as energy sources. These include agricultural residues such as crop stalks, husks, and animal waste; forestry byproducts like sawdust, wood chips, and bark; dedicated energy crops like switchgrass and miscanthus; municipal solid waste, including food scraps and yard trimmings; and aquatic biomass such as algae. Industrial byproducts also serve as significant biomass sources, with examples including bagasse from sugar production and black liquor from paper manufacturing. The diversity of biomass sources allows for flexible and localized energy production, often utilizing materials that would otherwise be discarded [4]. South Africa has a sizeable agriculture sector and all the country's agricultural waste could be used for energy. Annually South Africa's sugar industry produces about two million tonnes of sugar from about 20 million tonnes of cane [3].

Interestingly, the geographical distribution of this resource is highly concentrated. Just three main catchment areas dominate the production, collectively accounting for over 50% of the commercially available forestry waste in the country. This concentration highlights the potential for targeted biomass utilization strategies in these specific regions. Biomass feedstocks stand out as a unique and valuable resource in our quest for sustainable energy and materials. Unlike many other options, these organic materials offer a promising solution to meet the enormous demand for energy and raw materials required by our growing global population [5].

2. TYPES OF BIOMASSES.

Biomass classification is diverse and complex, lacking a single universal method due to the wide variety, quantity, and compositional differences among biomass types. The approach to categorization can vary based on the specific purpose and scope of the classification. Generally, two main classification systems are employed: one based on the natural occurrence of biomass in ecosystems or vegetation types, and another focused on its applications and use as a feedstock. The choice between these systems depends on the context and objectives of the biomass assessment or study, allowing for flexibility in how biomass is grouped and analysed [6].

3. MATERIALS AND METHODS

3.1 Materials

3.1.1 Wood and woody biomass

Woody biomass is sourced from various origins, each contributing to renewable energy. Forests are the primary provider, offering biomass through sustainable practices like thinning, logging residues, and forest management. Dedicated energy plantations grow trees specifically for bioenergy [7]. Woody biomass, primarily composed of carbohydrates and lignin, encompasses a range of plant materials derived from trees and woody shrubs. This category includes components such as tree residues, roots, bark, and leaves, both above and below ground. These materials can be harnessed for energy production through direct combustion, gasification, or various conversion processes. The woody biomass used for energy and fuel generation typically comes from four main sources: production residues from forestry and wood processing industries, non-merchantable timber residues, post-consumer wood waste, and woody materials found in urban and agricultural waste streams. This diverse range of sources highlights the versatility of woody biomass in contributing to renewable energy solutions, utilizing materials that might otherwise be considered waste products [8].

3.1.2. Herbaceous biomass

Key sources include dedicated energy crops such as switchgrass, miscanthus, and sorghum, which are cultivated specifically for bioenergy due to their high yield potential and adaptability to various climates. Additionally, agricultural residues like corn stover, wheat straw, and rice husks contribute significantly to herbaceous biomass supplies [9]. These sources are integral to the bioenergy sector, offering a renewable and sustainable alternative to fossil fuels, provided that their cultivation and harvesting are managed responsibly to maintain ecological balance.

3.2 Methods

Pyrolysis is the known process used to produce biomass. It is a process that is irreversible leading chemical composition change physical state of organic matter [10]. Pyrolysis results in liquid bio-oil, solid biochar, and non-condensable gas product. This is crucial primarily due to its potential to produce valuable biofuels and biochar, reduce waste, and mitigate environmental impacts. The advantages of Pyrolysis are that it requires low temperatures, combustion is avoided and the ability to produce a higher yield of liquid fuels [11]. Three main types of pyrolysis are used namely slow (conventional) pyrolysis, fast pyrolysis and flash pyrolysis [12]. The conditions of slow pyrolysis, such as temperature, heating rate, and residence time, significantly influence

the quality and quantity of the products. For instance, lower temperatures and slower heating rates favour the production of biochar with higher carbon content and stability [13]. Conversely, higher temperatures and faster heating rates tend to increase the yield of bio-oil and syngas [14]. The fast pyrolysis is advantageous when aiming to produce renewable biofuels and chemicals if process well optimized [15]. The flash pyrolysis is promising technology for biomass conversion and solid waste management [16].

Some parameters influencing the quality of biochar

Influence of temperature

Investigations on the porosity of biochar were conducted. Wood char was microstructures and gasification characteristics of wood char were investigated. Microscopic analysis revealed that biochar possesses a more porous structure compared to anthracite as shown in Figure 1. The pores in biochar are predominantly microporous and evenly distributed throughout the material. The high porosity of biochar creates an extensive network of interconnected channels and voids within its structure. During gasification, these pores facilitate the penetration of reactive gases deep into the biochar's structure, promoting more complete and efficient conversion. The enhanced gas-solid contact area improves the gasification reactions, thus faster conversion rates and more thorough decomposition of the biochar.

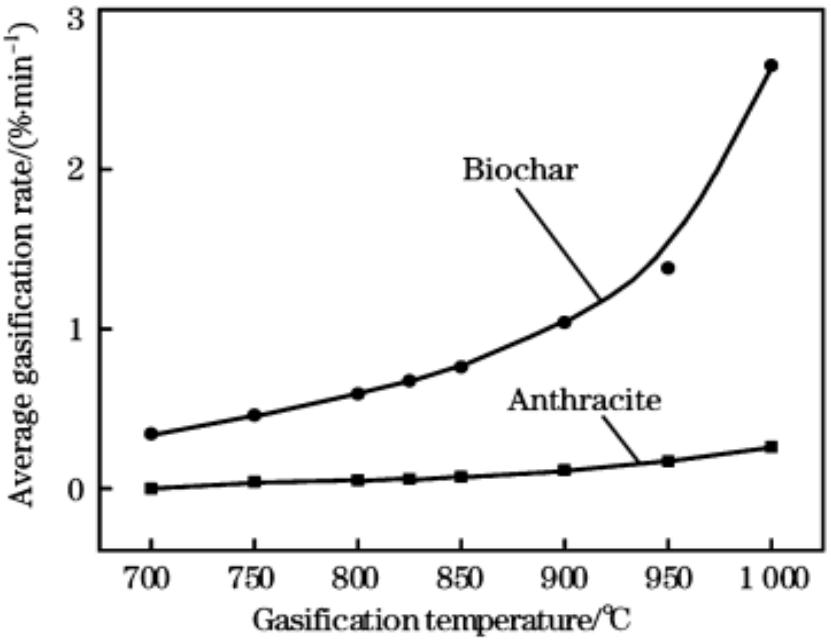


Figure 1 Microscopic analysis of the porosity for (a) anthracite and (b) wood char [17]

Figure 2 shows the influence of temperature on the porosity using palm kernel shells as raw material to produce palm kernel biochar.

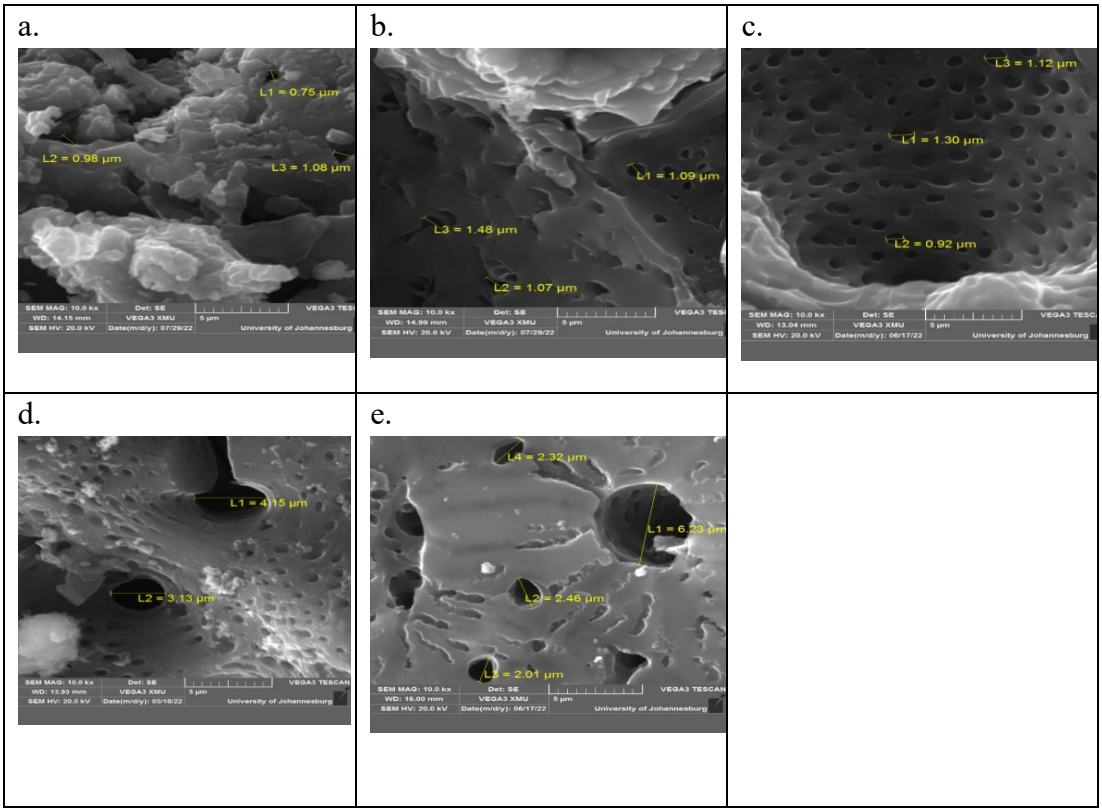


Figure 2 Influence of pyrolysis temperature on pore size at 500 (a), 600 (b), 700 (c), 800 (d) and 900 °C (e) [18]

It was observed that biochar exhibited high porosity, which would be responsible of its high reactivity. Due to increase surface available to react and assumingly improving the diffusion of reactants and products. The bulk density of biochar, which is generally lower than that of the original biomass due to volume decrease during volatile matters escape. This thermal stability is crucial in high-temperature metallurgical processes, where biochar must maintain its structural integrity to effectively act as a reductant. [19]

Influence of time

This is related to slow or fast pyrolysis. It has been proven that moderate temperature leads to high fixed-carbon content in the biochar [13].

4. Biochar in pyrometallurgy

A study was conducted to determine the ideal ratio of two reducing agents in the carbothermal reduction of iron ore at elevated temperatures. The reducing agents examined were biochar, specifically derived from pinewood pellets (PW), and coke. The research aimed to find the optimal combination of these two materials to achieve the most effective reduction of iron ore under high-temperature conditions [20]. Incorporating biochar as a partial substitute for coke in the reduction process enhances iron reduction efficiency. All treatments involving biochar yielded positive results. Notably, the mixture containing 80% biochar outperformed other combinations,

including the use of 100% coke. Under specific conditions of 1300°C reduction temperature and 20 minutes holding time, the metallization rate surpassed 90%. These impressive results can be attributed to several factors: the careful optimization of proportions and conditions, the high carbon and volatile matter content in biochar, and its larger specific surface area. The reduction kinetics were assessed using the distribution coefficients of matte/metal-to-slag. Notably, biochar demonstrated superior kinetic performance in reducing metals from the slag. This was evidenced by the substantial variations in the distribution coefficients of both trace elements and iron. These findings suggest that biochar could be a more effective reductant in this process compared to traditional options [21]. The impact of substituting anthracite with biochar as a reductant in the magnetizing-roasting process of pyrite cinder has shown a good prospect for the roasting [17]. The mushroom cultivated residues biochar were used as a reducing agent during iron production from ferric iron [22].

CONCLUSION

Biochar has emerged as a promising alternative to traditional coke in various pyrometallurgical processes, demonstrating significant potential to revolutionize the industry. These new carbon source materials, derived from biomass, have portrayed remarkable efficiency in many high-temperature reduction processes, especially in the production of ferroalloys where it has exhibited good performance versus results obtained with coke. The slag properties remain to be optimized because of difficulty encountered during slag/metal separation. Using secondary materials such as slag containing valuable metals such as copper, nickel, cobalt, germanium, gallium, zinc, carbothermic reduction process using biochar as reductant has shown very good prospect while the produced secondary slag structure remains to be more investigated for better slag/metal immiscibility.

The comparison between different biochar and generic coke, anthracite and coal has revealed that slow pyrolysis has enhanced reactivity of biochar with high porosity therefore which led to lower for lower energy consumption per ton of ferroalloy produced, which is a significant advantage in an energy-intensive industry. It was also found that biochar initiates reduction reactions at lower temperatures which contribute to saving energy therefore decreasing the production cost.

In copper slag cleaning processes, biochar has demonstrated superior kinetic behaviour in the reduction of metals.

The high efficiency of biochar in these pyrometallurgical operations have been attributed to several key characteristics:

- Porous Structure: Biochar typically possesses a highly porous structure, with a predominance of well-distributed micropores which increases the specific surface area significantly available for reactions. The enhanced surface area facilitates better gas-solid interactions, thus more efficient reduction processes. Further, the porosity promotes low activation energy and the diffusion of reducing gases throughout the material, leading to more complete reduction reactions.
- High Reactivity: Biochar often demonstrates higher reactivity compared to coke, particularly in gasification reactions. This partly due to its porosity, chemical composition, low ash content, high volatile matter and a more disordered carbon

structure compared to coke, which make biochar able to react at lower temperatures.

- Sustainable Source: As a renewable resource derived from biomass, biochar offers environmental benefits over coke, which is derived from non-renewable coal. The use of biochar can potentially reduce the carbon footprint of pyrometallurgical operations, aligning with global efforts towards more sustainable industrial practices.

However, it's important to note that the effectiveness of biochar can vary depending on its source material and production conditions. Factors such as pyrolysis temperature, heating rate, and biomass type all influence the final properties of biochar. Therefore, careful selection and possibly even tailoring of biochar properties for specific pyrometallurgical applications may be necessary to achieve optimal results.

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BREWERY'S SPENT GRAIN BIOREFINERY: A SUSTAINABLE APPROACH TO RECOVER VALUABLE MOLECULES AND PRODUCE GREEN ENERGY

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ABSTRACT

Biorefineries offer an advantageous and sustainable solution for managing by-products from the agro-industry while enabling the recovery of valuable molecules and biogas production from residual biomass. This study applied this approach to the beer industry's main by-products: Brewery's Spent Grain (BSG). BSG is typically used as animal feed but shows potential for biorefinery applications due to its high protein content and favorable C/N ratio. By treating this biomass with an ionic liquid consisting of triethylamine and sulphuric acid, nanostructured lignin (LN) was extracted and recovered, while protein hydrolysates (PH) were obtained by applying a hydrolytic process conducted in an alkaline environment. LN and PH are valuable products with potential uses in various fields, such as plant biostimulants and, in the case of LN, even nanocarriers for targeted active compound delivery. Furthermore, the remaining biomass was used as a substrate for the Anaerobic Digestion (AD) to produce biogas. The AD process was carried out in lab-scale batch reactors under mesophilic conditions (37°C), using a digestate as inoculum and untreated BSG as the control. The results showed that BSG has a high potential for biogas production, with the AD process ending after 63 days. The extraction of LN and PH from BSG reduced the biogas production time, thus resulting in lower operating costs, but showed a lower biogas yield than untreated BSG. This suggests that co-digestion with other waste products might be a better approach to improve the amount of bioenergy obtainable from these matrices. Overall, this study highlights the potential of BSG to be reused in a circular economy framework, adding value to this by-product and improving its management.

Keywords: Biogas, Biorefinery, Green-chemistry, Waste, Agroindustry

INTRODUCTION

The continuous global population increase intensifies energy demands, which non-renewable sources alone cannot satisfy. Fossil fuels, heavily relied upon, contribute to environmental issues, with carbon dioxide emissions from combustion processes being a primary cause of global warming [1]. Thus, there is a critical need to adopt renewable energy alternatives, and biogas has emerged as a promising clean energy source for both household and industrial use [2].

Biogas is produced through anaerobic digestion (AD), an environmentally friendly process where microorganisms break down organic matter without oxygen [2]. AD can

utilize biomass from various sources, including food, agricultural waste, and municipal waste. One significant by-product, Brewery's Spent Grain (BSG), originates from beer production and accounts for around 86% of the brewing industry's solid waste [3]. BSG is high in fiber, vitamins, and protein, which makes it a versatile substrate for microbial growth [4]. Although 70% of BSG is currently used as animal feed [5], its composition makes it suitable for other applications, including enhancing nutritional value in food products [6]. However, only 10% of BSG is used for biogas production, signaling the potential for broader applications in bioenergy [7].

Efforts to increase BSG's efficiency in biogas production involve treatment methods, which modify its complex structure [8]. For instance, thermal treatment and ultrasound applications improved methane yield, yet these methods are energy-expensive. A more holistic solution could be a biorefinery approach that extracts valuable compounds from BSG, such as lignin and proteins, prior to AD. Removing such compounds could produce value-added products and enhance AD efficiency by simplifying biomass structure for microbial degradation, increasing methane yield [8,9].

BSG's lignin content, averaging 11.4%, inhibits anaerobic degradation as lignin is resistant to microbial breakdown, which limits biogas output. However, lignin can be extracted for use in several industries, such as the agricultural sector, such as plant bio-stimulant [10]. Similarly, protein extraction is worth mentioning. With a protein content of around 26–30%, BSG can yield bioactive compounds for pharmaceutical and food uses. This also reduces ammonia release during AD, which would otherwise inhibit biogas production [11].

This study seeks to maximize BSG's potential through a 3G biorefinery approach that extracts nanostructured lignin (LN) and protein hydrolysates (PH), followed by AD of the remaining biomass. We will compare biogas yield from pre-treated and raw BSG and assess the co-digestion effects with by-products from the olive oil industry.

MATERIALS AND METHODS

The characterization of BSG used in this study is reported in Table 1.

BSG were used as the biomass from which extract PH and to isolate lignin and hemicellulose. The residual biomasses and untreated BSG underwent anaerobic digestion (AD) to asses their potential biogas production. BSG was also co-digested with olive oil production chain by-products: Olive Pomace (OP) and Olive Mill Wastewater (OMWW).

Table 1. Characterization of BSG (DM = dry matter).

Parameters	Value
Moisture (%)	78.30
Total Volatile Solids (%)	97.50
pH	5.06
Protein (% of DM)	24.30
TOC (% of DM)	26.66
TKN (% of DM)	3.90
Total P (g kg^{-1} DM)	1.02
Lipid (% of DM)	4.27
Cellulose (% of DM)	10.48
Emicellulose (% of DM)	33.24
Lignin (% of DM)	3.99

Moisture content of each biomass was determined by heating the sample at 105°C until a constant weight was achieved. Volatile solids were measured by placing the sample in a muffle furnace, gradually increasing the temperature to 550°C until a stable weight was reached.

Protein hydrolysates were obtained by hydrolyzing the initial biomass under mild temperatures in alkaline conditions. The remaining biomass, designated as BSGph in the text, was then used to evaluate its biogas production potential.

The lignin fraction was isolated using an ionic liquid (IL) composed of triethylamine and sulfuric acid [Et_3NH][HSO_4], followed by solubilization in ethanol and vacuum filtration. The resulting biomass is referred to in the text as BSGp.

Anaerobic digestion process and bioreactors

Lab-scale batch bioreactors were used to evaluate biogas production across all treatments. The reactors were maintained at mesophilic conditions (37°C) throughout the experiment. Biogas volume was measured using the volumetric method, while bio-methane content was determined by passing the biogas produced through an alkaline trap (0.5 M NaOH with thymolphthalein as a pH indicator) to dissolve CO_2 and separate it from the biogas mixture. The control consisted solely of the inoculum. Table 2 presents all treatments and their respective quantities.

https://doi.org/10.5593/sgem2024v/4.2/s17.12

Table 2. Composition of the sample used for biogas production and relative inoculum to biomass ratio.

Sample name	Inoculum		Tested Biomass	
	Quantity (g of DW)	Ratio	Quantity (g of DW)	Ratio
Control	2.4	Sole inoculum	/	/
BSG	1.8	¾	0.6	¼
BSGph	1.8	¾	0.6	¼
BSGp	1.8	¾	0.6	¼
OMWW+BSG	1.8	¾	0.3 of BSG + 0.3 of OMWW	¼
OP+BSG	1.8	¾	0.3 of BSG + 0.3 of OP	¼

RESULTS

This section presents and compares the biogas yields from all treatments to assess the impact of valuable molecule extraction on biogas production. Table 3 outlines the cumulative biogas production of each treatment, along with the respective production durations. The highest biogas yield was observed in BSG, followed by the co-digestion of BSG with OMWW, which produced 1075.6 $Nm^3$of biogas/gVS and 1130.4 $Nm^3$of biogas/gVS, respectively. A key distinction between these two treatments is AD duration, with BSG taking 62 days and OMWW+BSG requiring only 32 days. BSGp, the residual biomass after lignin extraction, yielded 814.9 $Nm^3$of biogas/gVS, followed by co-digested BSG with OP at 452.7 $Nm^3$of biogas/gVS and BSGph at 382.3 $Nm^3$of biogas/gVS.

Table 3 Cumulative biogas production and the relative methane concentration for each treatment. The shown value represent the average within the 3 replicates.

Biomass	*Nm^3 of biogas /gVS*	*CH_4 [%]*	*Day of production*
BSG	1075.6	76.59	62
BSGph	382.3	71.69	20
BSGp	814.9	60	21
OMWW+BSG	1130.1	54.5	36
OP+BSG	452.7	66.05	46

Figure 1 illustrates the daily biogas production for each sample, showing a generally consistent trend: an initial phase of high production, followed by a gradual decrease in biogas yield. For BSG, the production rate begins to decline after approximately 16 days. The only treatment exhibiting a distinct production pattern is OMWW+BSG, where biogas production is less uniform. This treatment shows an initial peak with the highest

single-day yield of 213.9 mL, followed by a secondary peak on day 14, with a production of 92 mL.

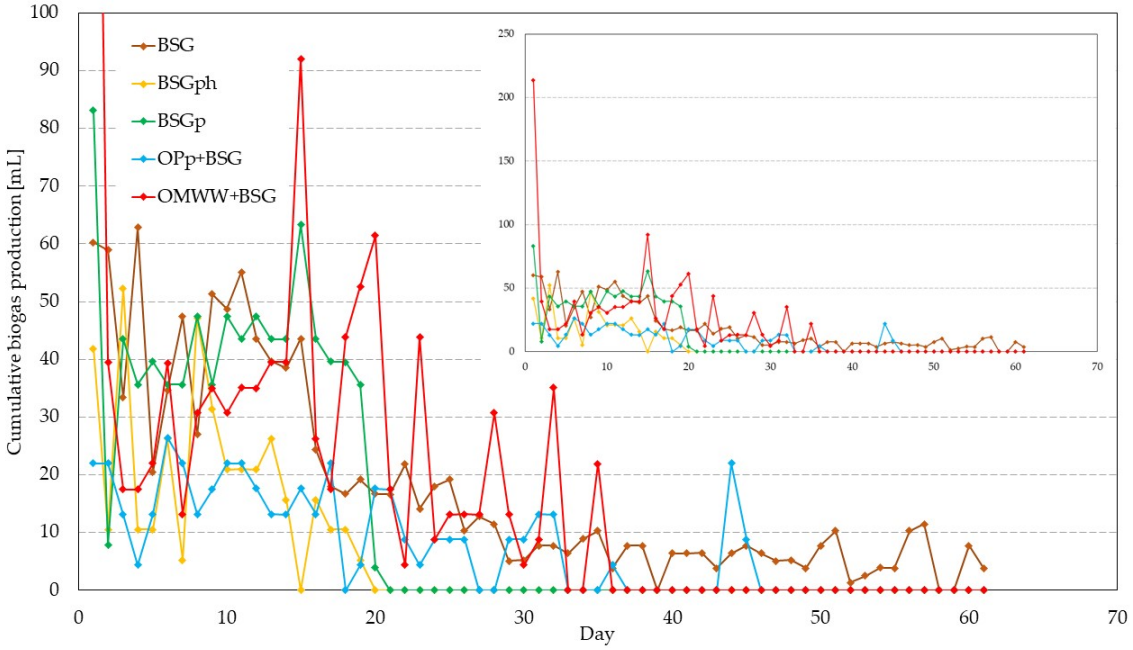


Figure 1. Daily production of all the samples. Data are expressed in mL/day.

In addition to biogas yield, biomethane concentration was also analyzed. Table 3 and Figure 2 show the relative CH_4 concentration in each biogas mixture. BSG demonstrated the highest biomethane concentration at 76.59%, corresponding to a volume of 823.8 mL. BSG was followed by BSGph and OP+BSG, with CH_4 concentrations of 71.69% and 66.05%, yielding 274.1 mL and 299 mL of CH_4, respectively, due to the lower overall biogas production of these biomasses.

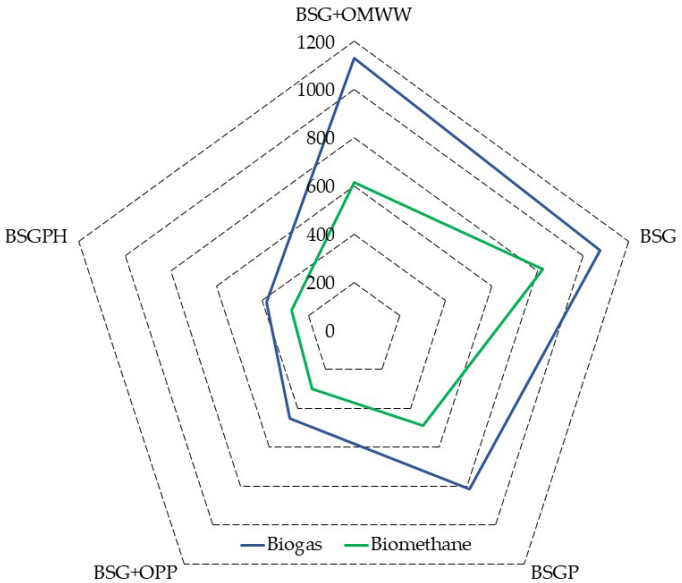


Figure 2. Comparison of biogas yield and corresponding CH_4 concentration across different biomass types

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DISCUSSION

The results indicate that each sample demonstrates different behaviour in biogas yield. BSG appears to be an effective biomass for biogas production, likely due to its composition and nitrogen content, which is crucial for microorganisms involved in AD . Regarding the shorter production period observed when BSG was co-digested with OMWW, this effect could be attributed to the enhanced degradation of OMWW in the presence of additional macronutrients provided, in this case, by BSG. This synergy results in an overall improvement of the biogas production process. [12]. The reduction in production time is essential when considering industrial-scale applications, as it implies lower operational costs, a critical factor for real-world implementation.

In the case of the residual biomass BSGp, the reduced biogas production period (21 days) compared to raw BSG may be attributed to lignin removal. The elimination of lignin, which typically hinders AD steps, appears to enhance the AD process by facilitating a more efficient reaction, resulting in accelerated biogas production [13]. In contrast, after protein hydrolysate extraction (BSGph) via enzymatic hydrolysis, the residual biomass showed the lowest biogas production. This outcome can likely be attributed to a significant reduction in nitrogen content, as protein extraction depletes nitrogen, leading to an imbalanced carbon-to-nitrogen ratio. Maintaining an appropriate C/N ratio is crucial for supporting AD microorganisms, and the nitrogen deficit adversely impacts biogas yield [14].

Evaluating methane concentration is important, as methane represents the primary energy source in biogas. In this aa study, BSG exhibited the highest methane concentration, making it the most effective substrate. This high biomethane yield can be attributed to several factors, including its favourable physical structure, which enhances microbial accessibility, and the absence of toxic compounds that can inhibit anaerobic digestion. In contrast, co-digestion with OMWW resulted in the lowest methane concentration, at only 54.5%, compared to 76.59% in BSG alone. This significant reduction can likely be attributed to the phenolic compounds in OMWW, which are toxic to acetoclastic methanogens responsible for the final step of anaerobic digestion, thereby decreasing overall methane production [15].

CONCLUSION

This work aimed to assess the biogas production potential of by-products from a third-generation (3G) biorefinery and to evaluate the co-digestion of BSG with other significant by-products from the olive oil production chain. The biorefinery approach offers a sustainable method for reusing organic by-products, enabling the extraction of valuable molecules while simultaneously addressing the challenges associated with waste management.

Raw BSG, BSG after the extraction of protein hydrolysates, and BSG following lignin extraction were tested for their biogas production and corresponding biomethane concentrations. BSG was also co-digested with olive pomace and olive mill wastewater. The results demonstrated the high biogas potential of BSG, as well as a high concentration of methane; however, the raw material has not yet been utilized to obtain any valuable molecules. Notably, BSGp produced an acceptable biogas yield in a shorter time frame, albeit lower than that of untreated BSG.

In contrast, the other residue from the 3G biorefinery, BSHph, yielded a low quantity of biogas, likely due to the reduced nitrogen content following protein extraction. Co-digestion with OMWW resulted in significant biogas production, yet the biomethane concentration was low. This reduction may be attributed to the specific biomass chosen for co-digestion—OMWW—which could inhibit the final steps of anaerobic digestion and limit biomethane formation.

Considering the primary objectives of the 3G biorefinery, which include the recovery of valuable products and renewable energy production, we can conclude that BSG exhibits high biogas potential and serves as a promising starting point for obtaining added-value molecules. To enhance biogas yields, the residual biomasses should ideally be co-digested with other by-products that can improve overall performance. However, the two biomasses selected for co-digestion with BSG in this study were not particularly efficient in terms of both biogas yield and methane concentration.

Future studies should explore alternative co-digestion strategies for the residues of the BSG biorefinery to identify more effective combinations that can optimize biogas production and biomethane concentration.

ACKNOWLEDGEMENTS

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EFFECTS OF CHEMICAL AND THERMAL TREATMENT OF FINE DISPERSED GEORGIAN HEULANDITE-CLINOPTILOLITE

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ABSTRACT

The article considers the processes leading to a change in the structure and properties as a result of calcination followed by acid treatment of heulandite-containing tuff from the Georgian Dzegvi-Tedzami deposit. The samples obtained by heat-acid treatment were studied by the X-ray energy dispersion spectra and diffraction patterns, as well as by adsorption of water and benzene methods. It was found that pre-heat treatment reduces weight loss and the degree of dealumination during subsequent acid treatment, and also affects the decationization process: with increasing preheating temperature, the participation of sodium ions in the process slows down, while the participation of potassium ions increases, the overall degree of decationization decreases, and after annealing at 800 °C, compensating cations do not wash out. The crystalline structure of heulandite is preserved after heating to 400-450 °C and subsequent acid treatment, which is confirmed by the preservation of the peak positions in the X-ray diffraction patterns; the change in peak intensity depends on the acid concentration and is associated with changes in the content and distribution of cations. After heating to 500 °C and higher temperatures, the acid-treated samples transform into an amorphous state with crystalline inclusions of chabazite, α-quartz and albite feldspar. The adsorption of water, reflecting the volume of micropores and all pores, as well as the adsorption of benzene, reflecting the hydrophobicity of the surface, decrease with increasing calcination temperature; subsequent acid treatment is of little significance.

Keywords: heulandite, chabazite, dealumination, decationization, dehydration, amorphization

INTRODUCTION

Natural and synthetic zeolites are widely used due to the unique set of molecular-sieve, sorption, ion-exchange and catalytic properties, determined by the structure of these hydrated aluminosilicates $M_x[Al_xSi_yO_{2(x+y)}]\cdot mH_2O$. The zeolite framework is built from alternating SiO_4 and AlO_4^- tetrahedrons forming cages and channels with “entrance windows” with a diameter of 0.5 – 1.2 nm, making up the microporous structure of the zeolite [1]. Unlike synthetic zeolites [2], natural zeolites have an irregular system of

micropores and a system of mesopores with diameters exceeding 2 nm. In synthetic zeolites, Na^+ usually appears as the M^+ ion, compensating for the negative charge of the crystal lattice; in natural zeolites there is a whole spectrum of $M^+ = Na^+$, K^+, $½Ca^{2+}$, $½Mg^{2+}$, etc.; large ions can block the "entrance windows", and the zeolite loses its adsorption capacity. To improve the performance properties of natural zeolites, it is recommended to use acid treatment [3]. The purpose of our research was to study the effect of acid treatment on the structure and properties of heulandite-bearing tuff from the Tedzami deposit, Eastern Georgia, and also to establish the effect of preliminary heat treatment of this natural zeolite on its acid resistance and other properties.

MATERIALS AND METHODS

Samples of tuff containing up to ≈90% of zeolite phase (high-silica heulandite mixed with chabazite in a ratio of 8:1) were collected in the southern section of the Tedzami-Dzegvi deposit, Eastern Georgia [4]. Preparation of samples included crushing of tuff on a cone crusher, sieving to sizes less than 44 μm (325 US mesh), washing with distilled water to remove clay impurities, and drying at a temperature of 95-100 °C.

The prepared samples, kept at 180-200 °C for 2 hours for dehydration, were placed in heat-resistant round-bottomed cups and calcined in a B400/410 muffle furnace (Naberthem, Carl Stuart Group) in the temperature range of 400-800 °C under static conditions for 1 hour; the samples were cooled in a desiccator with calcined $CaCl_2$ and weighed on an FA 2204N electronic analytical balance (Joan lab, China) to determine the weight loss. Acid treatment of heated samples was carried out in 0.5, 1.0, and 2.0 mol/L hydrochloric acid solutions in an OLS26 Aqua Pro shaking water bath (Grant Instruments, US) operating in linear mode at 75 ºC; treatment was carried out for 4-5 hours until a constant weight was achieved.

Chemical composition of samples was calculated from the X-ray energy dispersive (XR-ED) spectra obtained from a JSM-6490LV scanning electron microscope (Jeol, Japan) equipped with an INCA Energy 350 XRED analyzer (Oxford, UK). Powder X-ray diffraction (XRD) patterns were obtained from a D8 Endeavor diffractometer (Bruker, Germany) and modernized Dron-4 diffractometer (USSR) both employing the Cu-K_α line (λ = 0.154056 nm); the samples were scanned in the 2Θ range of 5º to 68º with a 0.02º step at a scanning speed of 1º/min. The adsorption capacity for water and benzene vapors was measured at room temperature and at a constant vapor pressure of water (relative pressure p/p_o=0.4 and saturated vapor pressure p/p_o=1.0) and benzene (p/p_o=1.0).

RESULTS

The weight loss during calcination of dehydrated samples averaged 12±1%, increasing slightly with increasing calcination temperature. The weight loss of calcined samples as a result of acid treatment depends on the heat treatment temperature and the acid concentration; the results are shown in Fig. 1.

The results for chemical composition of the heat-acid-treated samples calculated for 72 oxygen atoms in the unit cell are given in Tables 1 and 2 in terms of averaged empirical formulas of dehydrated zeolites.

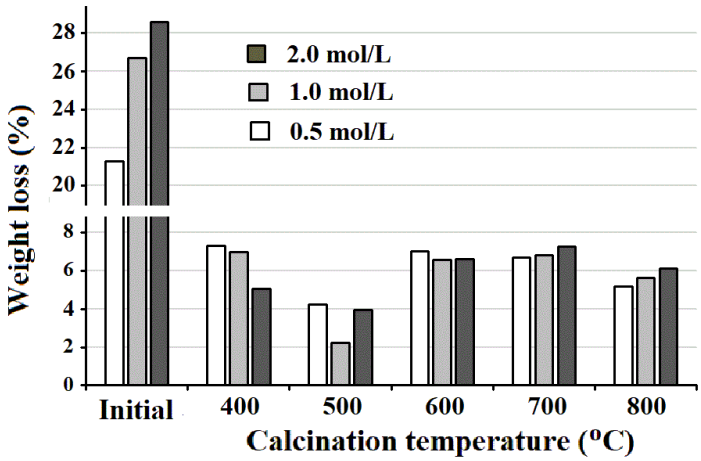


Fig. 1. Weight loss from acid treatment of initial and calcined heulandite.

Table 1. Composition of aluminosilicate framework of initial (100) and heat-acid-treated samples (CT – calcination temperature)

CT (°C)	Concentration of HCl solution (mol/L)			
	0	0.5	1.0	2.0
100	$Al_{7.8}Si_{28.2}O_{72}$	$Al_{4.59}Si_{31.4}O_{72}$	$Al_{4.26}Si_{31.7}O_{72}$	$Al_{3.43}Si_{32.6}O_{72}$
400	$Al_{7.63}Si_{28.4}O_{72}$	$Al_{6.05}Si_{30.0}O_{72}$	$Al_{6.29}Si_{29.7}O_{72}$	$Al_{5.65}Si_{30.4}O_{72}$
500	$Al_{6.84}Si_{29.2}O_{72}$	$Al_{6.59}Si_{29.4}O_{72}$	$Al_{6.52}Si_{29.5}O_{72}$	$Al_{6.82}Si_{29.2}O_{72}$
600	$Al_{7.55}Si_{28.5}O_{72}$	$Al_{7.09}Si_{28.9}O_{72}$	$Al_{6.79}Si_{29.2}O_{72}$	$Al_{6.69}Si_{29.3}O_{72}$
700	$Al_{7.71}Si_{28.3}O_{72}$	$Al_{6.99}Si_{29.0}O_{72}$	$Al_{7.68}Si_{28.3}O_{72}$	$Al_{6.62}Si_{29.4}O_{72}$
800	$Al_{7.63}Si_{28.4}O_{72}$	$Al_{6.9}Si_{29.1}O_{72}$	$Al_{7.38}Si_{28.6}O_{72}$	$Al_{6.74}Si_{29.3}O_{72}$

Table 2. Cationic composition of unit cell in initial (100) and heat-acid-treated samples.

CT (°C)	Concentration of HCl solution (mol/L)			
	0	0.5	1.0	2.0
100	$Na_{1.96}K_{0.47}Ca_{1.49}Mg_{1.17}$	$Na_{0.62}K_{0.67}Ca_{0.71}Mg_{0.47}$	$Na_{0.47}K_{0.40}Ca_{0.65}Mg_{0.46}$	$Na_{0.096}K_{0.50}Ca_{0.61}Mg_{0.26}$
400	$Na_{1.98}K_{0.46}Ca_{1.45}Mg_{1.14}$	$Na_{0.80}K_{0.56}Ca_{1.03}Mg_{0.79}$	$Na_{0.63}K_{0.52}Ca_{1.38}Mg_{0.52}$	$Na_{0.69}K_{0.46}Ca_{0.92}Mg_{0.54}$
500	$Na_{1.78}K_{0.48}Ca_{1.33}Mg_{1.06}$	$Na_{1.06}K_{0.57}Ca_{1.58}Mg_{0.61}$	$Na_{1.22}K_{0.50}Ca_{1.30}Mg_{0.53}$	$Na_{1.25}K_{0.46}Ca_{1.34}Mg_{0.46}$
600	$Na_{2.04}K_{0.53}Ca_{1.51}Mg_{1.13}$	$Na_{1.50}K_{0.48}Ca_{1.82}Mg_{0.81}$	$Na_{1.72}K_{0.46}Ca_{1.59}Mg_{0.33}$	$Na_{1.69}K_{0.40}Ca_{1.47}Mg_{0.38}$
700	$Na_{2.00}K_{0.46}Ca_{1.46}Mg_{1.08}$	$Na_{1.67}K_{0.46}Ca_{1.73}Mg_{0.75}$	$Na_{2.3}\text{-}K_{0.53}Ca_{2.02}Mg_{0.38}$	$Na_{1.64}K_{0.44}Ca_{1.615}Mg_{0.35}$
800	$Na_{1.91}K_{0.53}Ca_{1.45}Mg_{1.14}$	$Na_{1.50}K_{0.34}Ca_{1.88}Mg_{0.65}$	$Na_{2.10}K_{0.44}Ca_{1.94}Mg_{0.44}$	$Na_{1.57}K_{0.52}Ca_{1.72}Mg_{0.46}$

Analysis of the XRD pattern of the original heulandite-bearing tuff is given in [4], the assignment of peaks to the main heulandite phase and the admixture chabazite phase was carried out on the basis of the simulated XRD patterns from [5] according to data of [6] and [7]. The measured peak positions (Bragg's angles 2Θ) coincide with the simulated ones, but the peak intensities in the experimental and calculated XRD patterns differ due to different cationic composition. Despite the formation of an amorphous phase, all intense peaks (I/I_o>10%) of heulandite remain in the XRD patterns when heated up to 400 °C and the peak positions are quite consistent with the simulated spectrum of heulandite [5], but after acid treatment the intensity of most peaks changes. XRD patterns of only acid-treated and only calcined heulandite samples are shown in [4], Table 3 shows the relative intensities of strong peaks (I/I_o>10% in low-angle range and I/I_o>20% for 2Θ>23°) in the XRD patterns of the original sample, acid-treated samples, as well as samples calcined at 400 °C and then treated with acid in comparison

with the X-ray data of simulated pattern [5]. In the XRD patterns of samples annealed at temperatures above 500 °C, a broad band of the amorphous phase and a sharp peak of quartz (2Θ=26.6°) appear; after annealing the sample at 800 °C, the XRD pattern is a broad band of the amorphous phase of heulandite with overlapping broadened peaks of chabazite, as well as narrow peaks of such heat-stable minerals as quartz, quartz polymorph cristobalite, and albite feldspar.

Table 3. X-ray data of simulated pattern [5] and relative intensities of intense peaks in XRD patterns of initial, acid-treated and heat(400 °C)-acid-treated samples.

X-ray data from [5]				Relative intensity (%)						
Miller index	d (Å)	2Θ (°)	I/I_o (%)	Initial	Acid-treated samples			Heat-acid-treated samples		
					0.5	1.0	2.0	0.5	1.0	2.0
020	8.979	9.85	100	100	100	100	100	100	100	100
200	7.989	11.07	64.0	46.6	29.0	34.4	30.8	41	47	38
-201	6.792	13.03	17.2	30.0	23.7	28.1	26.9	46	67	46
220	5.969	14.84	12.9	4.9	<8	<8	<8	12.5	<12	<12
-311	5.258	16.86	11.3	30.0	21.0	31.2	30.7	46	60	42
111	5.157	17.19	32.0	37.9	25.0	34.3	32.7	50	73	48
-131	4.661	19.04	20.3	31.1	22.4	31.3	30.8	20	20	19
{131-240}*	4.003-3.914	22.21-22.72	60.2	115	89.5	131	108	132	186	146
-312	3.563	24.99	29.4	23.3	19.7	<10	<10	29	50	35
-222	3.433	25.96	50.8	46.6	38.2	46.9	50.0	46	67	58
-422	3.176	28.09	45.1	54.4	55.3	81.2	182	86	120	112
-441	3.132	28.49	34.1	23.3						
{151-112}**	2.988-2.975	29.90-30.03	41.6	59.2	47.4	62.5	52.0	55	93	58
530	2.819	31.74	43.6	39.8	26.3	35.9	30.8	25	40	31

* – peaks from (131), (400), (330), (-421) and (240) planes.
** – peaks from (151), (350) and (112) planes with relative intensities of 41.6, 27.8 and 12.7%, respectively.

Results of measurements of water vapor and benzene adsorption on heulandite calcined at different temperatures and then subjected to acid treatment in solutions with different concentrations of hydrochloric acid are given in Tables 4-5.

Table 4. Water vapor adsorption (mmol/g) at p/p_o=0.4 of heat-acid-treated samples.

p/p_o	[HCl] (mol/L)	Calcination temperature (°C)					
		100	400	500	600	700	800
0.4	0	5.35	4.03	1.71	0.28	0.27	0.10
	0.5	5.50	4.31	1.71	0.55	0.49	0.30
	1.0	5.43	4.21	1.78	0.47	0.49	0.43
	2.0	5.53	4.19	1.72	0.66	0.71	0.41
1.0	0	8.01	7.36	4.08	2.82	2.65	2.30
	0.5	9.76	6.53	4.12	2.44	2.15	2.11
	1.0	8.66	6.70	3.49	2.41	2.35	1.78
	2.0	9.58	6.04	4.04	2.73	2.33	2.05

Table 5. Benzene adsorption (mmol/g) at p/p_o=1.0 of heat-acid-treated samples.

[HCl] (mol/L)	Calcination temperature (°C)					
	100	**400**	**500**	**600**	**700**	**800**
0	1.40	1.01	0.76	0.43	055	0.25
0.5	1.57	1.21	0.50	0.59	0.52	0.46
1.0	1.53	1.26	0.62	0.49	0.45	0.47
2.0	1.51	1.13	0.84	0.44	0.60	0.34

DISCUSSION

According to Fig. 1, the weight loss of the original sample as a result of acid treatment increases with increasing concentration of the hydrochloric acid solution, but for calcined samples this pattern is violated. Overall, the calcined samples showed at least three times less weight loss compared to the original sample, indicating higher acid resistance of the amorphous phase.

As the results presented in Table 1 show, with increasing calcination temperature, the aluminum content in the unit cell increases compared to the content in the samples subjected to acid treatment only. The change in the silicate modulus, expressed by the atomic ratio Si/Al, is shown in Figure 2.

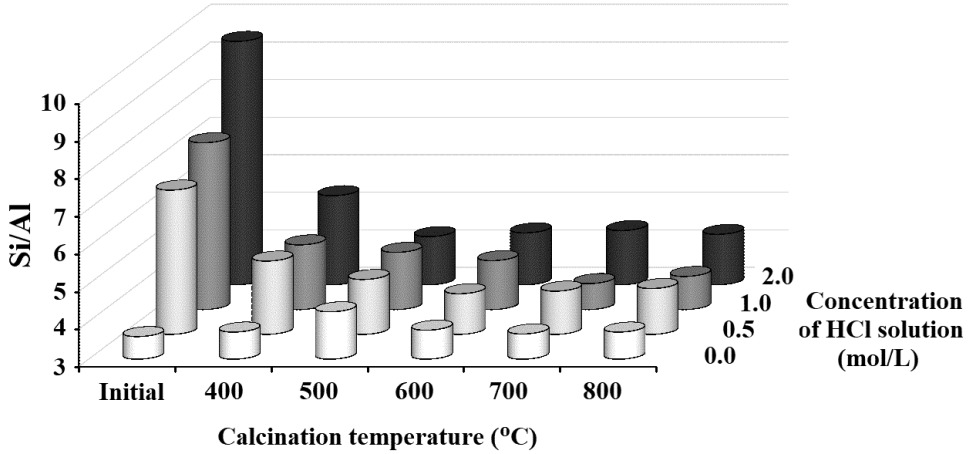


Fig. 2. The Si/Al ratio in samples calcined at different temperatures and treated with HCl solutions of various concentrations.

For the initial sample, Si/Al increases almost threefold, while after calcination at 400 °C the modulus increases only by 50%, after calcination at 500 °C it remains constant, and after annealing at higher temperatures increases by only 20%. Such effects once again indicate that in an acidic environment the leaching of aluminum from an amorphous aluminosilicate is more difficult compared to the state when it forms a microporous crystalline structure.

As for the change in the cation composition (see Table 2), in the initial sample, with an increase in the acid concentration, the total positive charge of the compensating ions decreases monotonically from ≈1 to ≈0.68; the content of Na^+ ions decreases by ≈9 times, the content of Mg^{2+} ions decreases by approximately two times, the content of Ca^{2+} ions changes insignificantly (−7%), and the content of K^+ ions increases non-monotonically. For heat-acid-treated samples, with an increase in the calcination

temperature, the decrease in the relative content of sodium ions (Na/Al) slows down, and after high-temperature calcination (700-800 °C), on the contrary, Na/Al even increases, that is, calcination promotes the retention of sodium cations in the zeolite framework. In the uncalcined sample, potassium cations are practically not washed out under the action of hydrochloric acid, and the relative content of K/Al increases, and this growth, although to a lesser extent, continues in samples calcined at temperatures up to 600 °C, but after high-temperature annealing, the K/Al ratio decreases. Apparently, heating the zeolite promotes the involvement of potassium ions in the decationization process. Preliminary heat treatment promotes the leaching of calcium and magnesium cations, as evidenced by a significant decrease in the relative Ca/Al and Mg/Al content, especially in concentrated solutions and with increasing calcination temperature. The change in the total charge of compensating cations depending on the calcination temperature and the concentration of hydrochloric acid is shown in Figure 3, from which it is evident that preliminary heating of the zeolite reduces the degree of decationization.

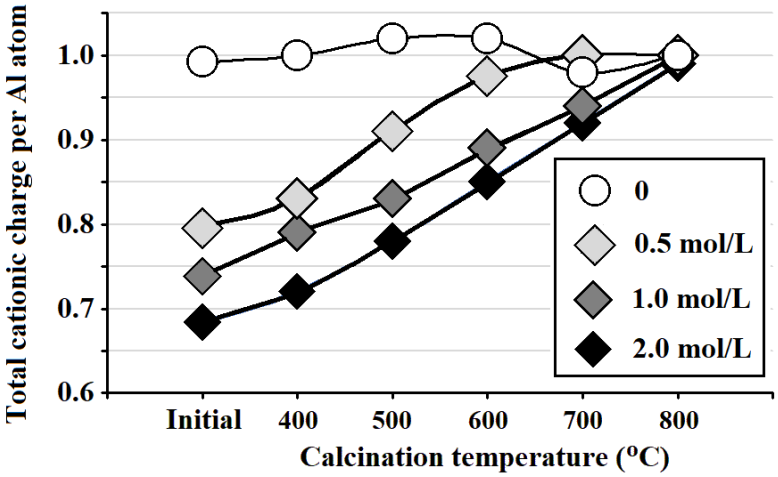


Fig. 3. Total cationic charge per Al atom in calcined initial (0) and acid-treated samples.

Changes in the cationic composition as a result of thermo-acid treatment are reflected in X-ray diffraction patterns (see Table 3). The increase in the intensity of the peaks in the region of 22-23° for the initial sample is leveled after treatment in a dilute solution (0.5 mol/L), but appears again after treatment in concentrated solutions, and preliminary calcination at 400 °C leads to an even greater increase in the relative intensity of these peaks. This is probably due to a change in the content of potassium ions that occurs during dealumination and decationization. In acid-treated samples, the peaks at $2\Theta \approx 28°$ from the -422 and -441 planes merge and the intensity increases sharply with increasing acid concentration; in heat-acid-treated samples this effect also manifests itself, but not monotonously and not to the same extent. However, changes in the intensity of most peaks are non-monotonic and cannot be interpreted [8].

XRD patterns of samples pre-calcined at 500 °C and higher temperatures, followed by acid treatment in solutions of any concentration, represent a wide band of the amorphous phase with superimposed narrow peaks of quartz and albite, as well as broadened peaks of thermostable chabazite (the temperature of the collapse of its crystalline structure is over 900 °C); peaks of wairakite ($Ca(Al_2Si_4O_{12})\cdot 2H_2O$), formed simultaneously with quartz at ≈500 °C [9], could not be identified.

Adsorption at a relative pressure of p/p_o=0.4 reflects the filling of micropores [10], while adsorption at saturated vapor pressure (p/p_o=1) shows the total volume of all pores [11]. For the initial sample, the volume of micropores accessible to water molecules (5.35 mmol/g or ≈0.1 cm^3/g) is about two thirds of the total pore volume (8 mmol/g or ≈0.15 cm^3/g); the adsorption in the micropores remains virtually unchanged as a result of acid treatment, and the total adsorption in all pores increases by about 20% (see Table 4). As for the thermal effect, the specific volume of micropores decreases with increasing calcination temperature, reaching very low values (<0.005 cm^3/g) at temperatures above 500 °C, the volume of all pores decreases monotonically with increasing calcination temperature; the difference between these two indicators, proportional to the volume of mesopores, increases from 0.05 to 0.06 cm^3/g before the onset of amorphization, and then decreases to 0.04 cm^3/g, which indicates the effect of thermal treatment on the mesopore system. The large size of the non-polar benzene molecule does not allow it to penetrate into the micropores and channels of heulandite; benzene adsorption occurs on the surface and reflects its hydrophobicity [12]. According to the obtained results (see Table 5), the change in benzene adsorption in etched samples is insignificant, but heat treatment significantly reduces the surface hydrophobicity.

CONCLUSION

Preliminary thermal treatment of heulandite-containing tuff from the Tedzami-Dzegvi deposit, Eastern Georgia, reduces weight loss and the degree of dealumination during subsequent acid treatment, and also affects the decationization process: with increasing preheating temperature, the participation of sodium ions in the process slows down, while the participation of potassium ions increases, the overall degree of decationization decreases, and after annealing at 800 °C, the replacement of compensating cations with H^+ ions and their leaching does not occur. Despite the amorphization that occurs at temperatures above 200 °C, the crystalline structure of heulandite is preserved even after heating to 400-450 °C and subsequent acid treatment, as evidenced by the preservation of the peak positions in the XRD patterns; the change in peak intensity depends on the acid concentration in the processing solution and is associated with changes in the content and distribution of cations. After heating to 500 °C and higher temperatures, the acid-treated samples transform into an amorphous state with crystalline inclusions of chabazite, α-quartz and albite feldspar; the presence of wairakite at temperatures from 500 to 750 °C could not be confirmed. The adsorption of water molecules in micropores and in all pores, as well as the adsorption of benzene, reflecting the hydrophobicity of the surface, decrease with increasing calcination temperature; subsequent acid treatment is of little importance.

ACKNOWLEDGEMENTS

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HANDLING OF FINES DURING PYROMETALLURGICAL PROCESSES: CHALLENGES AND PROSPECTS

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ABSTRACT

During the mining, handling, and processing activities, the production of fines is inevitable due to breakage of large particles caused by compression, abrasion, attrition and impact of the ore particles with one another and the equipment during beneficiation and handling. The fines generated as a result, are generally high-grade feed stock materials and add value to processes. Many attempts to recycle these fines have shown some limitations because of the quality of binders used for agglomeration. Pyrometallurgical processes are based on the principle of "look at the slag and the metal will look at it itself "to emphasise on the quality of the slag for better of metal recovery. Inorganic binders have proven to be impurities carriers therefore disturbing smelting processes due to poor slag composition. The current investigation deals with the impact of organic binders on copper slag briquettes used for copper recovery during carbothermic reduction. It transpired that organic binders have shown improvement on the behaviour of the copper slag briquettes during carbothermic reduction in the furnace. XRF, XRD and SEM-EDS have been used to characterise the head samples and products.

Keywords: Fines, binders, briquettes

INTRODUCTION

The value chain of metal production is summarized in different steps namely mining, ores treatment through different routes to produce either a material or metal of certain purity. During excavation operations fines are generally generated. However, depending on the type of ore mined and the chemical composition of the ore the amount may vary based on the mechanical properties of high level of minerals present in the ores. During crushing and grinding which constitute comminution, particle size reduction and minerals liberation occur [1]. While it is largely reported on fine generation during comminution, it is observed that even during high temperature operations fine are generated due different phenomena [2-7]. The proceeds of smelting are namely the metal, slag and off-gases. Depending on the process and the grade the slag may either be recycled or stockpiled. During handling of slag fine are also generated, which makes the recycling of slag challenging and causing a loss to the production. Valuable fines are therefore agglomerated using different ingredients amongst which binders. Inorganic binders have been largely used to valorise fines that are recycled in the value chain and increase the production. Not only that fines are contributing to production, but also due to gradual depletion of the ore bodies lumps fines have become a secondary source of

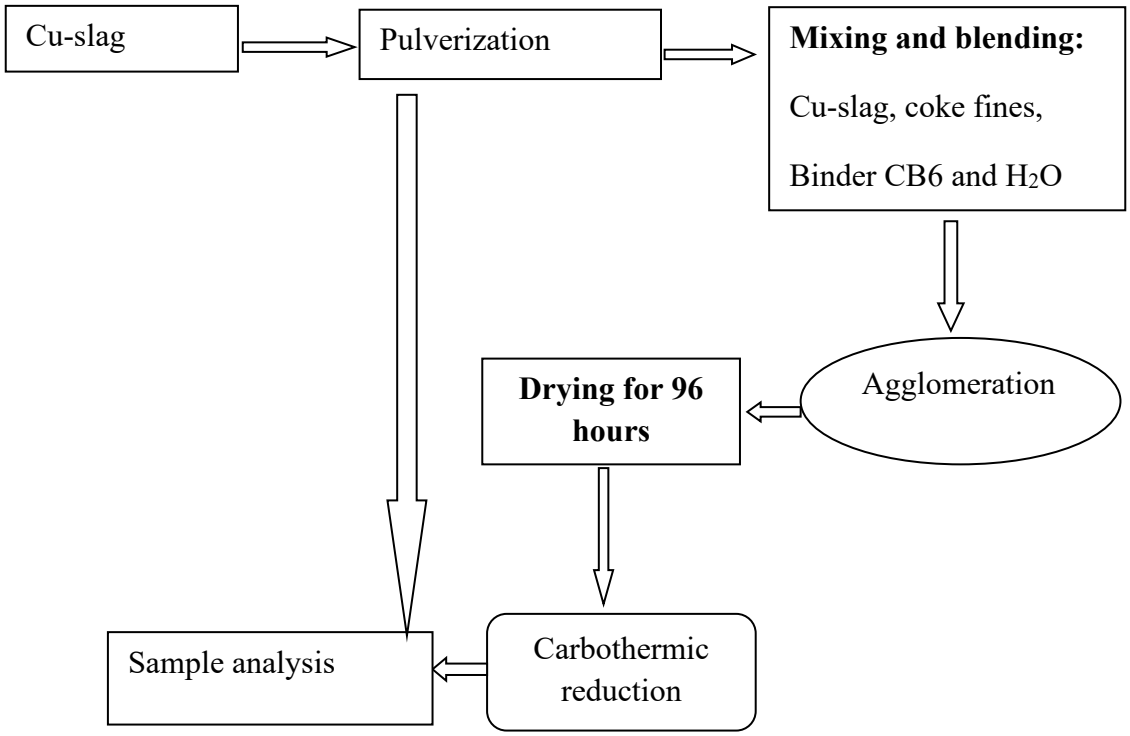
the feed. Molasses mixed with lime have been tested in making briquettes to produce ferrochrome [8]. Results have proven considerable improvement in the chrome recovery. Bitumen and starch were used to agglomerate manganese ore sinter fines during handling [9]. Results have shown that both starch and bitumen could be used to agglomerate the manganese ore sinter fines but under different conditions of moisture and pressure.

Challenges created by fines in the pyrometallurgical industry

The quality of the proceeds from a pyrometallurgical process is dependent on the chemical composition of the feed [10,11]. During agglomeration the recovery of Platinum Group Minerals (PGM's) by flotation, studies have recommended to subject the ore to three stages of milling during comminution [12]. It was found that although the recovery had increased, overgrinding may occur, and fines generated therefore negatively impacting the flotation stage. In the pyrometallurgical industry, the use of fine coke has been tested in the Blast furnace to produce pig-iron [13]. It was found that by adding 32% maximum in the furnace, the recovery decreased by 0.2 to o,4% for each 1% of coke fines added. The above demonstrates that not only the ore fines used in the furnace may affect the operations but any additives to the furnace have the same impact. Depending on the size of the vibro-feeder the size of ferro-alloy varies from one plant to another. The size requirement is strictly observed. During this operation a large quantity of fines is usually generated which is difficult to use in the steelmaking operating furnace or the ladle if it is secondary refining units due to their low recovery of alloy and the tendency to choke the suction duct [14]. In the Blast furnace, it has been found that when the injection rate of fines increased, the frequency of slips, the gas pressure, and the frequency and extent of the raceway shape variation increased. The injected fines were deposited at the surface of the dead-man and near the furnace wall where the burden descent velocity is low. When the high-concentration regions of fines are formed at the surface of the dead-man and near the furnace wall, the burden descent region in the lower part of the furnace reduced and the retention time of the burden decreased. The circulation of gas becomes inadequate, fines are likely to be deposited in the center and they descend with the burden. This is so detrimental to the operations of the furnace rendering ineffective the overall process [15]. It is therefore clear that fines are detrimental to metallurgical processes when they are not properly managed. Further, bentonite may improve the strength of briquettes while at the same time brings impurities such as silica and alumina. During briquetting of subbituminous coal using bentonite, the composition of bentonite revealed 51,01% silica and 10% alumina [16]. This is an indication that if used in a carbothermic reduction process, the slag composition would be badly affected, therefore affecting the quality if not the metal recovery.

MATERIALS AND METHODS

Materials used include copper slag sample from the copper matte production provided by Gecamines and STL in the Democratic Republic of The Congo. CB6 organic binder is provided by an anonymous company, coke fines, and graphite crucible from the university of Johannesburg. The methodology is summarised in the flow sheet.



Cu-slag was pulverised and mixed with coke fines as reductant, CB6 binder and 5% of water. The briquettes were made using Agglotek VA Resources machines and alumina tube furnace for carbothermic reduction experiments.

RESULTS AND DISCUSSION

Table 1 and Figure 1 provide results of the XRF and XRD respectively.

Table 1 XRF slag head sample

Compound	MgO	Al_2O_3	SiO_2	GeO_2	CuO	Fe_2O_3	CaO	TiO_2	Co_2O_3	ZnO
%Mass	2.93	5.17	32.85	0.014	3.88	26.32	17.45	0.48	2.03	4.93

XRF results reveal the presence of copper oxide, iron oxide, Germanium oxide, zinc oxide, cobalt oxide and a considerable amount of silica. The silica content confirms that the slag being delt with is fayalitic whereas XRD confirms the XRF results but depicts the presence of sulfides entrained during slag tapping.

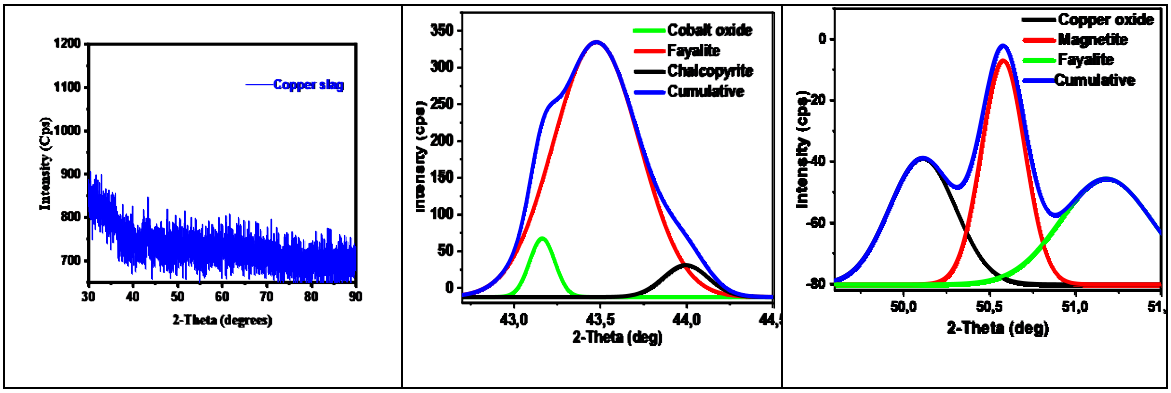


Figure 1 XRD of the slag head sample plotted with Origin (Kayembe at al., 2019)

The XRD peaks had to be decomposed using Origin software to be able to depict different phases. This was due to the presence high amount of silica that is an amorphous phase.

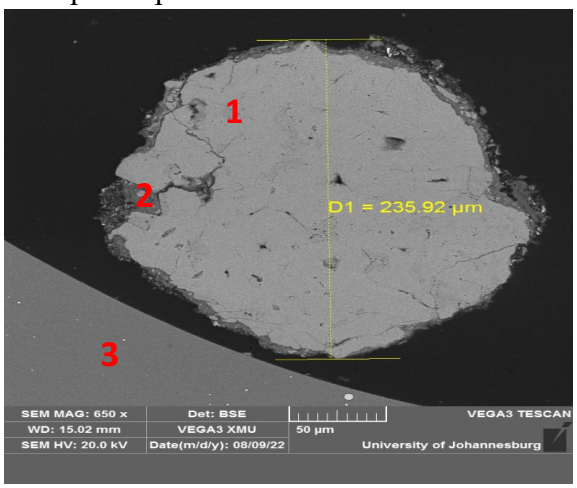


Figure 2 SEM-EDS of the slag head sample

The phases present in the slag head sample are presented in Table 2.

Table 2 Head slag sample spectra

	Mg	Al	Si	S	Ca	Fe	Cu	Zn	Ge	O	Possible phases
Spectrum 1	-	1.7	3.6	0.04	0.32	40.46	0.54	0.34	0.03	52.24	Cuprite, Covelite
Spectrum 2	3.1	2.7	19.41	-	9.66	3.48	0.32	0.11	0.01	60.45	Olivine, Fayalite
Spectrum 3	1.6	10.1	16.72	0.02	0.43	6.48	1.09	0.34	0.01	63.2	Pyrrhotite, covellite, Anorthite

The SED-EDS has revealed the presence of fayalite, cuprite, olivine, anorthite, covellite and pyrrhotite. During slap tapping some matte might be entrained. This explains the presence of these sulfides in the slag head sample because this slag emanated from the reverberatory furnace.

The cumulative moisture has shown in Figure 3. From Figure 3, it is observed that the Cumulative moisture decreased over time. The initial moisture for all the samples was 5%, but the drying was found to also depend on the amount of binder added. The moisture in samples with lowest binder decreased faster.

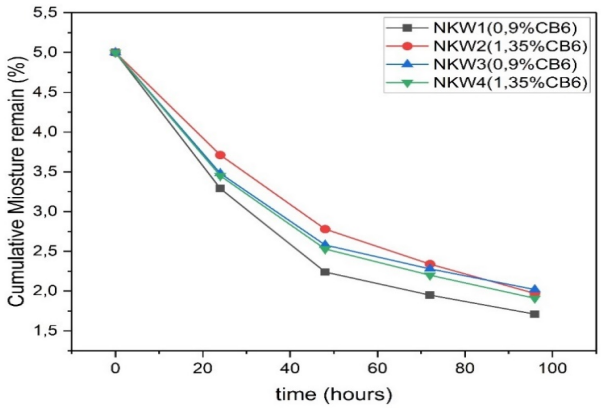
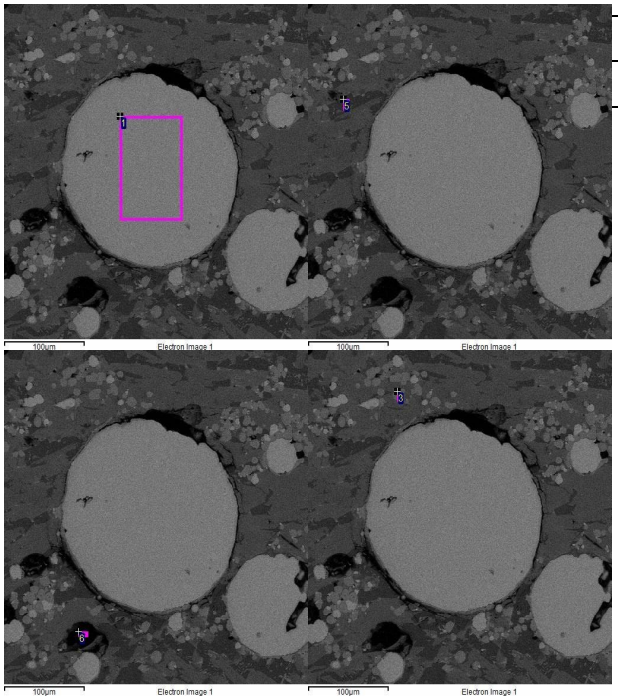


Figure 3 Cumulative % moisture remain (Nkwinika, 2023)

The SEM-EDS of the reduced slag is shown in Figure 4. It transpired that the reduction took place and metal has been produced. However, the slag/metal separation remains a challenge. The use of CB6 organic binder has shown its prowess in effectively binding slag fines and allowing the recovery of metal.



Element	Cu	Fe	Co	Ge
Mass%	23,9	67,1	8,95	0,05

Figure 4 SEM-EDS of the reduced slag

CONCLUSION

The handling of fines in pyrometallurgical industry remains a challenge. To address the issue different types of binders were used. Amongst the tested in different processes are inorganic binders mainly bentonite. Research have revealed that bentonite, although very efficient in obtaining good strength, bentonite has shown its limitations because of it bringing impurities that affect the slag composition, thus the metal recovery. A new trend of organic binders is being tested to avoid importing impurities into the pyrometallurgical processes. The current investigation has demonstrated that the use of organic binders is the route to explore because it shows very good prospects. The slag fines used contained copper, cobalt, iron, germanium, nickel, zinc, minor lead. CB6 is the organic binder tested. The quantity of the binder to be added remains a parameter to optimize to obtain good strength and porosity of the bonded pellets or agglomerates. Results revealed that the metal was successfully produced, however sla-metal separation needs to be addressed.

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KINETIC STUDY OF CEMENT-ASBESTOS THERMAL DECOMPOSITION PROCESS UNDER ISOTHERMAL CONDITIONS

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ABSTRACT

Asbestos is a general name applied to a group of silicate minerals which naturally occur in fibrous form. It is a natural mineral widely used in the past, especially in the construction industry. Despite its good performance properties, it is currently known that asbestos has carcinogenic properties. The problem of storing asbestos wastes is significant worldwide. This especially applies to countries where the production and use of asbestos products is prohibited by law. One of the possible methods of proceeding and solving the above problem is a thermal treatment, which results in thermal decomposition of dangerous asbestos fibers. The kinetic study of the thermal decomposition process carried out for cement-asbestos has been investigated by ex-situ thermal treatment. Obtained results allow for kinetic interpretation of this thermal transformation. The kinetic analysis of the isothermal data using an Avrami model yields values for the overall reaction order. The apparent activation energy of the thermal decomposition process for tested cement-asbestos sample is about 160 kJ/mol.

Keywords: cement-asbestos, thermal decomposition, kinetic study, isothermal

INTRODUCTION

Asbestos is not a term for a specific mineral, but a general name that covers fibrous varieties of silicate minerals from the serpentine and amphibole groups. Chemically, they are hydrated metal silicates, containing mainly Mg, Na, Ca or Fe. A characteristic feature of these minerals is their fibrous structure [1].

Asbestos minerals are a material with specific physical and chemical properties, used in a very wide range since the beginning of the 20th century. It has been used in approximately 3,000 products, including in the construction, chemical, transport, shipbuilding and professional energy industries [1,2]. The largest amounts of asbestos were used in construction for the production of insulating and cladding cement-asbestos boards and roofing. The cement-asbestos building materials (in Poland known also as ‘eternit’) were a very cheap and easy to produce an assortment of building materials. It is estimated that more than 85 % of the consumed asbestos in Poland alone, was used for the production of this type of building materials [3].

On the other hand, the carcinogenic properties of asbestos are now widely known [4]. They result primarily from the characteristic fibrous crystalline structure. In many countries, the use of asbestos has been banned and all materials containing asbestos are treated as hazardous materials or waste. It is common practice to deposit such waste in special landfills. The problem of waste containing asbestos concerns both asbestos used in the past and currently found in buildings and devices [5,6,7].

In times of increasing ecological awareness, the asbestos problem seems unsolved. Taking into account the waste management hierarchy and the fact that landfilling is the least desirable solution, the less environmentally harmful method for asbestos waste management should be considered. Asbestos disposal and recycling methods have been a subject of many studies [8,9,10]. Most of the proposed techniques concern the destruction of the harmful, fibrous structure of asbestos and transforming them into reusable material, mainly using thermal methods. Thermal treatment methods have less impact on the environment than other asbestos disposal processes. This thermal treatment is used to transform asbestos into an inert material within the temperature range at which the asbestos fibres become unstable and transform into new crystalline phases [11,12,13].

This study aims to analyse the thermal decomposition process of cement-asbestos waste. In this study, the kinetic parameters of this overall process were determined by ex-situ isothermal treatment including sample mass loss.

MATERIALS AND METHODS

In this study sample of corrugated cement-asbestos roofing panel was used. The specimen come from south of Poland and were exposed to external weather conditions for many years. Their main physical properties are summarized in Table 1. For further analysis, the material sample was crushed and ground to a grain size of less than 0.5 mm.

Table 1. Characteristics of cement-asbestos sample.

Apparent density; [g/cm^3]	1.94
Open porosity; [%]	15.4
Water absorption; [%]	7.9
Melting point; [°C]	1370
Form	gray powder, tendency to aggregate grains, visible white-yellow fibers

To determine the chemical composition and course of thermal decomposition of asbestos waste this cement-asbestos material was instrumentally studied by X-ray fluorescence spectrometry (XRF) as well as differential thermal analysis (DTA) and thermogravimetric analysis (TG/DTG). The chemical analysis of the sample was performed using a Panalytical Magix PW-2424 spectrometer, based on the fused cast-bead method described in PN-EN ISO 12677:2011 standard. The chemical analysis was supplemented by loss on ignition (L.O.I.) value measured by isothermal calcination at 1025 °C. Thermal analysis (DTA and TG/DTG) was performed on the STA 409 PC Luxx apparatus. About 100 mg of cement–asbestos sample was placed on an alumina crucible and heated from ambient temperature to 1450 °C at a rate of 20 °C min^{-1} in an air atmosphere with a 10 mL min^{-1} rate.

A kinetic study of considered cement-asbestos sample was conducted by ex-situ method, where material (starting amount of material was 5 g) was isothermally treated in a porcelain crucible at selected temperatures: 700, 725, 750, 775 and 800°C recording loss of mass at time intervals until a constant mass was obtained. At each considering temperature different heating times were used in order to finish thermal decomposition

reaction. Isothermal treatment was performed in electric laboratory furnace Nabertherm LT9/14.

RESULTS AND DISCUSSION

The presence of asbestos fibers in tested material was obvious. There was a clear presence of fibrous forms in the crushed material (Fig. 1). From the chemical point of view cement-asbestos material was composed mainly of calcium and silicon compounds accompanied by significant loss on ignition (Tab. 2) which is not surprising due to the presence of mainly cement matrix in the waste. The course of the thermal decomposition process of the cement-asbestos sample is presented in Fig. 2.

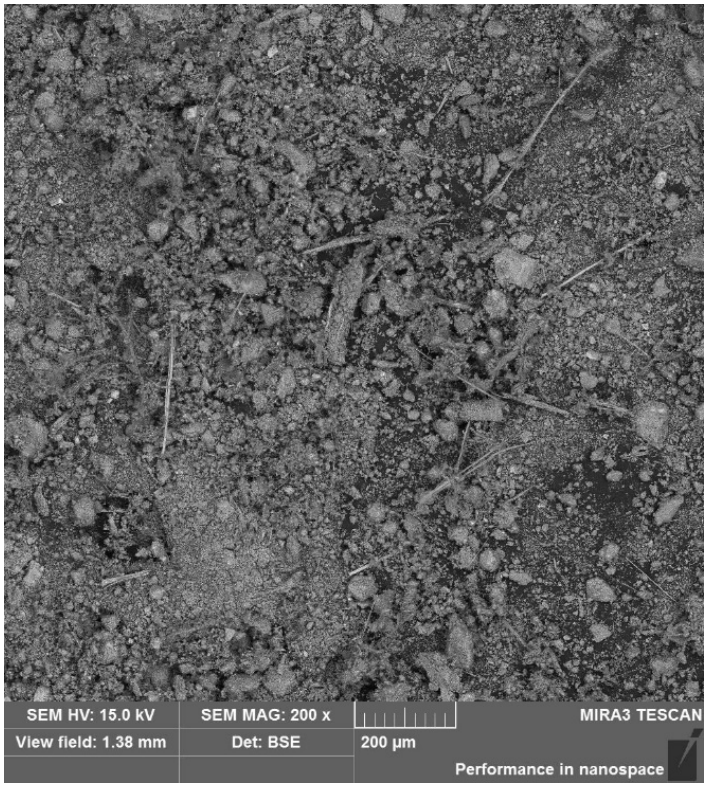


Fig. 1. SEM image of cement-asbestos sample with the presence of characteristic fibrous form

Table 2. Chemical composition of cement-asbestos sample, wt%.

SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	SO_3	P_2O_5	L.O.I.
19.7	3.7	3.0	0.2	43.0	3.5	0.2	0.2	2.2	0.1	24.0

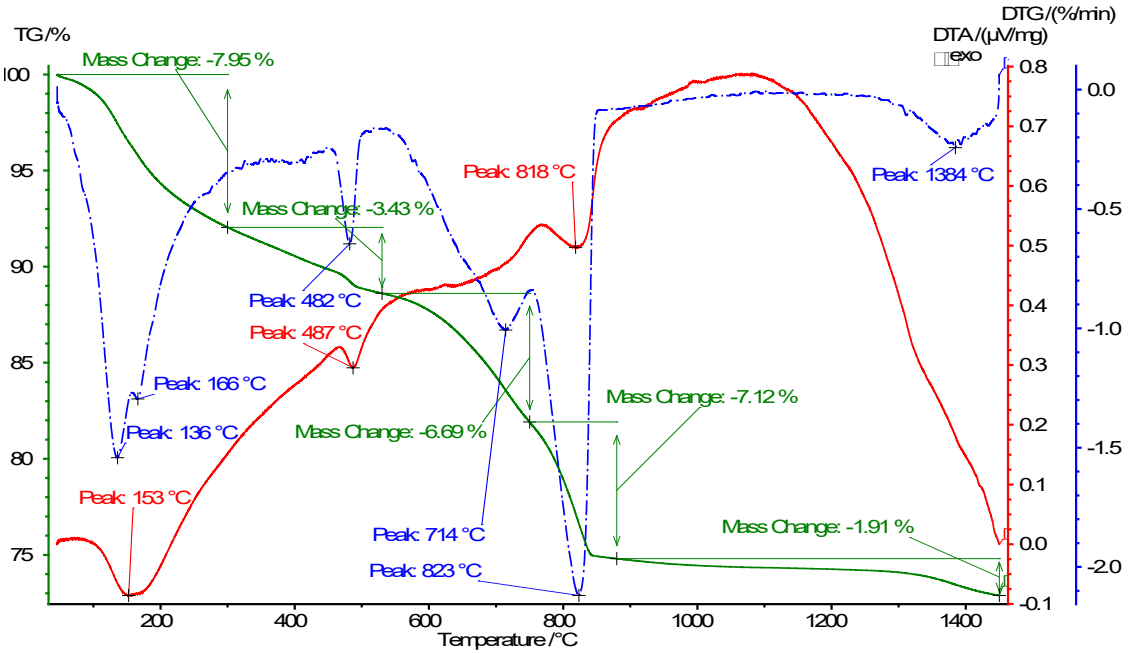


Fig. 2. Thermal analysis of cement-asbestos sample

Effects which came from the decomposition of the cementitious matrix dominated on DTA results (Fig. 2). All registered thermal effects were endothermic and connected with the mass change. Due to the small amount of asbestos in the cement-asbestos material, there were no visible characteristic effects from the decomposition of the asbestos minerals. In the temperature range of 100–300°C, a wide endothermic peak is visible and it may be connected with water release from the CSH phase. The endothermic peak at ~490°C indicates the presence of portlandite ($Ca(OH)_2$) from the hydrated cement matrix. Above 600°C the weak endothermic effect was observed. It is more visible on DTG curve with peak maximum at 714°C. This is the temperature region at which thermal decomposition of chrysotile asbestos occurs by dehydroxylation process. Beyond this process, the wide temperature range of this phenomenon may indicate another thermal process which occur in the sample like decomposition of carbonates from cementitious matrix, especially with low-degree of crystallinity. At a higher temperature (around 800°C) characteristic asymmetric peak is visible. It indicates the decomposition of calcite ($CaCO_3$) [12,14]. Based on these results, temperatures were selected for ex-situ kinetic tests.

Kinetics of a chemical process can be expressed by the general equation $d\alpha/dt = k \cdot f(\alpha)$, where α is the degree of conversion of the reaction, k is the rate constant at given temperature and $f(\alpha)$ is the kinetic model function, usually an empirical function dependent on the mechanism of reaction. The subject of the research is the process of thermal decomposition of cement-asbestos material, which consists of several stages, which results from the course of thermal analysis curves (Fig. 2). It is therefore not possible to express this process by a simple chemical reaction. Because during thermal treatment of cement-asbestos material volatile components that are decomposition products are released (H_2O, CO_2), the degree of conversion α of this process can be defined as the mass loss in relation to the base value, i.e. the value resulting from the loss on ignition or the value of total mass change from thermogravimetric analysis. In Figure 3,

the variations with time under isothermal conditions at the assumed working temperatures were reported.

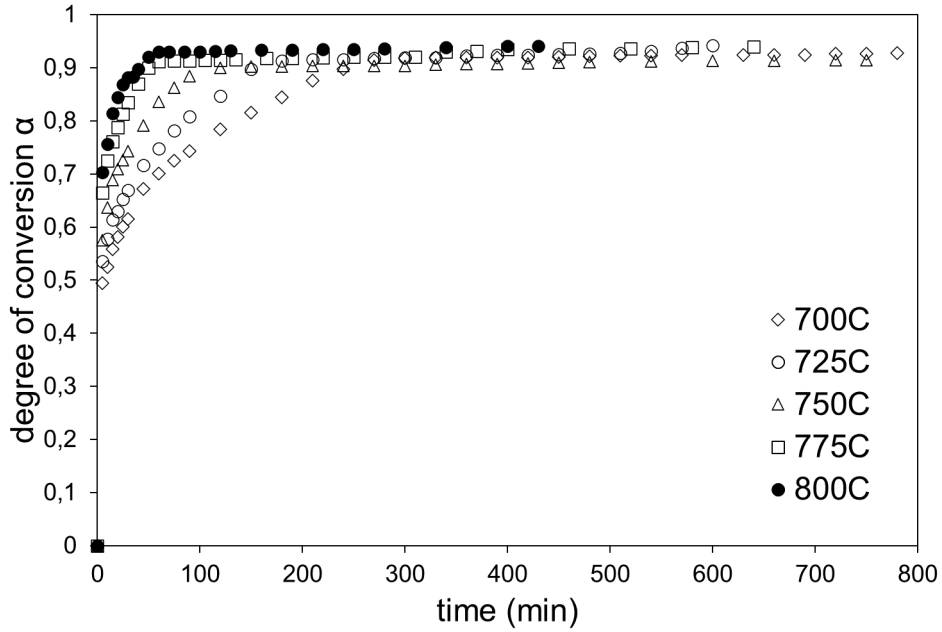


Fig. 3. Variations with time under isothermal conditions for degree of conversion α, determined by the difference in mass loss of sample

It is possible to employ a general empirical rate equation in which the function f(α) is expressed in some general manner with a variable parameter that reflects the rate-controlling mechanism. The analysis of the kinetic curves was performed using the classical model for heterogeneous solid-state reactions. A well establishment data analysis procedure is the Avrami-Erofeev method [15], which assumes:

$$\alpha = 1 - \exp\left[(-kt)^n\right]$$

where k is the kinetic constant and n is reaction order and it is indicative of the mechanism controlling the reaction rate. The logarithmic transform of this equation can be used to build the graph ln(-ln(1-α)) versus ln(t), which corresponds to the linearized form of the Avrami-Erofeev equation. The value of k (rate coefficient) and n (reaction order) can be calculated from the intercept and slope of the graph ln(-ln(1-α)) vs ln t, the co-called ln-ln plot. This is important issue because it allows for the interpretation of the reaction mechanism, while the rate coefficient is utilised in the Arrhenius equation with T (in Kelvin) and R (gas constant): $k = A \cdot \exp[-E_a/RT]$. The plot of ln(k) vs. 1/T yields the apparent activation energy (E_a) from the slope of the linear curve and the preexponential factor (A) from the line intercept. The corresponding ln-ln plots connected with obtained experimental data from Figure 3 are reported in Fig. 4. The curves show nearly the same slope. Kinetic constants k are reported in an Arrhenius plot in Figure 5, while Table 3 reports the calculated values of n, k and E_a.

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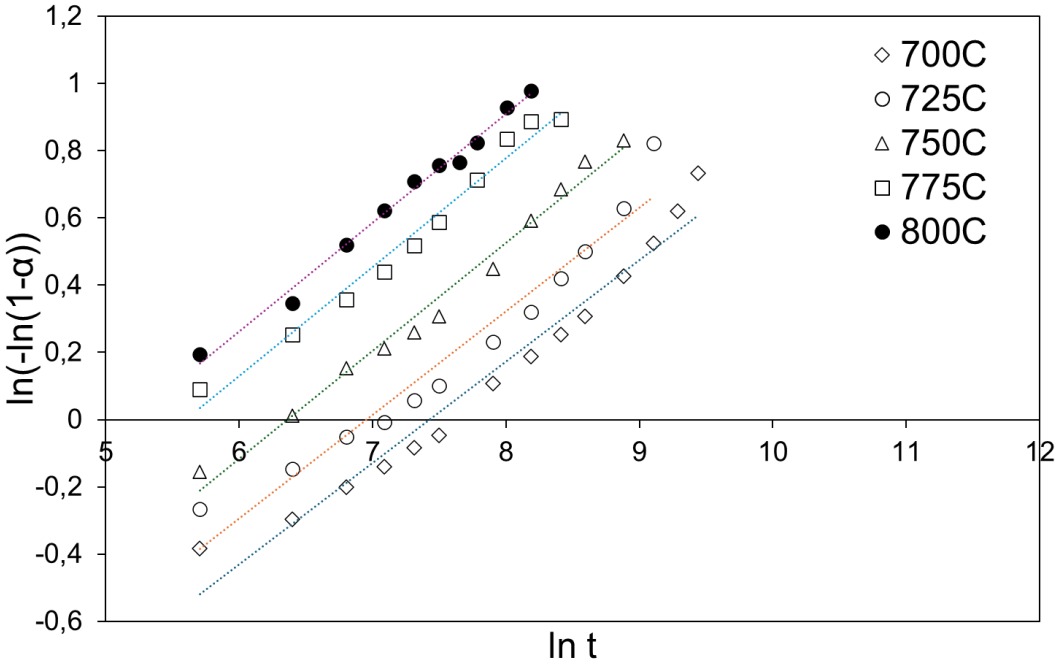


Fig. 4. Ln-ln plot for corresponding data for cement-asbestos thermal decomposition

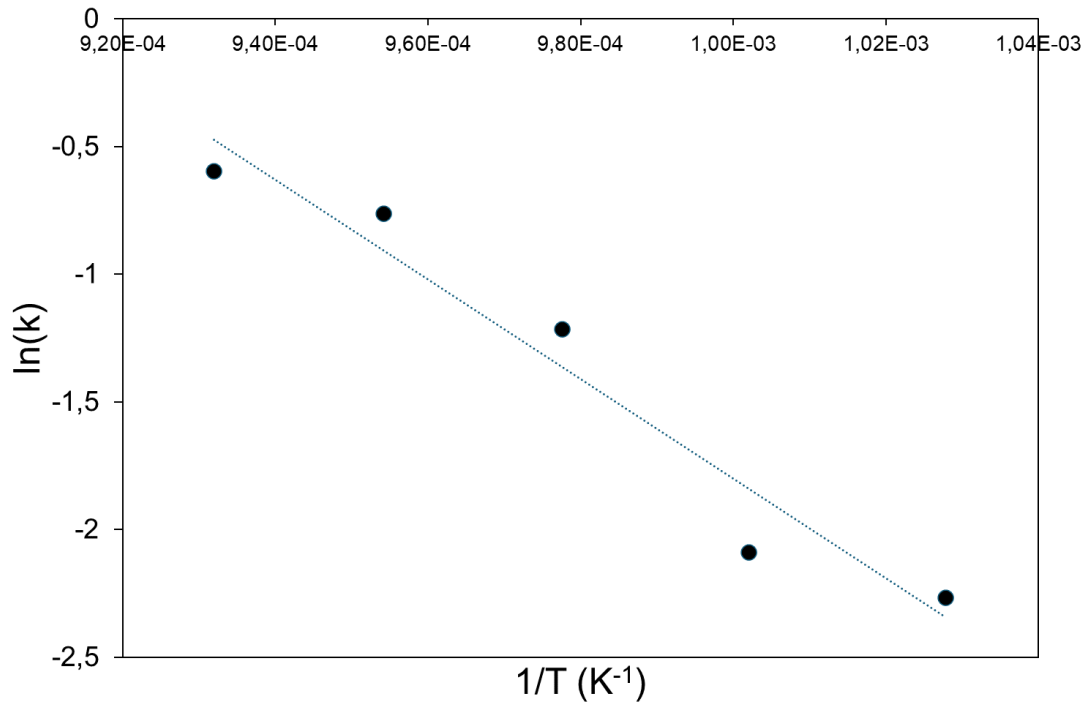


Fig. 5. Arrhenius plot for cement-asbestos thermal decomposition

Table 3. Calculated kinetic parameters for the cement-asbestos decomposition

Temperature, [°C]	700	725	750	775	800
Value of reaction order, n	0,30	0,31	0,32	0,32	0,32
Rate coefficient, k	0,104	0,124	0,297	0,467	0,551
Correlation coefficient	0,966	0,951	0,985	0,980	0,991
Activation energy, E_a [kJ/mol]	162				

CONCLUSION

In the present study, isothermal method of kinetic analysis was used to investigate the kinetics of the thermal decomposition of cement-asbestos material. Ex-situ thermal decomposition experiment was carried out in temperature values which allow for decomposition of asbestos minerals. From the mass change measurement during thermal treatment at selected temperatures the graph of conversion degree associated with decomposition of cement-asbestos versus time was determined. The heterogeneous solid-state reaction analysed by the Avrami-Erofeev model was the kinetic model that fit the experimental results with a fairly good fit. The empirical activation energy was evaluated from the Arrhenius plot and it achieved value close to 160 kJ/mol. The issues discussed in the article may be extremely useful when designing thermal methods for asbestos recycling on an industrial scale. In the further part of the research, kinetic tests should be carried out on a larger representation of cement-asbestos wastes to be able to estimate the average value of kinetic parameters.

ACKNOWLEDGEMENTS

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OPTIMIZING BIOGAS PRODUCTION FROM OLIVE OIL MILL RESIDUES: A COMPARATIVE EVALUATION OF TREATMENT TECHNIQUES FOR SUSTAINABLE RESOURCE RECOVERY

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ABSTRACT

The olive oil sector is one of the most widespread agricultural and agro-industrial activities in the Mediterranean region, and it also produces a significant amount of waste biomass. This research aimed to find energy valorisation for the olive oil by-products through biogas/biomethane production from olive pomace (OP) and olive mill wastewater (OW). To this end, these biomasses underwent preliminary treatments: the OP was processed using an ionic liquid (IL) consisting of triethylamine and sulfuric acid [Et_3N][HSO_4], which removed hemicellulose and lignin, thus allowing recovering of the insoluble OP, mainly composed of cellulose. On the other hand, OW was treated through freeze-drying. After that, the pulp from olive pomace (POP) and freeze-dried OW (FDOW) were subjected to anaerobic digestion in lab-scale reactors. The biogas output from these materials was compared to the biogas yield shown by the untreated biomasses (OW and OP). FDOW anaerobic digestion resulted in the highest amount of biogas production, likely due to surface and structural modifications caused by the freeze-drying treatment, which presumably enhanced microbial activity. In contrast, the IL treatment of POP significantly lowered the biogas production, which ended after two days of digestion, resulting in a minimal yield. Future research will focus on co-digesting POP and FDOW with a nitrogen-rich biomass, such as Brewery's Spent Grain, to potentially increase biogas output and better understand the cause of the low yield.

Keywords: Biogas, Biorefinery, Food industry, Recovery, Waste

INTRODUCTION

Currently, the overall area of olive production reaches 11.5 Mha with a 97% of worldwide olive-oil production centred in the Mediterranean area [1]. Olive oil is usually mechanically extracted from olives, producing two main by-products: olive mill wastewater (OW) (38 – 48%) and olive pomace (OP) (35 – 45%).

OW has an acidic pH (4.2 - 5.9), high content of water, high level of phenolic compounds (0.5 to 25 g L−1), and other organic substances (14 – 15%), such as lignin and cellulose. Improper disposal of OW has an adverse effect on the environment, like soil deterioration, hydrophobicity, and phytotoxic impact on plants [2].

The OP has a pH of 4.8 – 5.2 and a high concentration of phenolic compounds (200–300 mg/100 g), making it an environmental hazard [3]. Despite this, these wastes are

rich in bioactive compounds, which can be extracted to produce molecules of significant relevance.

However, OP and OW are rich in substances, such as lignin, that can slow down anaerobic digestion (AD). During the process of AD, lignin is nearly non-degradable because the enzymes required for lignin depolymerization need oxygen to function [4]. As a result, lignin limits the hydrolysis step, which is one of the four main stages of AD (hydrolysis, acidogenesis, acetogenesis, and methanogenesis), thereby reducing the efficiency of the entire AD.

Despite its negative impact on AD, lignin has diverse useful application in different industries, such as in pharmaceutical sector as drug carrier [5], in engineering field as component for 3D plastic material and in agriculture as bio stimulant for plants [6].

In this study, we evaluated the potential methane production of OP and OP after lignin extraction (OP-Pulp, referred as POP in the text). This evaluation is essential to understand the effect of lignin removal and to fully utilize the OP.

As previously mentioned, OW contains a high concentration of valuable molecules, but its composition poses a significant challenge for degradation and AD [7]. Indeed, it has been demonstrated that OW exhibits antimicrobial activity mainly due to its polyphenolic content, which limits bacterial growth and inhibits their activity [8].

To assess the biomethane potential of all waste materials from the olive oil production chain, we also tested the biogas production from both untreated and lyophilized OW. Lyophilization was evaluated to determine its effect as a pre-treatment, as it can stabilize the substrate and improve the physical characteristics of the matrix by creating a more porous structure and reducing the negative effects associated with traditional thermal drying [9].

This study evaluates and compares biomethane production from different treated waste materials—POP and lyophilized OW—with untreated biomasses, OP and OW in a circular economy perspective. Extraction of valuable molecules can act as pre-treatment for some biomass improving substrate characteristic for anaerobic digestion [10,11].

MATERIALS AND METHODS

The digestate used as inoculum was characterized in our laboratory (table 1).

Table 1. Main characteristics of the inoculum used to prepare the various samples.

Parameter	Digestate
Moisture (%)	88.08
pH	8.08
TOC (% on DM)	53.05
TKN (% on DM)	5.47

OP and OW were supplied by a local olive oil producer in Perugia, Umbria. The lyophilized OW was treated at the Department of Pharmaceutical Sciences in Perugia, Italy.

The POP was obtained by extracting lignin using the Ionic Liquid (IL) method at the Department of Agricultural, Food and Environmental Sciences in Perugia, Italy. The IL composed of triethylamine and sulfuric acid [Et_3NH][HSO_4] was synthesized according to Cequier et al. [12] and then used to treat pomace to remove hemicellulose and lignin, leaving as much cellulose as possible in the pulp (solid fraction after the treatment).

The mixtures obtained were left to react at 120 °C for 4 hours, then cooled to room temperature and added EtOH to solubilize lignin and hemicellulose. Finally, the solid fractions (the cellulose-enriched portion) were recovered by vacuum filtration and washed repeatedly with ethanol followed by water.

All the biomasses were characterized, and results are reported in Table 2.

Table 2. Main characteristics of the biomasses considered in the present study.

Biomass	Moisture (%)	pH	TKN (% on DM)	TOC (% on DM)
OW	88.08	5.1	0.53	61.2
FDOW	8.08	5.4	1.22	30.86
OP	53.05	5.5	0.7	47.7
POP	5.47	3.01	0.31	31.28

Anaerobic Bioreactors

Biogas production was conducted in batch bioreactors with a total volume of 75 mL. The temperature was maintained at 37 °C throughout the production period. The volume of biogas produced was measured using the volumetric method. Bio-methane production was evaluated using an alkaline trap (0.5 M NaOH with thymolphthalein as a pH indicator). Each sample consisted of ¾ of the dry weight of the inoculum and ¼ of the dry weight of the tested biomass. The control consisted only of the inoculum. Following all the treatments employed in the experiment:

- Sample OW: composed by 1.8 g (DW) of inoculum ¾ and 0.6 g of (DW) OW (¼);
- Sample FDOW: composed by 1.8 g (DW) of inoculum (¾) and 0.6 g of freeze-dried OW (referred as FDOW) (¼);
- Sample OP: composed by 1.8 g (DW) of inoculum ¾ and 0.6 g of (DW) OP (¼);
- Sample POP: composed by 1.8 g (DW) of inoculum ¾ and 0.6 g of (DW) POP (¼);

RESULTS

In this section, the production of biogas from untreated and treated olive pomace (OP) and olive mill wastewater (OW), is evaluated and compared. As previously indicated,

two pretreatments were selected: freeze-drying and lignin and hemicellulose removal for, respectively, OW and OP. Table 3 shows, the total production of biogas for each biomass, the associated content in methane and the production period.

Table 3. Total production of biogas, corresponding methane content and days of production for untreated and treated OP and OW.

Biomass tested	Total biogas [mL]	Total CH_4 [mL]	CH_4 (vol%)	Production time [days]
OP	437	290	66.30	43
POP	75	37	49.75	2
OW	412	235	56.99	32
FDOW	1743	1208	69.31	30

Olive mill wastewater byproducts (FDOW and OW) did not shown differences in production time; their production took 30 and 32 days, respectively. On the other hand, untreated OP required 43 days to complete the process, while POP biogas production stopped after only 2 days. Biogas yield of POP cannot be effectively compared to the relative untreated biomass OP, due to the short production period.

The untreated biomasses, OP and OW, produced almost the same quantity of biogas, 437 (43 days) and 412 mL (32 days), respectively. Regarding the effect of the pulp production process based on the IL, it strongly hindered anaerobic digestion. On the contrary, the freeze-drying process enhanced biogas yield leading to a total production of 1743 mL compared to the OW yield of 412 mL.

Table 3 shows the biomethane concentration for each type of biomass. The OP biogas mixture contains 66.30 vol% biomethane, compared to 49.75 vol% for POP. This demonstrates that IL pretreatment also altered the composition of the biogas mixture, reducing the methane concentration. For another byproduct, OW, the freeze-drying process had a positive effect, increasing the methane concentration from 56.99 vol% (OW) to 69.31 vol% (FDOW).

Normalization of biogas yield to biomasses volatile solids

Finally, the biogas yield for each substrate used in this study was related to the relative volatile solids (VS) quantity. VS were calculated as following the official protocol and are shown in table 4 and graphically shown in Figure 1.

Table 4. From left to right: total dry matter inserted in the bioreactor for each biomass, the volatile solids, both as percentage and in grams, and the total biogas produced per unit of mass of VS.

Biomass	*Dry Matter [g]*	*SV [%]*	*SV [g]*	*Biogas/VS [mL/g]*
FDOW	2.860±0.005	0.926±0.005	2.648±0.005	658.143
OP	1.000±0.005	0.970±0.005	0.970±0.005	524.055
OW	5.720±0.005	0.908±0.005	5.194±0.005	79.326
POP	1.000±0.005	0.954±0.005	0.954±0.005	78.616

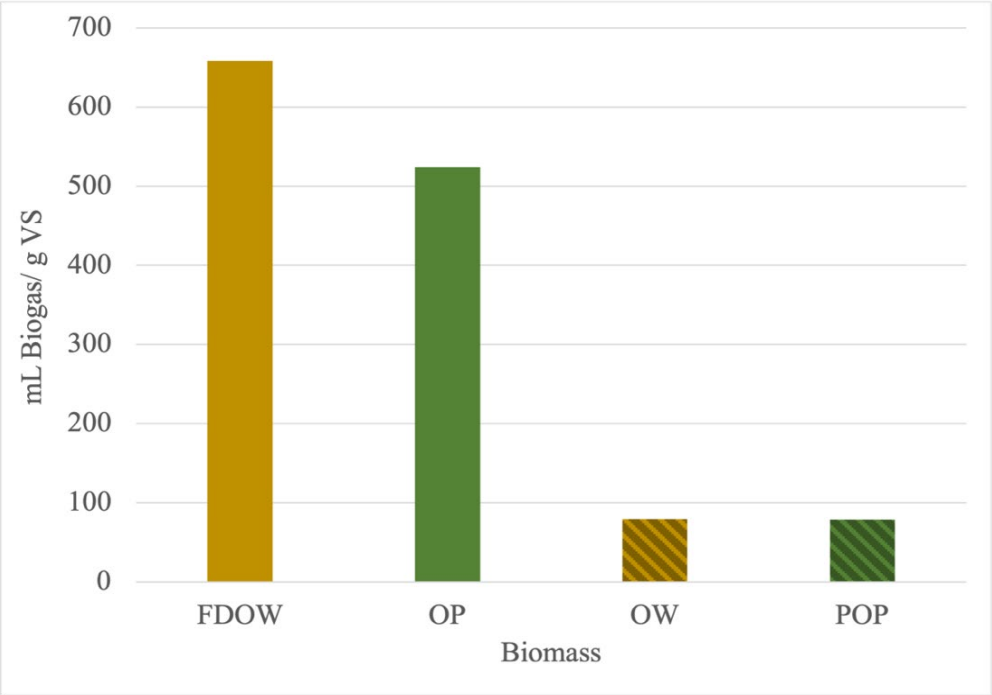


Figure 1. Quantity of biogas produced related to VS content, for each tested substrate.

Figure 1 and the data in Table 4 confirm the positive impact of freeze-drying on biogas yield: FDOW achieved a final biogas yield of 658.143 mL/g of VS, compared to 79.326 mL/g of VS for untreated OW.

Similarly, for OP and POP, the results remain consistent after normalization with volatile solids. Untreated OP had a final biogas yield of 524.055 mL/g of VS, compared to 78.616 mL/g of VS for POP.

DISCUSSION

The consistent difference in biogas yields between OW (79.326 mL/g of VS) and FDOW could be due to the effect of freeze-drying that reduces the moisture content of the biomass enhancing its preservation [13]. With this procedure, water is completely removed, and the remaining dry substance maintains most of the viable microbes and active substances present in the untreated biomass [14]. Consequently, the reduction in moisture increases biogas production per unit of biomass. Additionally, the treatment affects the substrate's morphology, creating ideal porosity for microorganisms, thereby enhancing their activity. In support to this, we estimated the C/N ratio of FDOW (25.29) that falls within the optimal range for anaerobic digestion, which is 20-30:1. This could explain its higher production compared to other biomasses.

The sharp reduction in biogas production of POP compared to OP may be explained by the Ionic Liquid method used to extract lignin and hemicellulose. This significant reduction could result from a decrease in nitrogen content following IL treatment, as ILs typically enhance the solubility of proteins by interacting with the functional groups of these biomolecules through their ions [15]. This is further supported by POP's high C/N

ratio of 101, which is far above the optimal range and could account for its low biogas production.

CONCLUSION

The study aimed to evaluate biogas production from two primary by-products of the olive oil production chain, OW and OP. Both biomasses were treated to enhance their physical and chemical properties related to biogas production. Freeze-drying was selected as the treatment for OW, which is typically used in anaerobic digestion but only in co-digestion, due to its high content of antimicrobial compounds. However, the results showed that freeze-drying had a positive effect on the anaerobic digestion process, leading to an increase in biogas production compared to the untreated biomass. According to the literature, this pretreatment improves the substrate by making it more accessible to microorganisms, thereby enhancing all steps of anaerobic digestion driven by microbial activity.

For OP, the treatment had a negative impact on biogas yield. IL method allows to recover nanostructured lignin from a biomass. This product can be used in different field, especially in agriculture such as bio stimulant [5]. After lignin extraction, the residual part is represented only by cellulose. Additionally, the use of ILs increases the solubility of proteins, which in turn reduces the nitrogen content. Given the importance of the carbon-to-nitrogen ratio in anaerobic digestion, this reduction in nitrogen negatively affects biogas production. Therefore, further studies should explore co-digestion of POP with nitrogen-rich biomasses, such as Brewery's Spent Grains, a by-product of the beer production chain, to improve biogas yield.

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RECOVERY OF GERMANIUM FROM COPPER SLAG USING SILICOTHERMIC PROCESS

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ABSTRACT

The depletion of primary raw materials and the demand in High Tech has played a big role in finding new ways of getting raw materials including recycling. Germanium being a semi-conductor currently in high demand is being sourced from secondary materials. The purpose of this project was to recover Germanium from copper slag in the presence of pure silicon using the carbothermic reduction process. The experiment was designed using Minitab software with Taguchi as the tool for statistical analysis and to design the experiment. The working temperature was kept constant at 1350 degrees Celsius and the mass of silicon, slag basicity and residence time in the furnace were investigated with the response being recovery of germanium to determine the optimum conditions under which there is a high recovery of Germanium as per the conducted experiments. The findings of this experiment are that the conditions that yield a high recovery of Germanium are 0,008 mass of pure silicon, 0,8 basicity and the optimum time was found to be 120 minutes. In this investigation targeted to meet the sustainable research and development goal of implementation of circular economy by virtue of recycling metallurgical waste that goal. Moreover, from the carbothermic reduction cobalt and copper were recovered consequently. The optimum conditions were tested using the main effects, interaction, and sensitivity to noise ratio plots all from Taguchi.

Keywords: Pure silicon, Germanium recovery, copper slag

INTRODUCTION

Germanium is a rare and critical element in modern technology. It is the next generation of electronics and renewable energy applications. It was discovered by a German chemist in 1886 in silver ores, upon further investigation it found that it is also a by-product of zinc, coal and copper processing. Copper ores smelting leads to copper slag production as one of the main products using pyrometallurgy process [1]. This material is generally considered as a secondary source valued metallic that can be extracted because of their economic concentrations. For that reason, copper slag can be processed as a secondary raw material because of substantial amount of copper and other valuable metals present [2, 3]. Many investigations have been conducted using different approaches and processes to recover these metals and gave promising results [4]. It was found that the transition of the basic slag was favored by CaO-Fe_3O_4 -Cu_2O which made the viscosity and conductivity difficult to understand because of the allegations that the viscosity and the conductivity in basic slags correlate if the slag contain FeO-SiO_2 and that the influence of commonly found compounds CaO-Fe_3O_4 -Cu_2O on the viscosity and conductivity are of great impact [5]. The production of one ton of refined copper is typically accompanied by the generation of 2.0–3.0 tons of copper slag [6]. The copper slag from Katanga province in the Democratic Republic of Congo was found to contain

germanium that is locked in the silica matrix [7]. Previous investigations have successfully recovered some high-tech metals, including germanium contained in copper slags through differential methods [8]. In the current body of knowledge regarding the study or recovery of various elements from secondary sources such as copper, researchers have explored the recovery of indium, gallium and selenium, Copper, Zinc, and Iron using the conventional carbothermic reduction or the use of hydrochloric acid and flotation process [8]. Studies have shown that pure silicon has the ability to effectively reduce Germanium oxide in the existence of a viable chemical pathway. This is supported by the established consensus that an s-prepared RF co-sputtered system of Ge and SiO_2 contains the elements Germanium including oxides of silicon and Germanium oxides. This means that the silicon will be in excess in the sputtered samples because of the non-stoichiometry of the oxide matrix such that in a ternary system as the Si-Ge-O, the direct decomposition of germanium presents itself as the easiest reaction for the reduction of GeO_2 to Ge as given by $GeO_2 \rightarrow Ge + O_2$. The estimation from the Gibbs free energy at thermodynamic equilibrium according to at 1 atmospheric pressure and 800 degrees Celsius, this reaction would not occur therefore the use of a reductants is highly encouraged in the matrix of the GeO_2 reduction. Furthermore, the presence of silicon in the ternary system at equilibrium, will reduce the Germanium oxide into Germanium and Si oxides. The Germanium oxide in a Si-O-Ge ternary system would be reduced to elemental Ge at temperatures above 800 degrees Celsius thus the reaction will follow this pathway:

$Si + GeOx \rightarrow Ge + SiOx$

$Si + GeOx \rightarrow Ge + SiO_2$

The Si-O bond is 8,3 eV and the Ge-O bond is 6,3 eV as reported, this means that under reducing condition, Germanium oxide will be favourably reduced to elemental Ge by sub stoichiometric SiOx at temperature exceeding 700 degrees Celsius in a N2 ambient following this reaction

$GeOx + SiOx \rightarrow Ge + SiO_2$

The current investigation aimed to recover germanium from copper slag using silicothermic process.

MATERIALS AND METHOD

1 Material and equipment

The copper slag sample that was used in conducting these experiments was from The Katanga Province in the DRC. Pure silicon provided by the University of Johannesburg of 99% purity, argon from Afrox. THM 15 alumina tube furnace was used to run the experiments.

2 Methods

The approach for the design of the research was qualitative research approach based of the aim of the study which heavily relies on the need for data generation in the form of conducting experiments, analysing the results to come to informed conclusions and observations. Minitab software was used in the design of the experiment and the analysis of results based of variance to determine the interactions of the variables and aid in reaching credible conclusions, the Minitab tool used to design the experiments

and analyse the results was Taguchi factorial design. The experimental flowsheet is presented in Figure 1.

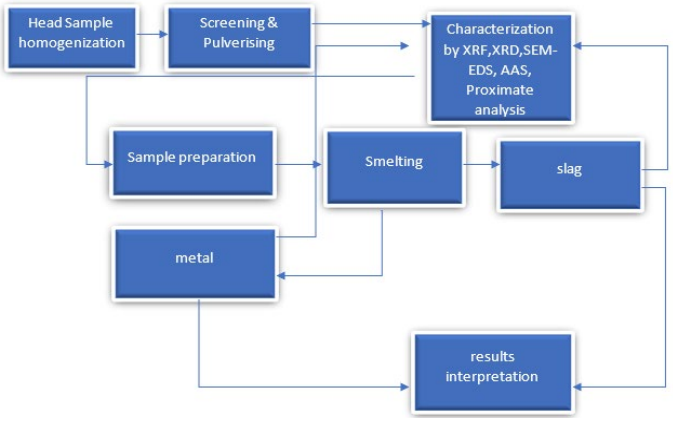


Figure 1 Experimental flowsheet

The experimental procedure followed upon the experimental design was to prepare the copper slag for characterisation and for use in conducting the experiments. The characterisation of the slag head sample and products were done using XRF, SEM-EDS, and XRD; carbon used was characterised using proximate analysis, and the pure silicon was analysed using XRF. Three samples of slag each mixed with 5% carbon while the mass of pure silicon varied from 0,007g, 0,008g and 0,009 respectively for each experiment. Graphite crucibles were used for the experiments in a neutral atmosphere by blowing argon gas in the alumina tube furnace at 1350 degrees Celsius for all the runs of experiments conducted. The results of the metal and slag were analysed from each crucible using XRD, XRF, and SEM-EDS.

RESULTS

XRD and SEM-EDS of the head sample are presented in figure 3 and 4 respectively.

1. XRD results of head sample

Figure 3 depicts XRD decomposed picks. The original result showed more noise which made difficult the identification of picks. This was mainly due to high silica content in the sample. The decomposition was facilitated using Origine 8.5 software.

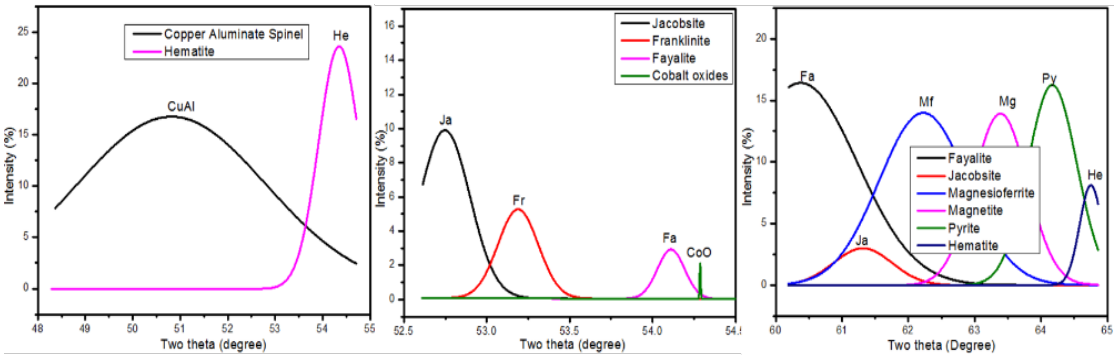


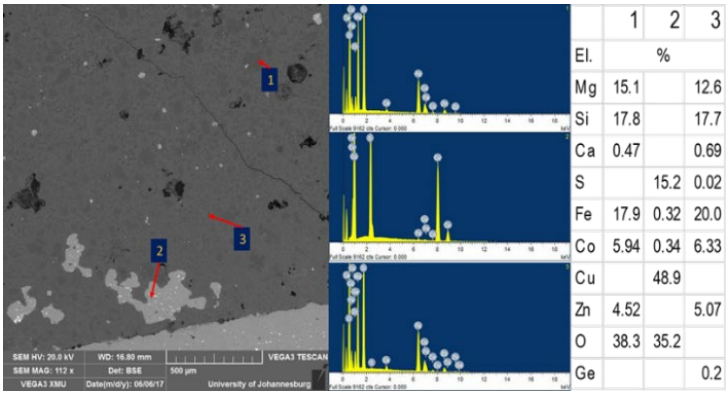
Figure 3 XRD results of the slah]g head sample

It transpired that germanium was not detected using XRD. This was assumingly due to low Germanium content. However, other base metals such as copper and cobalt were depicted. Same results were obtained previously [9] when the same sample was characterized.

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2. SEM-EDS of head sample

Figure 4 shows the SEM-EDS results of the slag head sample. It is observed that germanium is only detected on one spectrum and the atom percentage is critically low. This confirm results obtained with XRD.



	1	2	3
El.		%	
Mg	15.1		12.6
Si	17.8		17.7
Ca	0.47		0.69
S		15.2	0.02
Fe	17.9	0.32	20.0
Co	5.94	0.34	6.33
Cu		48.9	
Zn	4.52		5.07
O	38.3	35.2	
Ge			0.2

Figure 4 SEM-EDS result of the slag head sample [9]

Predominent silicon can be detected and is the most abundant element in the sample. This confirms that the slag is fayalitic therefore acidic.

Germanium Recovery

Residual plots

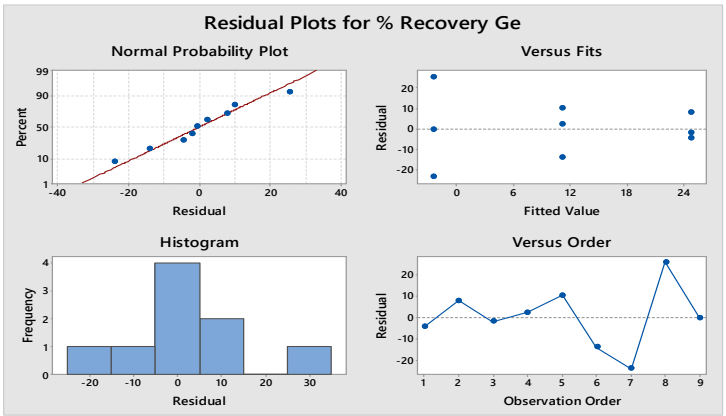


Figure 2 Residual plot for Ge recovery

According to minitab, residual plot asses the validity of a model, from the figures above, the bell-shaped histogram indicates a reasonable normal distribution, which is supported by the versus order being random. The randomness indicates a valid model while the versus fit is evenly distributed in both figures above and below the zero line. The normal probability plot points are on the straight line except the two unusual points. Residual plots are the indicators of the validity of a model according to the authors, the deviations of the observed data values from the predicted y value and estimate the error terms in the model. Results indicate that the randomness of the plot means that the assumptions are valid. The normal probability plot insinuates that the variables are influential on the response, which is what is needed. The bell shape of the histogram means that the data is not skewed while the residual against fitted values indicate that the variance is constant so there is a non-linear relationship.

3.1.2 Regression equation of the model

Ge %Recovery = 47,6 – 0,0076 Time + 21,8 basicity – 5315 silicon mass

Table 1 Different Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	47,6	19,0	2,51	0,054	
Time	-0,0761	0,0669	-1,14	0,307	1,00
basicity	21,8	11,6	1,88	0,119	1,33
Silicon mass	-5315	2317	-2,29	0,070	1,33

Table 2 Analysis of variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	175,58	58,53	2,42	0,181
Time	1	31,25	31,25	1,29	0,307
Basicity	1	85,20	85,20	3,53	0,119
Silicon mass	1	127,11	127,11	5,26	0,070
Error	5	120,75	24,15		
Total	8	296,34			

Table 3 Model summary

S	R-sq	R-sq(adj)	R-sq(pred)
4,91436	59,25%	34,80%	0,00%

In the analysis of the regression model, the p-value indicates the test of the null hypothesis whereby when the coefficient is zero it indicates that there is no effect, however, when the p-value is greater than 0,05 we can conclude that it has a meaningful addition to the established model as the variation of the of the p-value is related to the changes in the response variable. A p-value greater than 0,05 also indicates that the response has no association with the predictor, for this model we have observed that the only predictor related to the response is the constant.

Main effects and S/N ratio plots

The main effects graphs indicate that for Ge, recovery was optimal at 120 minutes, 0,8 basicity and 0,008g of pure silicon. In the metal analysis it was observed the presence of zinc and according to the main effects plot it was optimal at 120 minutes, 0,6 basicity and a silicon mass of 0,009. The main effect plots indicate the optimal conditions at which we were able to recover Ge and Zn, the regression model indicates a poor confidence level in the model and in the recovery response

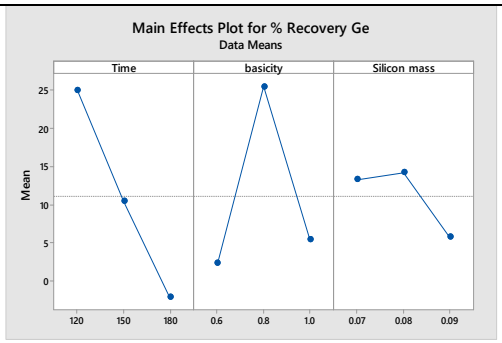


Figure 3 Main effects plot for %Recovery of Ge

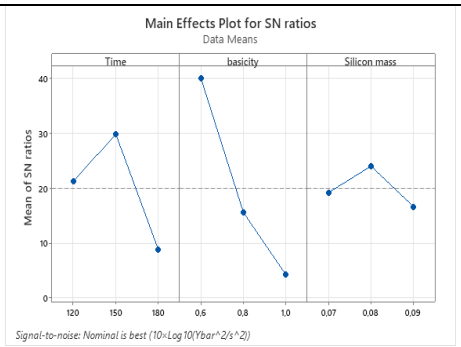


Figure 4 Signal to noise plot for Ge Recovery

The main effect plots indicate the optimal conditions at which we were able to recover Ge and Zn, the regression model indicates a poor confidence level in the model and in the recovery response.

3.1.5 SEM and XRD of metal

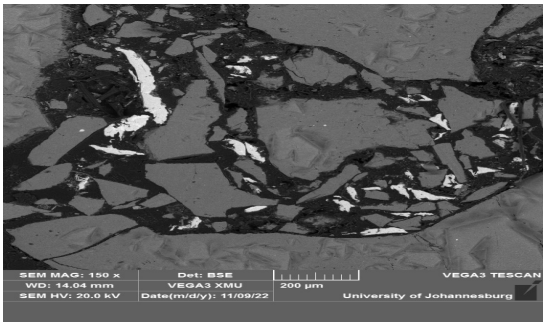


Figure 5 SEM of metal

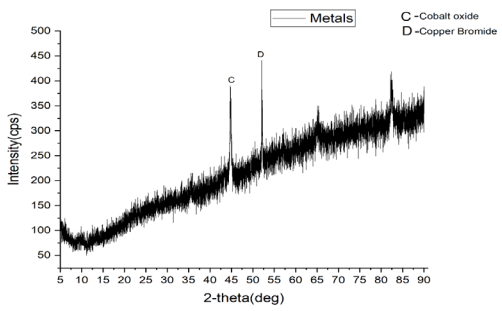


Figure 6 XRD results of metal

From both Figures 7 and 8, it can be observed that the chemical composition did not reach the immiscibility zone, hence metal droplets are locked in the slag. Figure 7 shows the SEM results which indicate the presence of copper, cobalt, iron, silicon, zinc and germanium, the comparison of the head sample and the recovered fraction we see an increase in weight percentage which implies that there was a good reduction efficiency of the above-mentioned metals. Figure 8 shows the XRD of the metal. The metal fraction shows two significant peaks, one being copper bromide and the other is cobalt. The other peaks show magnesium oxide and other variations of magnesium such as calcium magnesium iron which is expected because of its prevalence in copper slag. Moreover, we also have peaks that show the presence of calcium silicate.

DISCUSSION

According to the regression model that we have obtained we can indicate that due to the regression model obtained from the data generated in the experiments it can assumed that the model aids in the description of the statistical relations between the factors that were investigated to the response, the using this data and model made the prediction of

new observations and led to new conclusions. The results that indicate that there is no relation between the factors in this study is a highly unlikely hypothesis, this could have been an error in the analysis or quantification of the model at any given stage, a deeper look into the data and methods may be able to indicate where the deviation occurred.

The discrepancy of the poor confidence level in the regression model could be as a result of the quantification of the metals from example the very low Ge in the head sample, another path of possibility could be that the quantity of silicon that was used in the experiments was insufficient to displace the Germanium in the matrix or that the matrix was not broken down sufficiently to allow for the displacement as we had hypothesised. It was observed a mass transfer phenomenon with Si reporting to the salg whereas Ge was transferred to the metal. Previous studies have also revealed the mass transfer between the slag and FeSi that was added [9]. It transpired that Si removed Ge from the silicate matrix and transferred to the metal whereas Fe also got transferred to the metal. The later transfer is assumably due to the increase in activity coefficient of oxides that is favoured by the increase of the basicity. The disadvantage being that the metal had a dilution effect vis a vis germanium recovered.

CONCLUSION

The aim of this paper was to recover germanium from copper slag using pure silicon, moreover, the study was also conducted with the consideration of alleviating an environmental concern of accumulation of slag dumped which is environmental concern. The pathway explored to address this was to explore a pathway of recovering metals of economic value from the slag dumps and contribution to circular economy. The hypothesis was that we will be able to recover germanium from fayalitic copper slag in the presence of pure silicon because it provides an alternative pathway for the displacement of germanium from the silica matrix, we also hypothesized that due to the bonds found in Si-O and Ge-O the path favourable in smelting would be the bonds between Ge-O because of the lower eV in comparison. The significant results obtained were able to determine the optimal conditions of germanium recovery of 120 minutes, 0,008g mass of pure silicon and a basicity of 0,8. Taguchi was used as the tool to assess the optimum conditions for recovery. We used regression analysis to formulate the model, and it was found that the model could not forge conclusive results based on the p-value being greater than 0,05, this might be due to a possible variety of reasons unknown. The variables that were studied in response to germanium recovery do have a correlation to the response. The p-value of a regression analysis is often misinterpreted due to the unstated analysis protocols; this may be attributed to human error or bias. Further in-depth research needs to be conducted on the kinetics, residence time for metal settlement and thermodynamics of the process using pure silicon as a reductant.

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RECYCLING AND CIRCULAR ECONOMY: PROJECT MANAGEMENT BEST PRACTICES FROM EUROPEAN WHISKY INDUSTRY

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ABSTRACT

Drawing on case studies from 18 countries, the paper explores how project management methodologies are applied in European whisky industry to implement and optimize recycling initiatives, focusing on key processes such as glass bottle return schemes, advanced waste sorting technologies, and material reuse strategies. Critical project management insights include the importance of stakeholder engagement across production, sustainability, and regulatory teams, and continuous application of lean management principles to streamline recycling workflows and minimize waste. Agile project management is highlighted as a key enabler, allowing distilleries to adapt quickly to environmental regulations and evolving market demands. Distilleries with agile project management frameworks were able to rapidly integrate compostable packaging, shared ownership models, and renewable energy solutions. Furthermore, resource allocation and risk management play essential roles in ensuring efficient recycling operations, particularly in managing supply chains for reusable materials. This paper addresses a gap in whisky sector studies by providing a focused analysis of recycling through a project management lens, a topic that remains underexplored in this industry. By analyzing how newer distilleries, unburdened by legacy systems, lead in implementing circular economy practices, the paper offers practical insights for both academics and industry practitioners looking to integrate sustainability into their operations. These best practices offer a blueprint for the broader adoption of circular economy principles in resource-intensive industries, highlighting the whisky industry's role as a pioneer in sustainable production.

Keywords: circular economy, recycling, project management, agile, whisky industry

INTRODUCTION

Over the years, industries worldwide have increasingly been under compulsion to depart from traditional business models and adopting the principles of a circular economy [1]. Within this context, the European whisky industry faces significant environmental challenges as a resource-intensive sector. From ingredients sourcing and distilling to packaging and shipping, this industry uses up a lot of water, energy, and raw materials [2]. Whisky makers are currently facing an increasing regulatory and consumer pressure to embrace sustainable methods that minimize waste and reduce their ecological footprint. Consequently, they have implemented circular economy principles such as reusing and recycling by-products to help mitigate this environmental impact while aligning with global sustainability goals [3], [4]. Project management methodologies, particularly agile and lean approaches, have become instrumental in introducing and scaling these sustainability initiatives effectively. Research highlights a significant benefit from

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flexible project management approaches, especially those that allow for iterative improvements and stakeholder engagement [5]. Even though the whisky industry is moving towards more eco-friendly methods, there's not much research research on the use of structured project management techniques in recycling initiatives for this industry.

Agile project management, originally developed for the software industry, has proven increasingly relevant in manufacturing contexts, where adaptability and rapid iteration are crucial. Agile methodologies prioritize flexibility, cross-functional collaboration, and continuous feedback, making them well-suited to managing the uncertainties of implementing circular economy practices [6]. In the whisky industry, this translates into the rapid integration of new packaging solutions that are more environmentally friendly, such as compostable or biodegradable packaging, which helps reduce waste associated with traditional glass [7]. Agile methodology enables distilleries to test new packaging materials, renewable energy sources, and recycling processes in smaller, controlled cycles, allowing for quick adjustments before scaling up successful initiatives [4]. Furthermore, agile's emphasis on adaptability is critical in navigating evolving environmental regulations and consumer demands for sustainable products [8].

Agile's adaptive nature also proves useful in managing the supply chain for recyclable and reusable materials, which can be unpredictable due to fluctuations in material availability and quality [9]. By applying agile principles, whisky distilleries can more effectively manage the risks associated with supply chain variability, thereby enhancing the resilience and sustainability of their operations [2].

Lean management principles, known for their focus on waste reduction and process efficiency, complement circular economy goals by encouraging closed-loop systems, where by-products are repurposed rather than discarded [10], [11]. For example, pot ale, a by-product of whisky production, can be used as animal feed or converted into biofuel, supporting lean's goal of maximizing resource utility [3]. Key to lean management in recycling initiatives is the elimination of waste not only in the physical sense but also in terms of time, resources, and operational redundancies. Techniques such as value stream mapping and Kaizen (continuous improvement) allow whisky distilleries to identify inefficiencies in their recycling workflows, optimizing operations to reduce material waste and energy consumption [4]. Whisky distilleries have implemented lean practices to improve waste sorting efficiency, allowing for better separation of materials such as glass, aluminum, and organic waste [3]. Lean practices in whisky production have shown that reducing waste at the source, rather than merely treating it at the end of the production line, yields more substantial environmental and cost-saving benefits.

The whisky industry in Europe presents a unique landscape for studying project management in the context of sustainability [12]. Distilleries vary significantly in size, resources, and operational models, ranging from historic brands with longstanding production methods to newer, agile companies unencumbered by legacy systems. Agile and lean frameworks are particularly suited to complement circular economy objectives, helping distilleries respond dynamically to the complexities of sustainable production. Lean management principles applied in Scotch whisky production have helped reduce water and energy usage [13], enhance waste recycling, and support sustainable sourcing practices [3]. Younger distilleries have embedded various agile and lean project management techniques for implementing sustainability through flexible and effective

systems to handle challenging regulatory landscapes [8], optimize processes [13], and cut down on waste [3], [14].

Key recycling initiatives in the whisky industry include glass bottle return schemes, advanced waste sorting technologies, and the introduction of compostable packaging [7], [15]. By studying these varying approaches, we can uncover best practices that may be transferable to traditional distilleries and even other resource-intensive industries seeking to embrace circular economy principles in their recycling efforts.

Glass bottle return schemes have emerged as one of the most visible recycling efforts within the whisky industry. These programs are based on the concept of "closed-loop recycling," where used bottles are returned, cleaned, and reused, significantly reducing the need for new packaging materials. For example a whisky distillery in Scotland that is reducing its carbon footprint through an efficient bottle return program, aided by logistics partnerships that streamlined the return and cleaning processes [16]. However, the literature points to logistical challenges that hinder the effectiveness of these return schemes. The efficiency of bottle return programs often depends on the geographic distribution of distilleries and consumers, with greater distances increasing transportation costs and carbon emissions [17]. These schemes also depend heavily on consumer participation, which introduces variability in their efficacy. Studies have shown that awareness campaigns and financial incentives can improve participation rates in bottle return programs [18].

Advanced waste sorting technologies have proven to be transformative in improving material recovery rates within food and beverage industries [11]. The introduction of waste sorting technology can notably improve the efficiency and cost-effectiveness of recycling operations. However, the high upfront costs of waste sorting technologies present a barrier to widespread adoption within the industry. In addition, this integration of advanced sorting technologies introduces an additional layer of complexity, due to high demand for skilled labor to operate and maintain the system [11].

Material reuse and compostable packaging represent another critical area of innovation in whisky industry recycling. Several distilleries across Europe have adopted compostable packaging materials made from plant-based polymers or recycled paper products [7]. However, research by Granato et al. (2022) suggests that while compostable packaging offers environmental advantages, there are trade-offs in terms of material strength and shelf life, which may impact broader adoption.

This article aims to explore the project management methodologies applied to recycling initiatives within the European whisky industry, drawing on case studies from 18 countries. These case studies provide a detailed view of how young distilleries implement practices like glass bottle return schemes, advanced waste sorting technologies, and compostable packaging. The research focuses particularly on how agile and lean methodologies can enhance the effectiveness and efficiency of these initiatives, offering critical insights for both industry practitioners and academics.

MATERIALS AND METHODS

This study used a qualitative case study approach with semi-structured interviews. The research is part of a broader project aimed at understanding how whisky distilleries established after 2000 in continental Europe apply the 9R framework (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, **recycle**) in their business

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models. The research question in this study relates to: How do younger distilleries leverage agile and lean project management techniques to implement recycling practices ?

Using purposive sampling, distilleries from continental Europe established post-2000 were selected to ensure a focus on young businesses more adaptable to sustainable practices and unburdened by legacy systems. This narrowed the sample size from 580 to around 275 potential distilleries. Due to the limited public information available on privately-owned distilleries, participant invitations were sent by email. Additional participants were identified through snowball sampling, where initial respondents recommended others within their networks. The final case studies focused on 18 small distilleries established between 2000 and 2018 from the following countries: Netherlands (2000), Slovakia (2001), Hungary (2002), Spain (2002), Belgium (2004), Luxembourg (2004), Poland (2005), Switzerland (2005), Czech Republic (2008), Austria (2009), Lithuania (2010), Italy (2012), Finland (2014), Norway (2014), Estonia (2015), France (2015), Germany (2016), and Portugal (2018).

Data was collected over six months between February and August 2024. To minimize potential biases, researchers aimed to maintain neutrality during interviews, avoiding leading questions or influencing responses. Interviews took an average of 50 minutes and were conducted via video or phone to accommodate respondents' locations. The interviews were then transcribed for analysis using NVivo15 software. The collected data was analyzed using a project management framework coding and thematic analysis focusing on agile and lean methodologies. Key agile principles, including flexibility, stakeholder collaboration, and iterative development, were considered. Additionally, key lean principles were examined, such as how distilleries minimize waste, optimize recycling processes, and reduce resource consumption.

RESULTS

This study identifies distinct applications of Agile and Lean methodologies across European distilleries in implementing sustainable recycling practices.

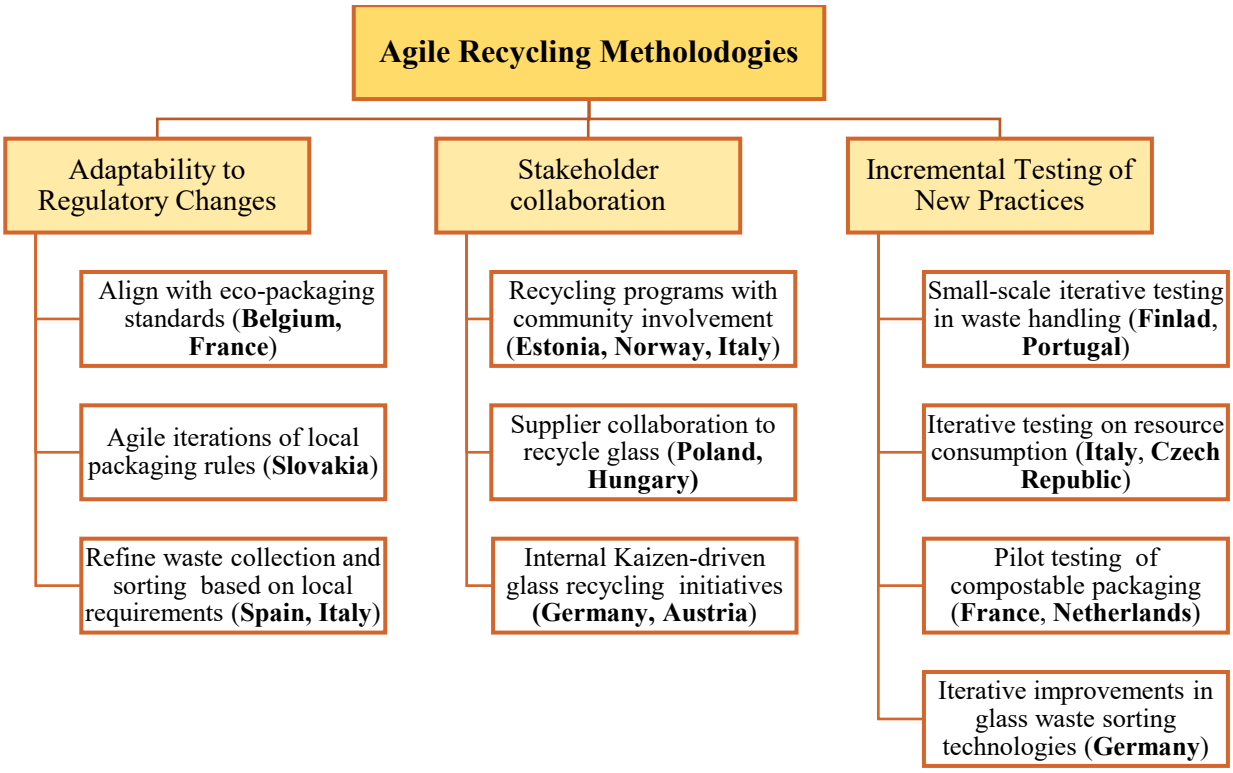


Figure 1. Grouping of emerging Agile Recycling Methodologies themes from NVivo coding

The NVivo 15 software coding theme results are briefly summarized as follows:

- Agile Recycling Methodologies (Figure 1 above) have identified main themes: *Adaptability to Regulatory Changes*, *Stakeholder Collaboration*, and *Incremental Testing of New Practices*. These themes are evident in distilleries in Belgium, France, Slovakia, Spain, and Italy, which align with eco-packaging standards, engage local communities in recycling initiatives, and apply Kaizen techniques to enhance glass recycling. Additionally, Finnish, Portuguese, Italian, Czech, French, Dutch, and German distilleries are conducting small-scale waste handling tests and iterative improvements to glass waste sorting technology.
- Lean Recycling Methodologies (Figure 2 below) encompass *Advanced Waste Sorting*, *Waste Valorization*, and *Small-Scale Efficiencies & Resource Management* themes. Advanced Waste Sorting involves high-efficiency automation, while Waste Valorization focuses on repurposing by-products. Small-Scale Efficiencies & Resource Management involves optimizing manual sorting, waste audits, and streamlining processes. Examples include Germany, France, Switzerland, and Austria using Kaizen to reduce lead times, and Slovakia and Italy repurposing by-products.

These themes identified with NVivo 15 software provide a comprehensive overview of how Agile and Lean methodologies support sustainability practices across varying regulatory and operational contexts.

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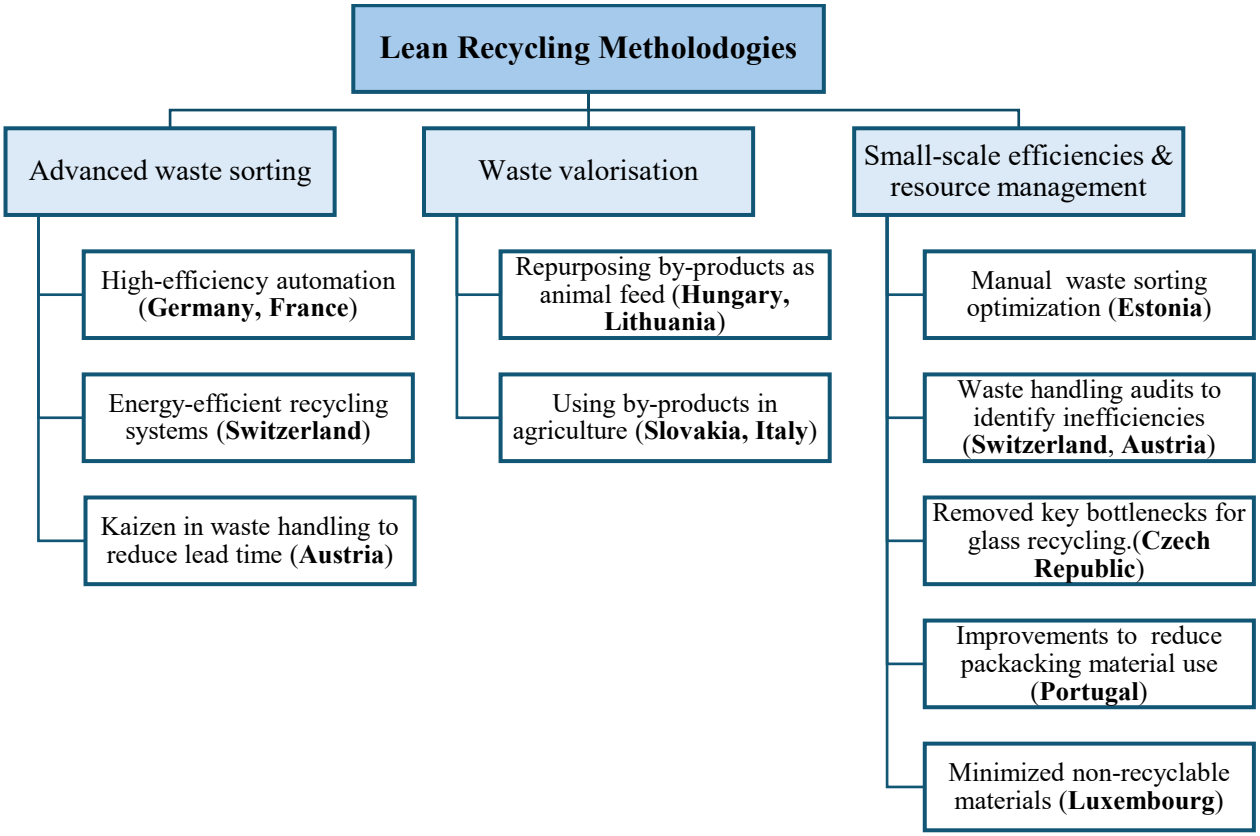


Figure 2. Grouping of emerging Lean Recycling Methodologies themes from NVivo coding

DISCUSSION

This study explored the application of Agile and Lean methodologies in recycling initiatives across European distilleries, identifying several key themes and practices. The study reveals that younger distilleries are adopting agile and lean project management techniques to integrate sustainable practices and respond effectively to regulatory demands. These younger distilleries adopt flexible, innovative sustainability solutions like glass bottle return schemes, advanced waste sorting technologies, and compostable packaging.

The results are consistent with findings in similar studies on sustainability in young versus established organizations. Previous research in other industries, such as food and beverage [15], [17], has reported that younger companies are more agile and responsive to sustainability trends, often adopting leaner, more innovative practices due to the absence of legacy systems.

The findings highlight that Agile methodologies are primarily applied to foster adaptability and stakeholder collaboration, while Lean methodologies are used to optimize processes and resource use. By categorizing these methodologies, we can better understand how distilleries approach sustainable practices and meet regulatory demands.

Agile methodologies in whisky distilleries focus on adaptability to regulatory changes and incremental testing of new practices. Countries like Belgium, France, Slovakia,

Estonia, Norway, and Italy use agile practices to align their eco-packaging strategies with EU regulations. Agile stakeholder collaboration is crucial in recycling programs, with Estonian distilleries involving local communities in feedback loops. Finland and Portugal implement small-scale waste handling tests to improve efficiency and reduce waste. Italy and the Czech Republic use agile resource testing practices to streamline recycling processes, reducing waste and establishing a foundation for sustainability initiatives.

Lean methodologies in whisky distilleries focus on advanced waste sorting and waste valorization. Countries like Germany, France, Switzerland, Hungary, Lithuania, Slovakia, and Italy use high-efficiency automation systems, energy-efficient recycling systems, and waste valorization to reduce resource usage and operational costs. By-products are repurposed, supporting a circular economy model and creating secondary value. Estonia, Switzerland, and Austria use small-scale efficiencies, optimizing manual waste sorting processes for limited capacity and minimizing non-recyclable materials. Portugal also improves packaging material use to enhance product recyclability.

Both agile and lean methodologies prioritize sustainable practices, but the approaches differ in execution. Agile methodologies often emphasize flexibility and stakeholder collaboration, as seen in the iterative testing and regulatory adaptability across Belgium, France, and Estonia. Lean methodologies, on the other hand, focus on process efficiency and waste reduction, as demonstrated by Germany's advanced sorting technologies and Hungary's waste valorisation practices.

A notable similarity is the shared commitment to resource optimization. Whether through lean small-scale efficiencies or agile iterative testing, countries like Finland and Portugal exemplify a focus on conserving resources while maximizing output. However, the primary difference lies in engagement focus: Agile methodologies emphasize community and stakeholder engagement, whereas Lean methodologies concentrate on internal efficiencies and streamlined processes.

This study's key limitations are its focus on a select sample of European distilleries, which may not represent the diverse industry approaches to sustainability due to differing regulatory environments, market pressures, and resources, and its reliance on qualitative interviews that could be subjective. Expanding the research to include distilleries from other regions, exploring alternative project management frameworks such as Six Sigma, conducting longitudinal studies, and incorporating quantitative data could provide a more comprehensive understanding of global best practices in recycling and sustainability. Further research could comparatively explore the impact of adopting similar recycling project management methods in traditional Scotch whisky distilleries.

CONCLUSION

This study provides a detailed examination of how Agile and Lean project management methodologies are applied within the European whisky industry to enhance recycling practices and support circular economy principles. The findings from this study are consistent with similar research in other food and beverage industries, where younger companies are generally more agile and responsive to sustainability trends.

This research not only fills a gap in understanding sustainable practices within the whisky sector but also provides key overview of current implementation. By drawing on case studies from 18 young distilleries, the research identifies core themes within **agile** and **lean** frameworks that align with sustainable objectives, including adaptability to

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regulatory changes, stakeholder collaboration, incremental testing, advanced waste sorting, and resource valorization.

The significant results of this study indicate that younger distilleries benefit from the absence of legacy systems, allowing them to implement agile and lean practices more readily. This adaptability positions them to serve as leaders in sustainable production within the resource-intensive whisky industry.

Agile project management, characterized by its adaptability and iterative development cycles, enables distilleries to respond swiftly to new environmental regulations and consumer expectations. Lean management, with its focus on continuous improvement, complements agile practices by streamlining processes and maximizing resource efficiency. Together, these methodologies create a powerful framework for driving sustainable innovation in recycling and circular economy practices within the whisky industry.

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THE INFLUENCE OF CONVENTIONAL AND LOW-PRESSURE HEAT TREATMENT ON THE COURSE OF CHRYSOTILE ASBESTOS DECOMPOSITION

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ABSTRACT

Recycling of chrysotile asbestos materials is a global problem. Even though the materials containing asbestos have good properties like resistance to elevated temperatures, high elasticity and mechanical strength, or abrasion resistance, it has been proven to be carcinogenic and banned in over 70 countries. Standard disposal of asbestos products - storing them in appropriately designated areas (landfills) - is a risk-taking method due to the possibility of secondary pollution of the surrounding environment and the waste of natural resources. One of the popular methods of neutralisation asbestos fibres is their thermal treatment. This study aimed to investigate the effect of thermal treatment in the range 25-1000°C in conventional parameters and under reduced pressure of -0.1 and -0.5 bar on the dehydroxylation process of chrysotile. The thermal decomposition course of chrysotile studied by differential thermal analysis (DTA) and thermogravimetric measurements (TG-DTG) showed the possibility of using low pressure to increase the efficiency of the thermal treatment process.

Keywords: asbestos, chrysotile, thermal decomposition, low vacuum

INTRODUCTION

Asbestos materials are commonly called silicate minerals from the amphiboles and serpentine groups with a fibrous structure. Among them, chrysotile deserves special attention, because of its wide application in industry, which on a global scale constitutes approx. 93% of the total mass of asbestos products. Chrysotile (white asbestos) is a hydrated magnesium silicate ($Mg_3(OH)_4Si_2O_5$), belonging to the group of serpentine minerals, characterised by a fibrous form of occurrence [1]. As is commonly known, asbestos materials, despite their undeniable, excellent properties, including high resistance to elevated temperatures, high mechanical strength, thermal insulation properties, and resistance to chemical compounds [2], are also characterised by carcinogenicity [3], which undoubtedly negates all the best features of this material. Therefore, for many years, especially in European countries, a policy of absolute ban on producing and withdrawing products containing asbestos has been applied. Following the regulations and commitment to the European Union, in 2002, Poland adopted a long-term program to remove asbestos and products containing asbestos. The mass of all asbestos products found in Poland is estimated at 15 million tons, and it should be noted that these materials are not subject to natural degradation. Standard disposal of asbestos products involves wrapping them in polyethylene foil and storing them in appropriately designated areas (landfills) [4], [5]. However, this procedure cannot be considered the final solution

to the problem of disposing of asbestos waste, due to the risk of secondary threats to the surrounding environment. A possible solution to the problem is to destroy asbestos by destroying its fibrous structure and transforming it into new mineral phases that can be reused, which is of great importance, considering non-renewable and shrinking amounts of natural resources. It therefore seems advisable to develop such asbestos waste disposal technology that will be simple, waste-free, with a minimised carbon footprint and low energy consumption. According to the literature, there are many methods of asbestos neutralisation, including chemical, biological, mechanochemical and thermal [6], [7], which the last seems to be the most promising, due to the lack of harmful post-process reagents and relatively short process time [8]. Analysis of the literature on thermal decomposition of chrysotile and asbestos materials has shown that at a sufficiently high temperature, the dehydroxylation process and thermal decomposition of chrysotile occur, with the formation of new phases. In the temperature range of 500-800°C, chrysotile $Mg_3[Si_2O_5](OH)_4$ loses chemically bound water. This causes the complete breakdown of the mineral structure and the formation of an amorphous material – meta-chrysotile. In the next stage, the amorphous structure crystallises and forsterite Mg_2SiO_4 and enstatite are formed. Forsterite belongs to neosilicates, while enstatite belongs to inosilicates. They don't exhibit carcinogenic properties [9], thanks to which they can be used, for example, as a raw material in building materials. Any method that lowers the temperature of the thermal decomposition process can significantly reduce costs and CO_2 emissions, an example of which is conducting the process under reduced pressure conditions. According to research conducted by S. Hashimoto et al. [10], it is possible to lower the dehydroxylation temperature of hydrated silicate minerals by up to 100°C. This study aims to compare and analyse the thermal treatment process of chrysotile fibres without and under vacuum. Also check the influence of low vacuum on dehydroxylation by other research methods like thermal analysis, X-ray diffraction and scanning electron microscopy.

MATERIALS AND METHODS

In the present study, chrysotile asbestos (CH) which materials was used to produce asbestos diaphragms in the past (chlor-alkali industry, Fig. 1), was examined before and after thermal treatment.

This process was carried out using the thermal analysis (DTA and TG/DTG) performed on the STA 409 PC Luxx apparatus. Chrysotile fibres (100 mg) were put on an open alumina crucible and heated from 20 to 1000°C at 10°C min^{-1}. Three samples were tested: first in an air atmosphere with a 30 mL min^{-1} rate and the rest in a low vacuum at -0.1 bar and -0.5 bar. This makes it possible to assess the influence of vacuum on the changes occurring during annealing in conditions with and without vacuum. The chemical analysis of chrysotile was carried out by X-ray fluorescence spectrometry (XRF) in a PANalytical Magix PW-2424 spectrometer, based on the fused cast-bead method with a loss on ignition (L.O.I.) value measured by isothermal calcination at 1025°C. The phase composition of chrysotile before and after thermal treatment was studied by X-ray diffraction (XRD) using a PANalytical X'pert Pro diffractometer (CuKα radiation, Ni filter, 40 kV, 30 mA, X'Celerator detector). Microstructure was characterised by scanning electron microscopy (SEM) using Mira3 electron microscope.



Fig. 1. Macrophotograph of raw chrysotile sample

RESULTS AND DISCUSSION

The microstructure of chrysotile asbestos fibres is shown in Fig. 2. Their molecular structure makes fibres thin, long, and flexible, creating tangled forms. The combination of tetrahedral silicate sheets bonded to octahedral magnesium hydroxide layers allows the fibres to bend and twist without breaking because the layers slide relative to each other. From a chemical point of view, chrysotile was theoretically composed mainly of magnesium (43.63wt% MgO) and silicon (43.37wt% SiO_2) compounds, and loss of ignition while dehydroxylation should be 13wt%. The main components of our raw chrysotile asbestos are magnesium oxide (~42wt%), silicon dioxide (~38wt%) and iron oxide (~4wt%), and the loss on ignition was about 16.00wt% (Table 1). The qualitative phase composition of raw chrysotile fibres identifies the main phase of chrysotile ($Mg_3Si_2O_5(OH)_4$), but also brucite ($Mg(OH)_2$), lizardite ($Mg_3SiO_5(OH)_4$), and magnetite ($Fe_{2.646}Si_{0.015}O_4$) were identified (Fig. 3).

Table 1. Chemical composition of chrysotile

Element	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	MnO	K_2O P_2O_5 ZrO_2	L.O.I.
wt%	38.08	0.21	4.21	0.01	0.12	41.94	0.04	0.11	below LOQ*	16.14

*LOQ – Limit of Quantification

The thermal decomposition of chrysotile includes such steps as loss of adsorbed water, removal of OH groups from the chrysotile structure, and recrystallisation into new phases after dehydroxylation [11], [12], [13]. The main thermal reaction is the dehydroxylation of raw chrysotile in which structurally bonded hydroxyl groups are removed from a solid and released as water vapour.

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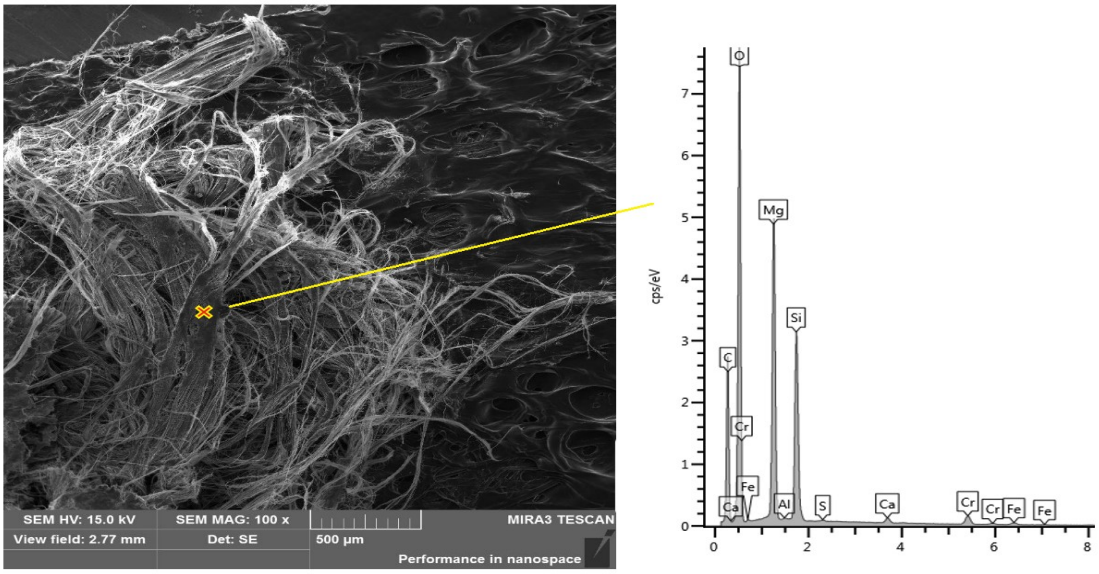


Fig. 2. SEM image of raw chrysotile fibres with EDS analysis, magn. ×100

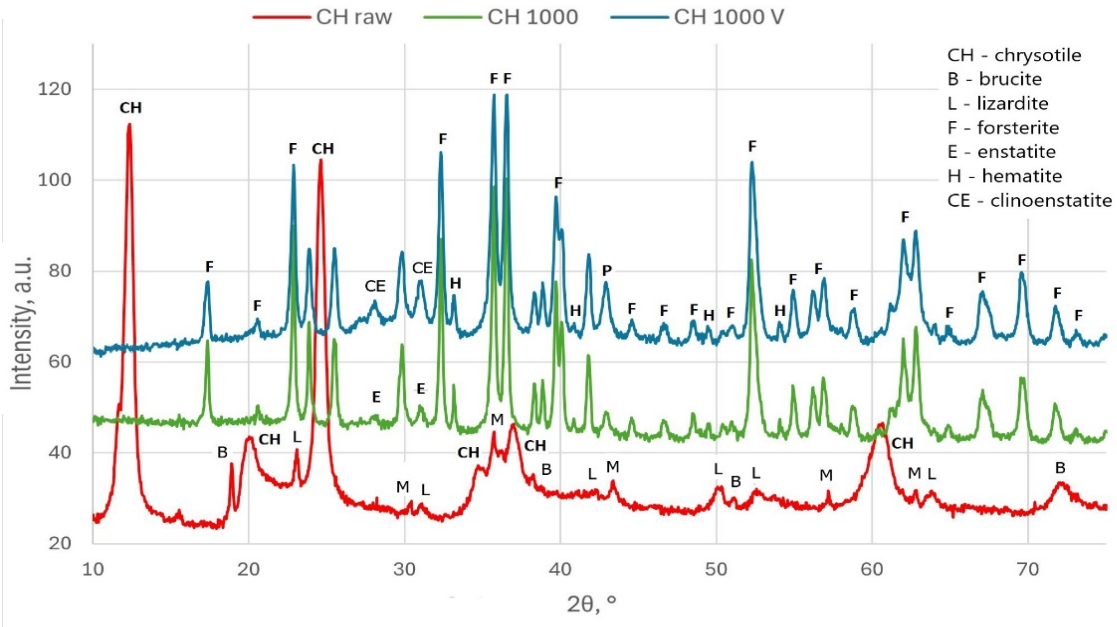


Fig. 3. X-ray diffraction patterns of raw chrysotile asbestos (red line) after heating up to 1000°C without (green line) and under low pressure (blue line)

Figures 4-7 show the thermal analysis of the chrysotile asbestos DTA curve (differential thermal analysis) and DTG/TG curves (thermogravimetry) which were obtained for different atmosphere parameters. Thermal behaviour for raw chrysotile fibres heated without vacuum at an airflow of 30 mL min^{-1} is presented in Figure 4.

First, the sample dehydrates and decarboxylates, and impurities are removed. Those reactions run at temperatures up to 535°C, corresponding to a weight loss of 5.34 wt%. At a temperature of about 396°C brucite is dehydroxylated.

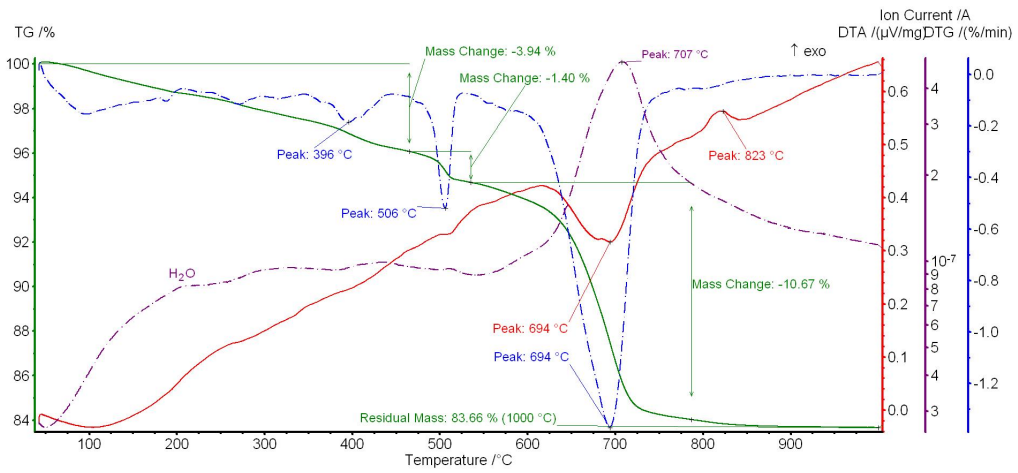


Fig. 4. Thermal analysis of raw chrysotile (conventional condition)

Dehydroxylation of chrysotile with ideal chemical formula is carried out by the reaction $Mg_3(OH)_4Si_2O_5 \rightarrow Mg_3Si_2O_5$ (meta-chrysotile) + $2H_2O$, where at a temperature between 550-800°C chrysotile loses chemically bound water, which provides to a weight loss of 10.67 wt%. A strong endothermic peak with a maximum of 694°C evidences this. This effect is connected with the loss of water molecules visible in the EGA curve with a maximum of ~700°C. As a result of this decomposition, meta-chrysotile is formed (amorphous phase) and further increase in temperature leads to the crystallisation of forsterite and enstatite as evidenced by the exothermic peak on the DTA curve with a maximum at 823°C, according to the reaction $Mg_3Si_2O_5 + 2H_2O \rightarrow Mg_2SiO_4$ (forsterite) + $MgSiO_3$ (enstatite). Maximum weight loss was 16.34 wt%, corresponding with a loss on ignition in chemical analysis.

A comparison of DTA, TG and DTG curves for all samples is shown in Figures 5-7. All of them showed no significant differences, but some changes. All samples showed two characteristic peaks on DTA curves (Fig. 5). The first was the endothermic peak from chrysotile dehydroxylation, and the second was the exothermic peak from forsterite/enstatite crystallisation. The endothermic peak on the DTA curve (Fig. 5) from the sample heated in -0.5 bar, shows that dehydroxylation in that condition starts at a lower temperature, however, the finish temperature is similar under all three heat treatment conditions. The curve for -0.5 bar is characterised by a long lightly flattened line corresponding to temperature range to chrysotile dehydroxylation. There is no visible effect of the applied low vacuum on the maximum crystallisation temperature of forsterite and enstatite, which is 822-823°C.

All TG curves show that weight loss after dehydroxylation is close to each other, but the mass change accompanying decarboxylation shifts towards lower temperatures, which is also visible on DTG curves (Fig. 6). The endothermic peak in conventional conditions at 506°C connected with decarboxylation, in low vacuum moved almost 80°C towards a lower temperature.

In low vacuum, the dehydroxylation onset temperature also shifts. However, it is a maximum shift of 25°C, but the predictions regarding the effect of using a higher vacuum seem to be positive. The vacuum influences on start point dehydroxylation temperature contribute to the effective neutralisation of this mineral's carcinogenic properties and more effective crystallisation of the amorphous phase into safe mineral phases.

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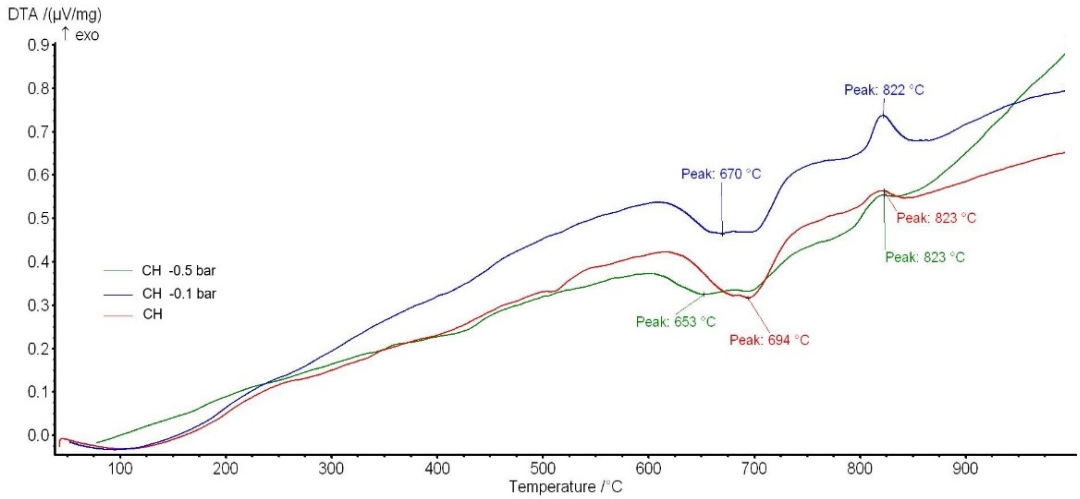


Fig. 5. Comparison of DTA curves of chrysotile sample after different atmosphere conditions

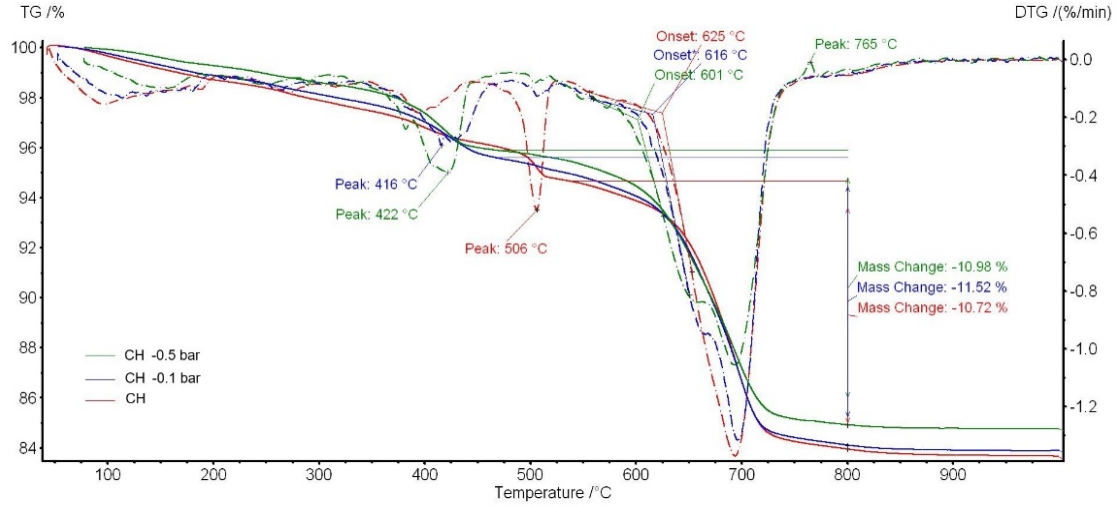


Fig. 6. Comparison of TG/DTG curves of chrysotile sample in different atmosphere conditions

The low vacuum used affects the crystallisation rate of thermally stable mineral phases, such as forsterite and enstatite. According to the semi-quantitative method, enstatite crystallisation is more efficient in low vacuum (Table 2). Its content increased tenfold compared to the sample heated without a vacuum. Crystallisation to clinoenstatite was possible due to stressed conditions [8].

Table 2. The fraction of mineral phases after heat treatment of chrysotile at 1000°C, semi-quantitative XRD method

Mineral phases, %	without vacuum	under -0.5 bar
Forsterite	97.4	86.9
Periclase	1.0	1.9
Enstatite/Clinoenstatite	0.9	10.6
Hematite	0.7	0.6

The microstructure of fibres after heat treatment at 1000°C shown in Fig. 7. Heat-treated fibres are different from raw ones. They are short with brittle fractures. Even if the fibre structure is preserved, mineralogical data show that the asbestos structure has deteriorated. The microstructure of long elastic fibres collapsed, and the new material is brittle and easy to mill for materials, which can be used as materials for production building materials. A sample heated in a vacuum of -0.5 bar has a higher grinding potential.

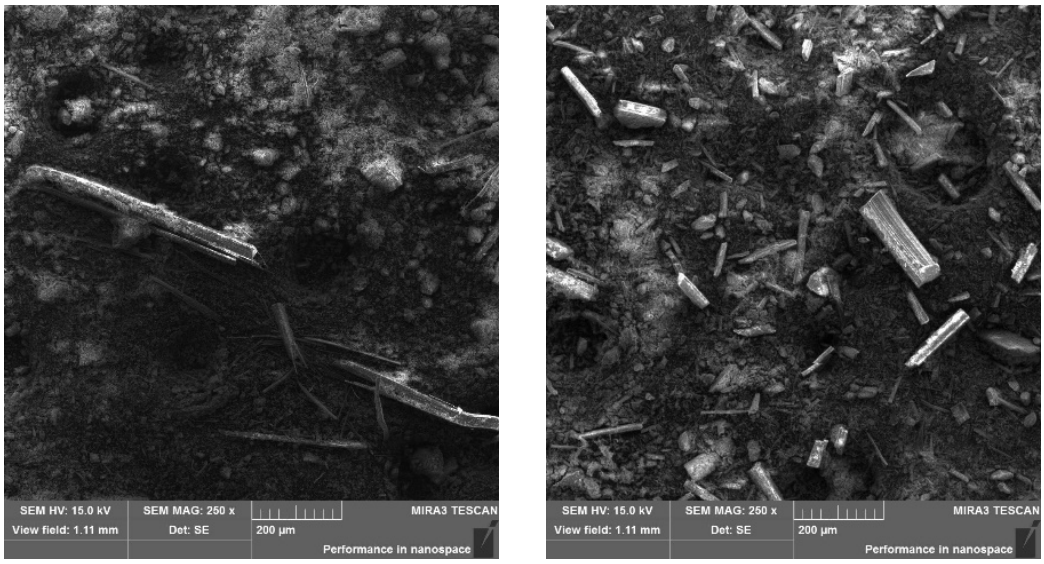


Fig. 7. Microstructure of fibres after heat treatment at 1000°C without (a) and under low vacuum (b), mag. ×250

CONCLUSION

In the present study, the thermal decomposition of asbestos during conventional and reduced pressure heat treatment was characterised. Dehydroxylation of chrysotile involves the removal of hydroxyl groups from its structure, typically through thermal treatment. Under a low vacuum, the partial pressure of water vapour is reduced. This accelerates the dehydroxylation reaction as lower water vapour pressure favours the removal of hydroxyl groups. This study indicates, that chrysotile undergoes thermal to forsterite and enstatite while thermal treatment up to 1000°C regardless of the pressure conditions. The low vacuum affects the removal of chemically bound water faster than in conventional thermal treatment and the crystallisation process of thermally stable phases, which are non-carcinogenic. It also contributed to a more efficient crystallisation of clinoenstatite. The results of the preliminary research presented in this paper are promising. Investigations should be continued taking into account the thermal treatment under higher vacuum and with isothermal treatment.

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THERMODYNAMIC ANALYSIS SULFATIZING ROASTING OF STALE NICKEL-COBALT-CONTAINING WASTES FROM OPERATING PLANTS

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ABSTRACT

Metallurgy is one of the leaders in terms of the amount of accumulated waste worldwide. Every year the amount of waste placed in dumps, sludge ponds, tailings ponds only grows. However, at present, tailings, slag, dust, etc. of metallurgical enterprises are considered the most promising for secondary use and the extraction of valuable metals from tailings is an important problem in the world.

In Kazakhstan, the technology of processing nickel-cobalt-containing tailings is practically undeveloped. Sokolov-Sarybai Mining Production Association Joint-Stock Company (SSGPO JSC) in Kazakhstan, loses more than 7 thousand tons of nickel and 14 thousand tons of cobalt per year. For processing this type of raw material, a combined technology that includes preliminary roasting and leaching processes is acceptable.

The aim of the work is a thermodynamic analysis of the roasting process of wet magnetic separation (wms) tailings of the SSGPO JSC, containing such main components as nickel, cobalt and iron sulfides.

Thermodynamic analysis of the roasting of wms tailings in the temperature range from 500 to 750°C showed that in the presence of a limited amount of oxygen, the formation of iron sulfides of the following compositions is possible: $Fe_{0.877}S$, FeS, Fe_2S_3, Fe_7S_8. Nickel and cobalt sulfides are converted into Ni_3S_2, Ni_3S_4 and $CoS_{0.89}$, CoS, respectively. In this temperature range, within the homogeneity region, the transformation of cobalt and nickel sulfides also occurs. The calculated values of the Gibbs free energy confirm the possibility of reactions of formation of low-sulfide compounds and the optimal condition for firing is the temperature range of 600-700°C. Depending on the firing conditions, interconversion of iron, nickel and cobalt sulfides occurs.

The results of thermodynamic analysis confirm the possibility of extracting iron, nickel and cobalt from wms tailings in the form of soluble low-sulfide compounds with subsequent extraction from the tailings in the form of individual metal powders. Combined technology for processing this type of raw material will be a good example of the use of circular economy principles.

Keywords: thermodynamic analysis, roasting, nickel sulfide, cobalt sulfide, wastes.

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INTRODUCTION

Smartphones, electric vehicles, renewable solar panels, wind turbines, and new clean energy technologies are highly dependent on metals, including lithium, nickel, copper, cobalt, chromium, and manganese [1]. Consequently, a reliable supply of these minerals is crucial to ensuring the transition to sustainable energy, driving up demand.

The gradual depletion of mineral reserves [2-3] is leading to a mismatch between current production rates and projected demand for these metals.

The Republic of Kazakhstan has substantial reserves of nickel and cobalt, primarily found in low-grade oxidized ores like those at Kempirsai, Gornostayev, and Bozshakol, as well as iron-bearing ores and concentrates from Sokolovsky and Sarbaisky. The complex mineralogy, including intergrowths of cobalt and iron minerals and isomorphic substitution of cobalt in pyrite, combined with the low nickel and cobalt content, renders standard metallurgical processes ineffective. As a result, there is currently no nickel or cobalt production in Kazakhstan [4].

It is essential to consider alternative raw materials, including water resources, low-grade ores, tailings, slags, and electronic waste. The growing demand for nickel has stimulated research into recovering nickel from secondary sources like wet magnetic separation tailings [5]. Two primary approaches for nickel extraction from these waste materials are: hydrometallurgical processing, involving leaching of the waste and subsequent nickel recovery; and pyrometallurgical processing, which involves thermal treatment of the waste [6].

Significant quantities of nickel and cobalt are lost in tailings and metallurgical process residues. For instance, the SSGPO JSC annually loses over 7,000 tons of nickel and 14,000 tons of cobalt. The non-standard composition of pyrite-cobalt concentrates produced at this plant necessitates the development of new technologies for their efficient processing and recovery of valuable components.

In this context, the research, development, and implementation of optimal technologies for the production of nickel and cobalt from low-grade nickel and cobalt-bearing raw materials, concentrates, and technogenic waste is a pressing issue.

Pre-roasting, followed by leaching and selective extraction with subsequent metal or compound refining, is an effective combined technology for increasing the metal concentration in feed materials, including tailings [7, 8].

Nevertheless, simple roasting of ores does not always provide the expected results. Research has demonstrated that high-temperature sulfatization of oxidized ores, employing a sulfuric acid dosage of 0.7 g per gram of ore at 420 °C, significantly enhanced nickel extraction, reaching 80-82%.

As demonstrated in studies [9, 10], the most promising technologies for processing pyrite-containing materials involve smelting or activating dissociative roasting of the feedstock followed by hydrometallurgical or pyrometallurgical processing of the calcine. When smelting low-grade nickel-bearing ores using pyrite concentrates as a sulfidizing agent, nickel and cobalt concentrate in the matte. For more complete nickel and cobalt recovery, the matte should be low-grade. Dissociative roasting of pyrite-containing materials can be carried out under various conditions: in vacuum, in an inert gas atmosphere, in combustion products, sulfur dioxide, air, etc., at different

temperatures, with or without melting of the processed products, and in various roasting units [1]. Hydrometallurgical methods, which provide high-complexity processing of various types of feedstock, are considered the most promising for further processing of calcines or low-grade mattes.

To provide a thermodynamic basis for the pre-roasting process, we have performed a thermodynamic analysis of systems containing nickel, cobalt, iron, sulfur, and oxygen under thermal processing conditions.

MATERIALS AND METHODS

The initial materials and reagents

In this study were used tailings from the wet magnetic separation process at the SSGPO JSC, obtained during the processing of iron ores, were used as the feedstock. Physicochemical analysis was conducted using X-ray diffraction, atomic emission spectroscopy, and chemical analysis.

A thermodynamic analysis of sulfide behavior under activating roasting conditions was conducted using HSC Chemistry 5.11 software from Outokumpu Technology. The analysis was based on the equilibrium conditions of heterogeneous chemical reactions involving gaseous substances. Thermodynamic characteristics of the main reactions were calculated, and isothermal sections of phase equilibrium diagrams were constructed for the Fe-O-S (Fig. 1 a), Ni-O-S (Fig. 1 b), and Co-O-S (Fig. 2) systems at temperatures ranging from 600 to 800°C.

RESULTS AND DISCUSSION

Physicochemical analysis of SSGPO JSC wms tailings samples revealed the presence of iron, nickel, and cobalt sulfides, as well as other impurities (hereinafter referred to as pyrite concentrate). The chemical composition of the wms tailings is presented in Table 1.

Table 1: Chemical composition of the wms tailings.

Chemical composition, %												
$Fe_{общ}$	Cu	Co	Ni	$S_{общ}$	Pb	Zn	SiO_2	Al_2O_3	CaO	MgO	TiO_2	As
12,62	0,05	0,013	0,0081	3,46	0,019	0,069	37,23	12,97	12,59	4,72	0,59	0,006

The main minerals in the tailings are pyrite, diopside, clinochlore, albite, and others. Nickel and cobalt content is low, with millerite and heazlewoodite being the primary minerals.

As the SO_2 concentration decreases, iron disulfide undergoes a series of transformations, forming lower iron sulfides: $FeS_2 \rightarrow Fe_2S_3 \rightarrow Fe_7S_4 \rightarrow Fe_{0,877}S \rightarrow FeS$. When pyrite is thermally treated in the presence of roasting gases, the aforementioned lower iron sulfides, as well as Fe_3O_4 and possibly $FeSO_4$, are formed.

To predict the behavior of sulfides under activating roasting conditions, the following partial pressure diagrams were selected and studied: Fe-S-O, Ni-S-O, and Co-S-O.

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It is well known that the composition of the gas phase during thermal treatment plays a decisive role and determines the composition of the cinder. The thermodynamics of transformations in the Fe-O-S, Co-O-S, and Ni-O-S systems have been analyzed in detail in works [11].

Analysis of the $logp_{SO2} – f(logp(O2))$ partial pressure diagram for the Fe-S-O system revealed that at 900 K and a partial pressure of sulfur dioxide close to atmospheric $lgP_{SO2} = 0$, pyrite undergoes the following transformations: $FeS_2 \rightarrow Fe_2S_3 \rightarrow Fe_3O_4 \rightarrow FeSO_4 \rightarrow Fe_2(SO_4)_3$ (Fig. 1a).

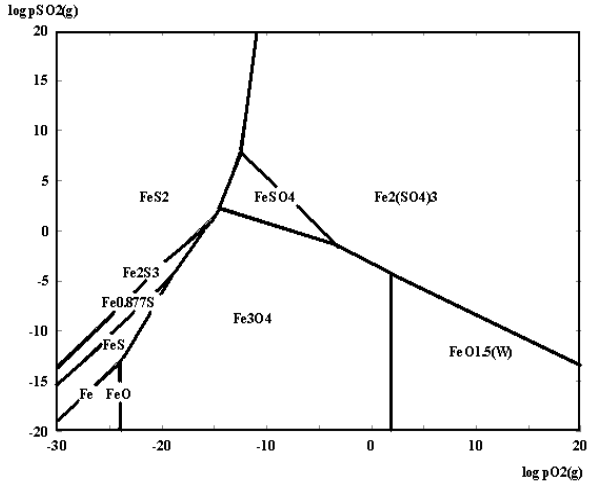


Figure 1 a – Isothermal section of the phase equilibrium diagram for the Fe-O-S system at 900 K

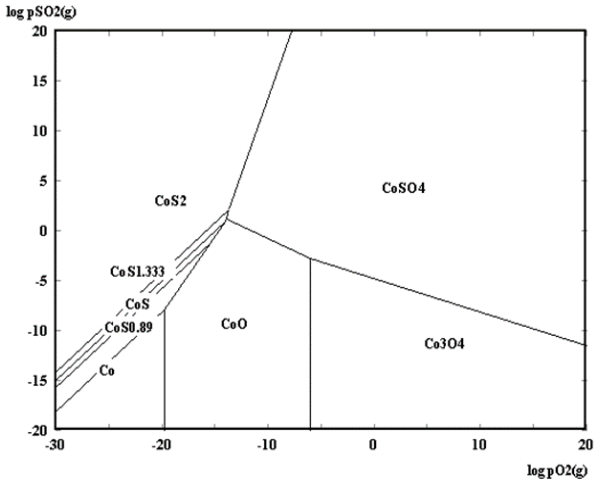


Figure 1b – Isothermal section of the phase equilibrium diagram for the Co-O-S system at 900 K

Analysis of the phase equilibrium diagrams in the Co-O-S system reveals that the oxidation of cobalt sulfide at 900 K and a partial pressure of sulfur dioxide of $lgPSO_2 = 0$ proceeds sequentially through the phases $CoS_2 \rightarrow CoS_{1.333} \rightarrow CoS \rightarrow CoO \rightarrow CoSO_4$ (Fig. 1b). When the SO_2 concentration in the gas phase decreases, thermal dissociation of cobalt disulfide occurs with the sequential formation of lower cobalt sulfides: $CoS_2 \rightarrow CoS_{1,333} \rightarrow CoS \rightarrow CoS_{0,89}$. Under thermal treatment conditions with a deficiency of oxygen and in the presence of roasting gases, the formation of the aforementioned lower cobalt sulfides, as well as CoO, $CoSO_4$, and a small amount of Co_3O_4, is possible.

The oxidation of nickel sulfide at 900 K under a near-atmospheric sulfur dioxide partial pressure proceeds sequentially through the phases $NiS_2 \rightarrow Ni_3S_4 \rightarrow NiS \rightarrow NiO \rightarrow NiSO_4$, as shown in figure 2.

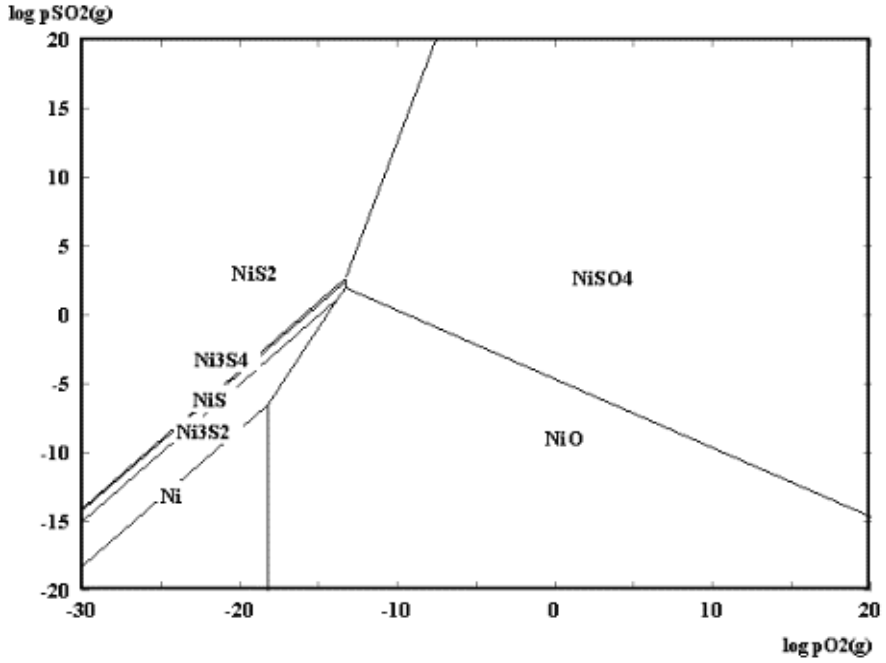


Figure 2: Isothermal section of the phase equilibrium diagram for the Ni-O-S system at 900 K

An analysis of the isothermal sections of partial pressure diagrams (Figures 1-2) indicates that during the roasting of nickel-cobalt-containing materials in a wide range of gas phase compositions (O_2 + SO_2), the following compounds are the most stable: FeS, $Fe_{0,877}S$, Fe_2S_3, FeS_2, Fe_3O_4, $FeSO_4$, $Fe_2(SO_4)_3$, CoS_2, $CoS_{1,333}$, CoS, $CoS_{0,89}$, CoO, $CoSO_4$, Co_3O_4, NiS_2, Ni_3S_4, Ni_3S_2, NiS, NiO, $NiSO_4$.

In the event of oxygen deficiency, sulfur-containing compounds such as FeS, $Fe_{0,877}S$, Fe_2S_3, FeS_2, CoS_2, $CoS_{1,333}$, CoS, $CoS_{0,89}$, NiS_2, Ni_3S_4, Ni_3S_2, NiS are the most stable. As the oxygen potential in the system increases, the thermodynamic probability of forming metal oxides and sulfates increases. Moreover, sulfate formation primarily occurs from oxidized compounds.

A thermodynamic analysis of the roasting process for iron, nickel, and cobalt sulfides was conducted.

Gibbs free energy calculations were performed for the likely primary reactions during the thermal treatment of nickel-cobalt-containing sulfide ores (Table 2).

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Table 2 – Thermodynamic analysis of potential reactions during the dissociative roasting of materials.

Chemical reaction		ΔG^o, kJ/mol	
		273 K	900 K
1.	$FeS_2 + 1/2O_2 = 1/2Fe_2S_3 + 1/2SO_2$	-130,30	-143,19
2.	$FeS_2 + 0,86O_2 = 1,14\ Fe_{0,877}S + 0,86\ SO_2$	-208,20	-245,42
3.	$FeS_2 + O_2 = FeS + SO_2$	-241,97	-280,78
4.	$FeS_2 + 6/7O_2 = 1/7Fe_7S_8 + 6/7SO_2$	-203,90	-237,17
5.	$Fe_2S_3 + 5/7O_2 = 2/7Fe_7S_8 + 5/7SO_2$	-147,20	-187,95
6.	$Fe_2S_3 + 0,719O_2 = 2,281Fe_{0,877}S + 0,719\ SO_2$	-155,60	-204,28
7.	$Fe_2S_3 + O_2 = 2FeS + SO_2$	-223,34	-275,17
8.	$Fe_7S_8 + O_2 = 7FeS + SO_2$	-266,49	-305,26
9.	$Fe_{0,877}S + 0,123O_2 = 0,877FeS + 0,123SO_2$	-29,66	-31,05
10.	$CoS_2 + O_2 = CoS + SO_2$	-250,42	-268,37
11.	$CoS_2 + 1,11O_2 = CoS_{0,89} + 1,11SO_2$	-279,36	-295,41
12	. $CoS_{1,333} + 0,333O_2 = CoS + 0,333SO_2$	-80,14	-86,00
13.	$CoS_{1,333} + 0,443O_2 = CoS_{0,89} + 0,443SO_2$	-109,07	-113,03
14.	$CoS + 0,11O_2 = CoS_{0,89} + 0,11SO_2$	-28,94	-27,04
15.	$NiS_2 + 2/3O_2 = 1/3Ni_3S_4 + 2/3SO_2$	-172.08	-183,36
16.	$NiS_2 + 4/3O_2 = 1/3Ni_3S_2 + 4/3SO_2$	-344,68	-360,84
17.	$Ni_3S_4 + O_2 = 3NiS + SO_2$	-263,38	-272,94
18.	$Ni_3S_4 + 2O_2 = Ni_3S_2 + 2SO_2$	-517,79	-532,46
19.	$NiS + 1/3O_2 = 1/3SO_2 + 1/3Ni_3S_2$	-84,81	-86,50

During the roasting of FeS_2 in the presence of limited oxygen, iron sulfides with various compositions can be obtained via reactions (1-4): $Fe_{0,877}S$, FeS, Fe_2S_3, Fe_7S_8 within the homogeneity range. Additionally, depending on the roasting conditions, these iron sulfides can undergo mutual transformations according to reactions (4-9).

Nickel and cobalt sulfides exhibit similar behavior. According to reactions 10 and 11, cobalt disulfide can transform into $CoS_{0.89}$ and CoS, while reactions 15 and 16 describe the conversion of nickel disulfide to Ni_3S_2 and Ni_3S_4. Reactions 12-14 and 17-19 represent transformations of cobalt and nickel sulfides within their homogeneity ranges. In the presence of excess oxygen, oxygen-containing compounds of iron, nickel, and cobalt, such as metal oxides and sulfates, are formed.

Based on the phase diagrams of the Fe(Ni, Co)-S systems, it can be concluded that the presence of wide homogeneity ranges allows for the formation of low-sulfur iron compounds with a broad range of compositions, as well as variable composition cobalt and nickel sulfides under thermal treatment conditions (700-1100 K).

CONCLUSION

For the efficient processing of pyrite concentrates obtained from the tailings of wet magnetic separation at SSGPO JSC, a combined method involving preliminary roasting and subsequent leaching of valuable components is optimal. Thermodynamic analysis conducted under thermal treatment conditions at temperatures of 650-700 °C confirmed the possibility of forming low-sulfur iron compounds with various compositions, as well as cobalt and nickel sulfides with variable compositions.

The thermodynamic properties of these natural sulfide compounds (Fe_7S_8, $Fe_{0.877}S$, Fe_2S_3, FeS, $CoS_{1.333}$, CoS, $CoS_{0.89}$, Ni_3S_4, Ni_3S_2, NiS), as determined experimentally within their respective homogeneity ranges, can serve as foundational data for thermodynamic modeling and analysis of processes involving these sulfides.

These results indicate that the roasting process not only enhances the recovery of valuable components but also allows for the modification of the composition of the final goods, thus opening up new opportunities for optimizing the processing of pyrite concentrates. The combined approach based on thermal treatment can significantly improve the efficiency of leaching processes and, consequently, enhance the economic performance of the overall process.

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SECTION

AIR QUALITY, POLLUTION CONTROL, AND CLIMATE CHANGE MITIGATION

THE IMPACT ANALYSIS OF GHG REDUCTION INDICATORS ON CARBON EMISSIONS IN TRANSPORT SECTOR OF KOREA

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ABSTRACT

The international community declared a commitment to Net Zero through the Paris Agreement to address accelerating climate change. Countries worldwide agreed to participate by submitting and implementing Nationally Determined Contributions (NDC). South Korea also joined this declaration, aiming to achieve Net Zero by 2050. Achieving Net Zero requires the establishment of policies tailored to each country, along with regular assessments to ensure effective strategy implementation. The Greenhouse Gas Inventory and Research Center of Korea (GIR) has introduced 19 reduction indicators related to policies in the road transport sector and conducts assessments based on these indicators to evaluate greenhouse gas reduction efforts in the transport sector. However, the effectiveness of these assessments has not yet been verified. This study analyzed the relationship between the reduction indicators in the road transport sector and greenhouse gas emissions. The results indicated that only some indicators had a tangible impact on emissions, making it challenging to directly evaluate the implementation of the national reduction strategy based solely on the current indicators. Accordingly, we propose establishing a Measurable, Reportable, and Verifiable (MRV) system using diverse mobility and behavioral data. Such a system would enable policy stakeholders to accurately diagnose and monitor greenhouse gas reduction efforts, thereby enhancing policy effectiveness.

Keywords: Impact Analysis, Net Zero, Transport Sector, NDC(Nationally Determined Contribution), GST(Global Stocktake)

INTRODUCTION

To address accelerating climate change, the international community declared carbon neutrality through the Paris Agreement. To achieve the Paris Agreement's goal of mitigating global warming by "limiting the rise in average global temperature to below 2°C compared to pre-industrial levels by 2100," swift commitments to carbon neutrality have been made as part of the global climate crisis response. In line with this trend, South Korea joined the movement in October 2020 by pledging to achieve carbon neutrality by 2050. In addition, South Korea adjusted its 2030 Nationally Determined Contribution (NDC) target for greenhouse gas emissions in the transportation sector, raising the reduction rate from 26.3% (based on 2018 levels) to 37% by 2030.

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Greenhouse gas emissions from the transportation sector, associated with public mobility, totaled 97.9 million tons of CO_2eq in 2021, accounting for 16.8% of total emissions. This share has remained relatively stable at 16.6% in 2019 and 17.1% in 2020. The road sector, mainly driven by fossil fuel (e.g., gasoline, CNG) use in internal combustion vehicles, is responsible for 97.6% of total transportation emissions, according to the 2021 implementation review report.[1]

In May 2021, South Korea established the 2050 Carbon Neutrality Committee to facilitate the transition to a carbon-neutral society. Additionally, in August 2021, the "Framework Act on Carbon Neutrality and Green Growth" was enacted to provide a legal foundation for setting and achieving the 2050 carbon neutrality target.

Achieving carbon neutrality requires data collection and precise measurement. Indicator development plays a critical role in understanding trends and changes related to carbon neutrality and supporting informed policy decisions toward goal attainment.

Since 2020, under the Second National Climate Change Response Basic Plan, South Korea's Greenhouse Gas Inventory and Research Center (GIR) has conducted annual assessments of greenhouse gas reduction performance. For the transportation sector, 19 indicators (15 quantitative and 4 qualitative) are presented to evaluate reduction policies, and implementation assessments are conducted based on these indicators.

However, the proposed indicators have limitations in terms of alignment with government policies, redundancy across different policies, and adaptation to changes in the transportation sector. Moreover, their correlation with actual reductions in carbon emissions in Korea has not been verified.

Therefore, this study aims to assess the explanatory power of greenhouse gas reduction indicators on carbon emissions in the transportation sector by analyzing their correlation and to determine the suitability of these indicators for implementation assessments. Additionally, the study proposes an MRV (Measurement, Reporting, and Verification) system for carbon emissions in the road transportation sector that can accommodate technological advancements and new mobility services in response to changing times.

MATERIALS AND METHODS

In accordance with the "Key Tasks of the Second National Climate Change Response Basic Plan," South Korea conducted its first evaluation of the implementation status of national greenhouse gas reduction targets in 2020[1]. Implementation assessments are being conducted for greenhouse gas reduction targets across various sectors, including national, energy transition, industry, buildings and public, transportation, and other sectors.

In the transportation sector, as shown in Table 1 below, 19 reduction indicators are presented, broadly classified into quantitative and qualitative indicators. In this study, to analyze the impact on greenhouse gas emissions in the road transportation sector, quantitative indicators related to road emissions were selected, excluding those for rail, maritime, and aviation, and data were collected accordingly.

Table1. Reduction indicators on Carbon Emissions

Type		Reduction indicators on Carbon Emissions	Units
Quantitative Indicators	①	**Cumulative Number of Electric Vehicle(Passenger car)**	**10K**
	②	**Cumulative Number of Hydrogen Vehicle(Passenger car)**	**10K**
	③	**Cumulative Number of Hybrid Vehicle(Passenger car)**	**10K**
	④	**Cumulative Number of Electirc Vehicle(Passenger Van, Freight Truck)**	**10K**
	⑤	**Cumulative Number of Hybrid Vehicle(Passenger Van, Freight Truck)**	**10K**
	⑥	Improvement of Average Fuel Economy in Vehicles	-
	⑥-1	Passenger car	km/L
	⑥-2	Passenger Van, Freight Truck	km/L
	⑦	**Blending Ratio of Biodiesel**	**%**
	⑧	**Extension of ITS(Intelligent Transport Systems) Infrastructure**	**km**
	⑨	Extension of Rail Network	**km**
	⑩	**Extension of Bicycle Path**	**km**
	⑪	**Number of Eco-Driving Training participants**	**Counts**
	⑫	Freight Transport Volume Transferred from Road to Rail	**10K**
	⑬	Freight Transport Volume Transferred from Road to Maritime	**10K**
	⑭	Improvement Rate of Aircraft Efficiency	**%**
	⑮	**Public Transport Modal Share**	**%**
Qualitative Indicators	⑯	Introduction of Average Fuel Economy System for Medium and Heavy-Duty Vehicles	-
	⑰	Construction of Eco-Friendly Replacement Vessels (New Ships), Expansion of Alternative Maritime Power(AMP) Systems	-
	⑰-1	Introduction of LNG-Powered Vessels (New Ships)	-
	⑰-2	Expansion of Alternative Maritime Power (AMP) Systems	-
	⑱	Decommissioning of Aging Vessels and Construction of Replacements (Existing Ships)	-
	⑲	Expansion of Eco-Friendly Logistics Operations	-

In this study, data on greenhouse gas emissions from the road transportation sector, along with data corresponding to reduction indicators over a 10-year period (from 2011 to 2021), were collected to analyze the correlation between greenhouse gas emissions in the transportation sector and each implementation indicator.

The greenhouse gas emissions from the road transportation sector are based on the emissions confirmed in the "2023 National Greenhouse Gas Inventory Report of Korea" by the Greenhouse Gas Inventory and Research Center (GIR), specifically using the emissions from the road sector (1A3b) within the transportation sector. Indicators related to the low-emission vehicle promotion policy include the cumulative deployment numbers for passenger cars (electric vehicles, hydrogen vehicles, hybrid vehicles) and vans and trucks (electric vehicles, hydrogen vehicles), with data sourced from the "Molit Statistic System."

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The blending ratio of biodiesel is an implementation indicator related to the renewable energy fuel blending mandate, using the mandatory blending ratio of biodiesel used in automotive diesel. Data on the extension of Intelligent Transport Systems (ITS) infrastructure were compiled using information from municipalities under investigation by ITS Korea. The number of participants in eco-driving training is based on data from the Korea Transportation Safety Authority, which has provided education on fuel-efficient driving through eco-driving training since 2010, focusing on passenger cars, vans, and trucks. The modal share of public transportation is derived from the "Molit National Transport Statistics Annual," representing the sum of the shares for buses, general railways, and subways. Indicators for the fuel economy improvement system are presented as the average fuel economy of passenger cars and small vans and trucks. According to the "Regulations on the Energy Consumption Efficiency and Labeling of Automobiles," fuel economy was reported based on urban driving mode measurements until 2011. From 2012 onwards, a combined fuel economy method similar to that used in the U.S., including a 5-cycle correction method, was introduced. Due to differences in measurement methods, this data was not included in the analysis. Additionally, data related to the extension of the rail network and logistics transport for rail, maritime, and aviation were not included in the analysis as they do not pertain to the road sector. The basic statistics for the collected reduction indicators are presented in Table 2 below.

Table 2. Basic Statistics for Reduction indicators on Carbon Emissions

Variables	mean	std	max	min
GHG Emissions from Road Transportation Sector(ktCO2eq)	88,793	5,665	95,462	79,775
Cumulative Number of Electric Vehicle(Passenger car) (counts)	44,814	61,354	185,256	335
Cumulative Number of Hydrogen Vehicle(Passenger car) (counts)	3,304	6,285	19,270	0
Cumulative Number of Hybrid Vehicle(Passenger car) (counts)	324,359	275,805	907,853	38,474
Cumulative Number of Electic Vehicle(Passenger Van, Freight Truck) (counts)	6,001	14,239	46,057	9
Cumulative Number of Hybrid Vehicle(Passenger Van, Freight Truck) (counts)	21	44	134	0
Blending Ratio of Biodiesel (%)	3	0	3	2
Extension of ITS(Intelligent Transport Systems) Infrastructure (km)	4,129	3,791	11,584	445
Extension of Bicycle Path (km)	21,022	3,179	25,249	15,307
Number of Eco-Driving Training participants (counts)	2,685	1,598	4,993	309
Public Transport Modal Share (%)	31	3	33	23

The dependent variable is set as greenhouse gas emissions from the road transportation sector, while the independent variables include the cumulative deployment numbers of vehicles, the biodiesel blending ratio, the length of ITS infrastructure, the extension of bicycle paths, the number of eco-driving training participants, and the modal share of public transportation. To analyze the correlation between these reduction indicators and emissions, Multiple Regression Analysis was performed. To avoid multicollinearity issues and to identify the significant impact of cumulative vehicle numbers, the

cumulative deployment numbers of electric vehicles and hybrid vehicles were selected as representative variables of the vehicle promotion policy for the analysis.

RESULTS

Table 3. Results of Multiple Regression Analysis

Variables	Estimate	S.E.	t	p-value
GHG Emissions from Road Transportation Sector(ktCO2eq)	35576.360	6042.616	0.009	0.009
Cumulative Number of Electric Vehicle(Passenger car) (counts)	0.063	0.083	0.758	0.503
Cumulative Number of Hydrogen Vehicle(Passenger car) (counts)	0.016	0.034	0.469	0.670
Blending Ratio of Biodiesel (%)	34.241	2511.050	0.013	0.989
Extension of ITS(Intelligent Transport Systems) Infrastructure (km)	-2.341	0.999	-2.341	0.101
Extension of Bicycle Path (km)	1.490	0.705	2.113	0.124
Number of Eco-Driving Training participants (counts)	-2.149	0.463	-4.63	**0.018**
Public Transport Modal Share (%)	927.868	218.603	4.244	**0.023**

The results of the multiple regression analysis show that the adjusted R-squared is 0.99, indicating a strong model fit, and the significance F is less than 0.05, specifically 0.0012. This suggests that one or more of the reduction indicators significantly explain carbon emissions in the transportation sector.

Upon examining each variable, it was found that the number of eco-driving training participants and the modal share of public transportation, both with p-values below 0.05, have a significant impact on greenhouse gas emissions. Other data did not show a significant effect on greenhouse gas emissions in the transportation sector. Currently, the Korea Transportation Safety Authority provides comprehensive training on fuel-efficient driving techniques through experiential education, focusing on avoiding sudden acceleration and deceleration and maintaining a consistent speed. Therefore, as the number of eco-driving training participants increases, it is expected that more drivers will practice environmentally friendly driving habits, leading to a reduction in emissions. In fact, a study on the effects of eco-driving experiential education conducted by the Korea Transportation Safety Authority revealed an average fuel economy improvement of 17.44% compared to before the training, with average fuel consumption decreasing by 16.15% during driving. Consequently, the average CO2 emissions decreased from 591.12 gCO2 before the training to 495.64 gCO2 after the training, representing a 16.1% reduction.[7]

The modal share of public transportation refers to the proportion of trips made using modes other than passenger cars. Therefore, it can be interpreted that as the number of public transportation users increases, there will be an impact on carbon emissions. However, while the modal share of public transportation has a p-value below 0.05, indicating it is a statistically significant variable, the standard error is very large, suggesting it may not have meaningful explanatory power.

The variables used in the analysis were limited to the reduction indicators proposed by the government to assess the correlation with greenhouse gas emissions in the transportation sector. However, the proposed indicators are limited to some of the policies implemented by the government, including overlapping policies, and exclude

carbon emissions from unmentioned modes or individual travel. Therefore, it is difficult to interpret the derived coefficients as having a clear quantitative relationship with carbon emissions.

CONCLUSION

The analysis of the correlation between the reduction indicators of the road transportation sector and greenhouse gas emissions through Multiple Regression Analysis revealed that the number of eco-driving training participants and the modal share of public transportation have a significant impact on greenhouse gas emissions in the transportation sector. However, the current reduction indicators proposed by the government do not have a direct correlation with actual greenhouse gas reduction, making it challenging to use these indicators for performance monitoring. Therefore, there is a need to establish a system that can accurately diagnose the status of greenhouse gas reduction in the transportation sector, reflecting technological advancements and new mobility services in response to changing times. Consequently, this study proposes a system for collecting and monitoring transportation-related data in real-time to assess the progress toward achieving carbon reduction targets.

Greenhouse gas emissions and reduction activities must be evaluated in a Measurable, Reportable, and Verifiable manner. To achieve this, functionalities should be implemented to systematically support the reporting of reduction amounts, policy decisions, and compliance checks. Reflecting the policy decision needs of each stakeholder, we have categorized them into National, City, and Transport Company platforms (TMEP, Transportation Emissions Management Platform), as shown in Figure 1.

At the local government level, traffic data can be collected through the existing ITS (Intelligent Transport Systems) infrastructure. Through the Transport Company platform, real-time data on the driving distance, fuel efficiency, energy consumption, and charging status of vehicles operated by each company can be continuously collected. Additionally, personal mobility data collected from telecommunications, navigation, and vehicle manufacturers can be gathered through the institutional framework of the "My Data" service, which integrates dispersed data. The collected traffic data can be calibratedand linked to produce carbon emissions estimates based on total driving distance using a Tier 3 methodology. The emissions based on total driving distance for each local government enable near-real-time monitoring of greenhouse gas emissions that reflect actual conditions. This information is shared with the National TEMP, allowing the national government to support decision-making on the current status of carbon emissions in the transportation sector and how much progress is being made toward achieving the Nationally Determined Contributions (NDC), as well as what policies need to be implemented to achieve those targets.

By establishing such an MRV (Measurable, Reportable, Verifiable) system, policymakers can accurately diagnose and assess the status of greenhouse gas reduction efforts, thereby enhancing the effectiveness of policies and ultimately enabling efficient carbon emission reductions nationwide.

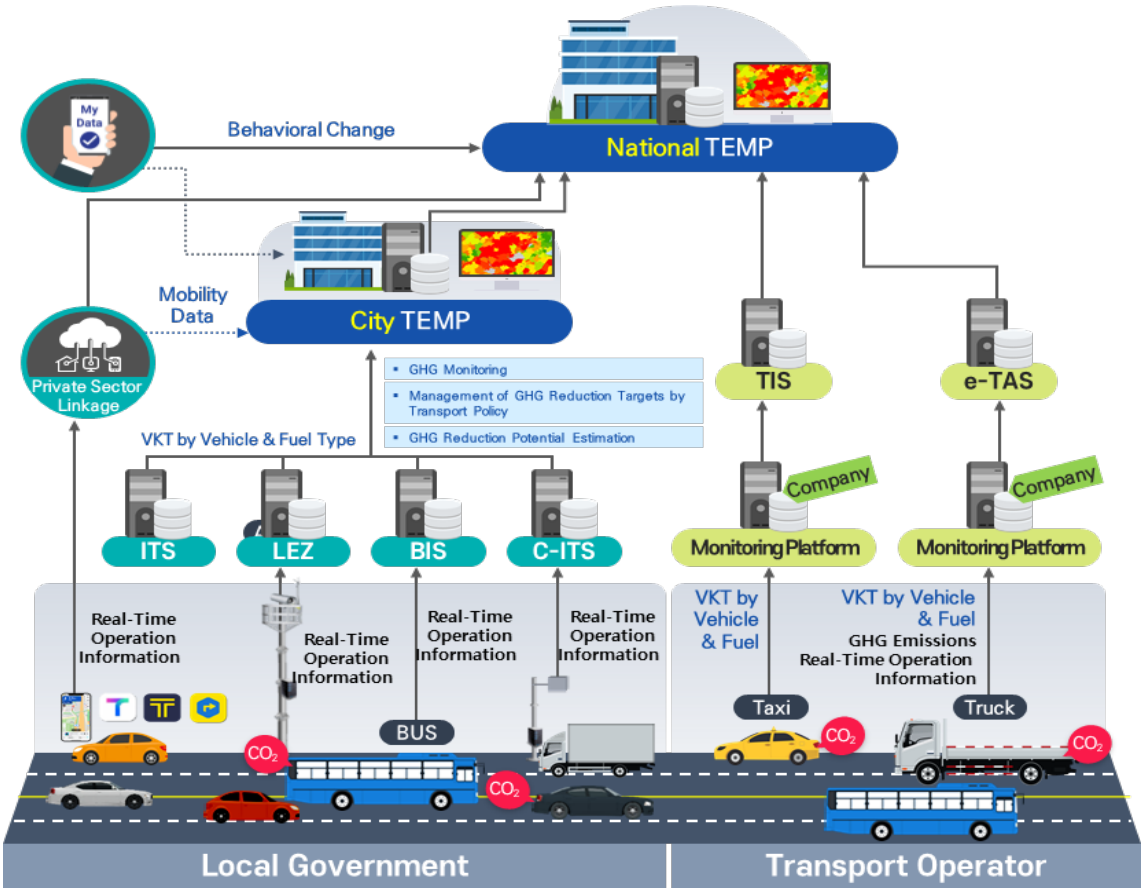


Figure1. Data Linkage System for Road Transport Sector

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ASSESSING THE OH-INITIATED BREAKDOWN CHEMISTRY OF CAMPHENE AND 3-CARENE UNDER NO_X-FREE SIMULATED ATMOSPHERIC CONDITIONS

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ABSTRACT

Camphene and 3-carene are key atmospheric monoterpenes used in cosmetics, fragrances, and food flavouring. In order to assess their impacts on human health and the environment it is essential to have a thorough understanding of the degradation mechanisms involved in their reactivity. The present study aimed to investigate the OH radicals initiated atmospheric degradation of camphene and 3-carene under simulated NO_x-free conditions. The experiments were conducted using facilities provided by the 760 L Environmental Simulation Chamber made of Quartz (ESC-Q-UAIC) together with state-of-the-art instruments, including a proton-transfer-reaction time-of-flight mass spectrometer (PTR-ToF-MS, model 6000 X2, IONICON) coupled with an aerosol chemical composition analyzer (CHARON). In the present study, the rate constants of the reactions of camphene and 3-carene with OH radicals were determined to be $(7.81 \pm 0.95) \times 10^{-11}$ cm^3 $molecule^{-1}$ s^{-1} and $(5.37 \pm 0.60) \times 10^{-11}$ cm^3 $molecule^{-1}$ s^{-1}, respectively. The obtained kinetic results, based on the relative rate technique with propene and 1,3,5-trimethylbenzene as reference compounds, are in agreement with the values reported in the literature. The measurements performed with the PTR-ToF-MS with CHARON particle inlet demonstrated that the photooxidation processes of camphene and 3-carene result in the formation of low-volatile species which play a significant role in the formation of secondary organic aerosols. Among the identified photooxidation products, camphenilone ($C_9H_{14}O$) and caronaldehyde ($C_{10}H_{16}O_2$) were assigned to the signals at the mass-to-charge ratio values of 139.112 Da and 169.122 Da, respectively, in both gas- and aerosol-phase measurements. The findings of this study will offer crucial insights to be incorporated into the Master Chemical Mechanism (MCM) for the detailed description of the gas-phase chemical processes involved in the tropospheric degradation of camphene and 3-carene, which are currently lacking.

Keywords: camphene, 3-carene, OH radicals, gas-phase reaction rate, gas-phase oxidation products, secondary organic aerosols, PTR-ToF-MS

INTRODUCTION

Camphene and 3-carene are among the most abundant monoterpenes released into the atmosphere [1]. They are widely used in cosmetics, fragrance production, and as food flavoring agents [2]. Given their unsaturated and highly reactive nature [3], it is of great importance to gain an understanding of the atmospheric degradation mechanism of these compounds in order to assess their impact on human and environmental health. Biogenic volatile organic compounds, such as camphene and 3-carene undergo reaction with atmospheric oxidants including hydroxyl (OH) and nitrate (NO_3) radicals, and ozone (O_3) molecules. This leads to the formation of various oxygenated compounds, contributing to the formation of secondary organic aerosols (SOAs) [4]. Comprehensive experimental characterization of their atmospheric reaction mechanisms is essential for generating critical data to parametrize atmospheric models that quantify their roles in the oxidative capacity and SOA formation [5]. Previous experimental studies on camphene and 3-carene have been focused on gas-phase reaction rates and product yields [3-5], including investigations into their gas-phase reactions with OH radicals and O_3. While SOA formation from monoterpene ozonolysis has been extensively documented [6], further research on OH radical oxidation, particularly for camphene and 3-carene, is required to gain a deeper understanding of their contributions to SOA production.

The present study aims to i) determine the gas-phase reaction rates of camphene and 3-carene with OH radicals, and ii) investigate gas-phase reaction products of camphene and 3-carene under NO_x-free conditions. Furthermore, this work provides, for the first time to the authors' knowledge, a detailed analysis of the time profile of potential photooxidation products in both the gas and aerosol phases under NO_x-free conditions.

MATERIALS AND METHODS

Experimental setup and relative kinetic method: Gas-phase reaction rates of camphene and 3-carene with OH radicals were determined employing the relative kinetic method and using the ESC-Q-UAIC chamber, a cylindrical photoreactor with a volume of 760 L and a length of 4.2 m. The chamber consists of three quartz tubes surrounded by 64 lamps, as described in detail elsewhere [7]. The decay of camphene, 3-carene, and reference compounds in the reactor vessel was monitored by IR spectroscopy using a Bruker Vertex 80 FTIR coupled to a White type mirrors system mounted inside the chamber, providing a total optical path of 492±1 m. The OH radicals were generated *in situ* by photolysis of hydrogen peroxide at 254 nm. 1,3,5-trimethylbenzene (TMB), with $k_{(TMB+OH)} = (5.86 \pm 0.88) \times 10^{-11}$ $cm^3 \times molecule^{-1} \times s^{-1}$, and propene ($C_3H_6$) with $k_{(C3H6+OH)} = (2.44 \pm 0.37) \times 10^{-11}$ $cm^3 \times molecule^{-1} \times s^{-1}$ were used as reference compounds in the kinetic experiments [8]. Gas-phase FTIR spectra of camphene, 3-carene, 1,3,5-trimethylbenzene, and propene were recorded at 298 K and 1000 mbar air pressure (**Figure 1**). Individual VOC spectral features were used to monitor the sink of the organic compounds: 882 cm^{-1} for camphene, 786 cm^{-1} for 3-carene, 991 cm^{-1} for propene, and 835 cm^{-1} for 1,3,5-trimethylbenzene.

The chemical reactions of the compounds inside the reaction vessel, along with their specific reaction rates, are described by reactions R1-R4:

$$\text{monoterpene} + OH \rightarrow \text{products} \quad k_1 \quad \text{(R1)}$$

$$\text{reference} + OH \rightarrow \text{products} \quad k_2 \quad \text{(R2)}$$

monoterpene (+wall, + hv) → products k_3 (R3)

reference (+wall, + hv) → products k_4 (R4)

Before the kinetic investigations, all the compounds were tested to check eventual losses due to wall deposition or photolysis processes. Control experiments showed that camphene, 3-carene, and 1,3,5-trimethylbenzene are also subject to losses in the absence of OH radicals, mainly due to wall interaction, with a minor contribution from photolysis at 254 nm. The following coefficients, including wall deposition and photolysis processes, have been cumulatively determined: $k_{3(camphene)} = (3.26 \pm 0.20) \times 10^{-5}$ s^{-1}, $k_{3(3\text{-carene})} = (4.54 \pm 0.25) \times 10^{-5}$ s^{-1}, $k_{4(TMB)} = (1.32 \pm 0.04) \times 10^{-4}$ s^{-1}.

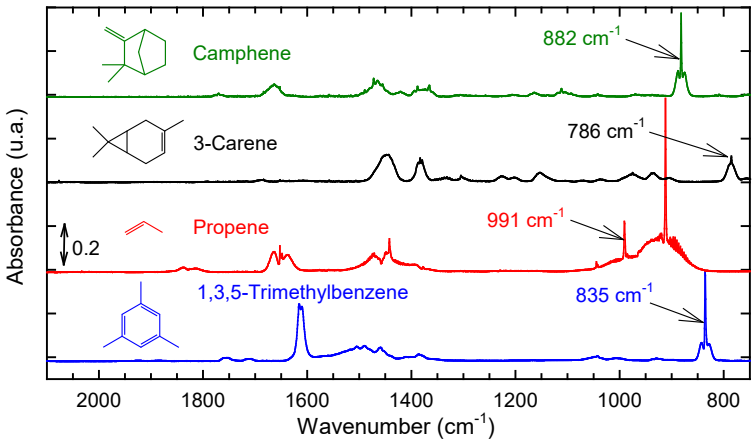


Figure 1. Gas-phase FTIR spectra of camphene, 3-carene, propene, and 1,3,5-trimethylbenzene recorded in the ESC-Q-UAIC chamber at 298 K and 1000 mbar air pressure.

By plotting the total decay over time for both reference compounds and monoterpenes, and by taking into account the above mentioned correction, the kinetic expression shown in Eq. (1) was used to ascertain the reaction rates of camphene and 3-carene:

$$\ln\left(\frac{[monoterpene]_{t_0}}{[monoterpene]_t}\right) - k_3(t - t_0) = \frac{k_1}{k_2}\ln\left(\frac{[reference]_{t_0}}{[reference]_t}\right) - k_4(t - t_0) \qquad (1)$$

where: $[monoterpene]_{t0}$ are the initial concentrations of camphene and 3-carene, $[reference]_{t0}$ are the initial concentrations of the reference compounds (propene and 1,3,5-trimethylbenzene) at t_0, $[monoterpene]_t$ and $[reference]_t$ are the concentrations of monoterpenes and reference compounds during the reaction time t, k_1 and k_2 are the gas-phase rate coefficients for the OH radical reactions with the monoterpenes and reference compounds, respectively, while k_3 and k_4 are the rate coefficients for wall deposition or photolysis losses for monoterpenes and TMB, respectively.

Proton-transfer-reaction time-of-flight mass spectrometry: Investigations on monoterpenes gas-phase and aerosol-phase reaction products under NO_x-free conditions in the ESC-Q-UAIC reactor were performed using a proton transfer reaction mass spectrometer (PTR-ToF-MS, Model 6000X2, IONICON) with a CHemical Analysis of aeRosolON-line (CHARON) particle inlet. The instrument was operated with H_3O^+ as primary ion, at a drift pressure of 2.79 mbar, drift voltage of 450 V, E/N of 116 Td, drift temperature of 100 °C, inlet temperature of 100 °C, and sample flow rate of 50 cm^3min^{-1}. The ioni TOF 4.2 software was used for instrument control and PTR-MS Viewer 3.4

software for data processing and analysis. The OH radicals were generated *in situ* by H_2O_2 photolysis at 254 nm to ensure a NO_x-free condition simulated atmospheric system.

Chemicals: Substances (purities, manufacturer) used in the present study were: camphene (98.3%, Sigma-Aldrich), 3-carene (99%, Sigma-Aldrich),1,3,5-trimethylbenzene (98%, Sigma-Aldrich), propene (99.5%, Sigma-Aldrich), hydrogen peroxide (35 %, Merck), and purified dry air (generated from a Kaiser-Zander compressor).

RESULTS

The results of the experimental investigation conducted in the absence of nitrogen oxides, on the gas-phase reactions of camphene and 3-carene with OH radicals are presented below. Section 1 outlines the findings from the relative rate method employed to determine the rate coefficient (k_1) of the interest monoterpenes. Section 2 discusses the results of gas- and aerosol-phase products formation from the OH-initiated oxidation of camphene and 3-carene under controlled NO_x-free conditions, using PTR-ToF-MS with a CHARON particle inlet.

1. Kinetic measurements on the gas-phase reactions of camphene and 3-carene with OH radicals

Figure 2 depicts the relative kinetic plot obtained through *in situ* FT-IR analysis for camphene (**Figure 2a**), 3-carene (**Figure 2b**), and the reference compounds in the presence of OH radicals. The ratio of k_1/k_2 was determined from linear regression analysis of the kinetic data points. **Figure 2** insertions present the measured relative decay of propene to TMB due to OH radicals-initiated reactions. The data correspond to a $k_{C3H6+OH}/k_{TMB+OH}$ ratio of (0.447 ± 0.049) and (0.450 ± 0.016) in the camphene and 3-carene experiments, respectively. The values are comparable with the literature-proposed ratio of (0.416± 0.088) [8]. The total conversion of monoterpenes during the course of the experiments was 44% for camphene and 65% for 3-carene. The total conversion of TMB varied between 42% and 46%, and for propene, between 25% and 31%.

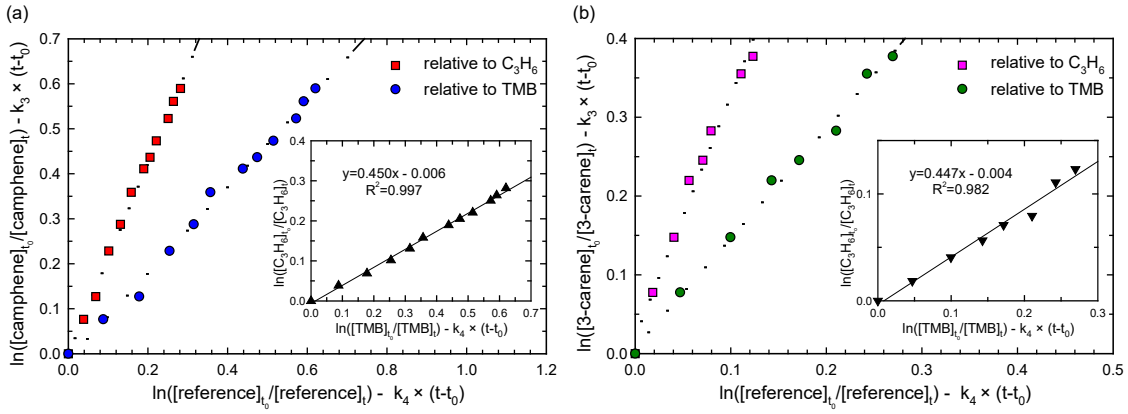


Figure 2. Kinetic data plotted according to Eq. (1) for the reaction of OH radicals with camphene (**a**), and 3-carene (**b**).

The experimental data obtained from this study are presented in **Table 1**. The k_1/k_2 ratios ($\pm 2\sigma_R$) and gas-phase rate coefficients (k_1) derived from each reference compound (i) are indicated.

Table 1: The gas-phase OH radicals kinetic results, reaction rate coefficients, and average atmospheric lifetimes for camphene and 3-carene obtained within the present study.

Monoterpene	Reference	$k_1/k_2 \pm 2\sigma_R$	$k_1 \pm \sigma_i$	$\bar{k}_1 \pm \bar{\sigma}$	k_1[a]	τ[b]
			(10^{-11}cm^3×molecule^{-1}×s^{-1})			(hour)
camphene	TMB	0.957±0.046	5.61±0.88	**5.37±0.60**	**5.19±1.14**	**4.6**
	C_3H_6	2.124±0.077	5.18±0.80			
3-carene	TMB	1.387±0.086	8.13±1.32	**7.81±0.95**	**8.45±1.27**	**3.1**
	C_3H_6	3.060±0.322	7.46±0.95			

[a][8];[b]$\tau = 1/([OH] \times \bar{k}_1)$

$$\overline{k_1} = \frac{\sum_1^i \left(k_{1,i} \times \left(\frac{1}{\sigma_i^2}\right)\right)}{\sum_1^i \left(\frac{1}{\sigma_i^2}\right)} \quad (2) \qquad \sigma_i = k_1 \sqrt{\left(\frac{2\sigma_R}{k_1/k_2}\right)^2 + \left(\frac{\sigma_{reference}}{k_2}\right)^2} \quad (3) \qquad \bar{\sigma} = \sqrt{\frac{1}{\sum_1^i \left(\frac{1}{\sigma_i^2}\right)}} \quad (4)$$

The average kinetic coefficients ($\bar{k}_1$) were calculated as the weighted average of the k_1 reaction rate coefficients according to the formula given in Eq. (2). The uncertainties associated with these values were derived from the equations given in Eq. (3) and Eq. (4). The resulting values are presented in **Table 1**. Additionally, the rate coefficients at 298 K for the interest monoterpenes, as available from the EUROCHAMP kinetic database [8], are presented in **Table 1**. On the assumption that the 24 h average concentration of OH radicals in the atmosphere is 1.13 × 10^6 cm^{-3} [9], the average tropospheric lifetimes for camphene and 3-carene were calculated (**Table 1**).

2. Investigation of the products from the gas-phase OH-initiated oxidation of camphene and 3-carene

The time variation of camphene, 3-carene, and oxidation products measured by PTR-ToF-MS during experiments conducted with OH radicals under NO_x-free simulated conditions are presented in **Figures 3** and **4**. The origins of the coordinate systems in **Figures 3** and **4** indicate the start of the reaction. The value of 95.086 m/z was selected to represent the camphene and 3-carene signals, thus avoiding the contributions from newly formed products.

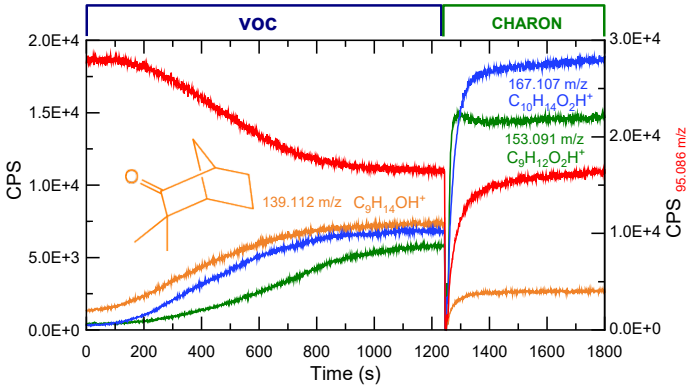


Figure 3. The time profiles of camphene (95.086 m/z) and interest oxidation products (139.112 m/z, 153.091 m/z, and 167.107 m/z), in both gas and aerosol phases, measured by PTR-ToF-MS during the experiment performed with OH radical under NO_x-free conditions.

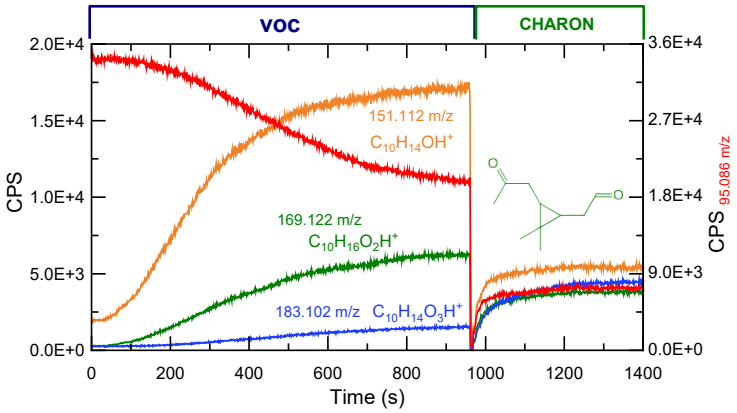


Figure 4. The time variation of 3-carene (95.086 m/z) and interest oxidation products(151.112 m/z, 169.122 m/z, and 183.102 m/z), in both gas and aerosol phases, measured by PTR-ToF-MS during the experiment performed with OH radical under NO_x-free conditions.

DISCUSSION

The experimentally determined OH reaction rate coefficients of camphene and 3-carene were found to be $k_{camphene+OH}$ = (5.37±0.60) 10^{-11} $cm^3 \times molecule^{-1} \times s^{-1}$ and $k_{3\text{-}carene+OH}$ = (7.81±0.95) 10^{-11} $cm^3 \times molecule^{-1} \times s^{-1}$. Based on the 24-hour average tropospheric concentration of OH radicals of 1.13 × 10^6 $radicals \times cm^{-3}$ [9], the average lifetimes of camphene and 3-carene were estimated to be 4.6 and 3.1 hours, respectively. These lifetimes are expected to decrease significantly when reactions with O_3 and NO_3 radicals take place. A comparison of these experimental kinetic results with the available literature reveals good agreement with the reported values of (5.19±1.14) × 10^{-11} $cm^3 \times molecule^{-1} \times s^{-1}$ for camphene and (8.45 ±1.27) × 10^{-11} $cm^3 \times molecule^{-1} \times s^{-1}$ for 3-carene [8].

The distributions presented in **Figure 3** show that once the OH radical is formed this leads to a rapid decay of the camphene signal (95.086 m/z). This decay is accompanied by an increase in the intensity of the signals corresponding to the oxidation products $C_9H_{14}O$ (m/z 139.112), $C_9H_{12}O_2$ (m/z 153.091), and $C_{10}H_{14}O_2$ (m/z 167.107). The time profiles of these oxidation products in the aerosol phase reveal that different amounts are partitioned into the aerosol phase. The behavior of the 3-carene oxidation products in the gas phase (**Figure 4)** shows the largest increase for the 151.112 m/z ($C_{10}H_{14}OH^+$) signal, followed by smaller increases for the 169.122 m/z ($C_{10}H_{16}O_2H^+$) and 183.102 m/z ($C_{10}H_{14}O_3H^+$) signals. In the aerosol phase, the signal intensities of the selected oxidation products were found to be comparable. These findings suggest that the predominant reaction pathway favours the formation of the $C_{10}H_{14}O$ oxidation product in the gas phase. Investigation with the CHARON particle inlet coupled to PTR-ToF-MS enabled the identification of camphenilone ($C_9H_{14}O$) and caronaldehyde ($C_{10}H_{16}O_2$), key oxidation products of camphene [5], and 3-carene [3], corresponding to the 139.112 m/z and 169.122 m/z signals, respectively. It is noteworthy that these products were detected in both the gas and aerosol phases, which serves to emphasize their partitioning between the two phases during the oxidation process.

CONCLUSION

This study presents the findings of an investigation into the OH radical-initiated oxidation of camphene and 3-carene, conducted under controlled NO_x-free atmospheric conditions. The experiments yielded substantial insights into the gas-phase reaction rates of OH radicals and the products formed in the gas and aerosol phases when camphene and 3-carene are involved. The kinetic data derived from the relative rate method, $k_{camphene+OH}$ = (5.37±0.60) 10^{-11} $cm^3 \times molecule^{-1} \times s^{-1}$ and $k_{3\text{-}carene+OH}$ = (7.81±0.95) 10^{-11} $cm^3 \times molecule^{-1} \times s^{-1}$, using 1,3,5-trimethylbenzene and propene as reference compounds show good agreement with previous research. Distinct time profile contributions of camphene and 3-carene photooxidation products were observed in gas and aerosol phases, highlighting their specific roles in SOA formation. Among the assigned photooxidation products, camphenilone ($C_9H_{14}O$) and caronaldehyde ($C_{10}H_{16}O_2$), which are key oxidation products, were observed in both the gas and aerosol phases. Further research is planned to identify additional oxidation products of camphene and 3-carene, which could provide important data to be considered in the Master Chemical Mechanism (MCM), currently unavailable for the investigated monoterpenes. These findings will enhance the understanding of the gas-phase chemical processes involved in the tropospheric degradation of camphene and 3-carene, especially in remote areas governed by the OH-initiated processes.

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ASSESSMENT OF HEAVY METAL CONTAMINATION IN URBAN SNOW: A CASE STUDY OF NICKEL AND COPPER IN JELGAVA, LATVIA

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ABSTRACT

Snow water pollution, especially from heavy metals, is a growing global environmental concern, as urbanization and industrial activities increasingly contribute to the contamination of precipitation. Snow, acting as a natural filter, accumulates atmospheric pollutants, which are subsequently released during snowmelt, entering stormwater systems and surface water bodies. This issue has been observed across Europe, North America, and other industrialized regions, where heavy metals such as nickel (Ni) and copper (Cu) are prevalent contaminants. In Latvia, studies on snow pollution remain limited, making it crucial to understand how urbanization impacts snow water quality, particularly in cities like Jelgava. This study, conducted during the winters of 2023 and 2024, focuses on the accumulation of heavy metals in snow samples from Jelgava city. A total of 177 snow samples were collected each year from various urban locations, alongside 3 samples from outside the city as controls. The aim is to identify areas with the highest pollution levels and assess their potential contribution to stormwater pollution. The results revealed that nickel concentrations in the urban snow samples had an average of 0.124 mg/L, with values ranging from 0.033 mg/L to a maximum of 0.393 mg/L. Copper concentrations, however, showed greater variability, with an average of 0.906 mg/L, a minimum of 0.000 mg/L, and a maximum of 4.427 mg/L. Pollution areas were identified using Arc GIS and using the IDW method. These findings indicate that urban snowmelt in Jelgava could be a significant source of heavy metal pollution, particularly copper, to the city's drainage systems and natural water bodies.

Keywords: Waste burning, metal industry, pollution accumulation, food chains, toxicity

INTRODUCTION

Heavy metals such as nickel (Ni) and copper (Cu) are common pollutants in urban environments, primarily caused by anthropogenic activities [1]. However, the natural process of precipitation—rain and snow—plays a crucial role in the transport and redistribution of these heavy metals in urban areas [2]. Snow, in particular, acts as a temporary reservoir for atmospheric pollutants, including metal particles. These metals are accumulated in snow during winter and are then released into urban stormwater systems during snowmelt, significantly increasing the pollution of water bodies. Similarly, nickel and copper particles are washed from urban surfaces by precipitation, delivering them to drainage systems and natural water bodies [2], [3]. Nickel pollution in urban environments is associated mainly with industrial emissions, particularly from

metal processing and fossil fuel combustion [4]. Elevated nickel levels in urban areas are also contributed by vehicle emissions and brake wear. When nickel particles enter the atmosphere, they are deposited onto surfaces such as roads, buildings, and soil, where they accumulate and can be remobilized by precipitation [5]. Copper is widely used in urban infrastructure, including electrical wiring and roofing materials. The presence of copper in urban environments is contributed by the corrosion of copper-based infrastructure, industrial discharges (such as from factories or power plants), and traffic-related sources (e.g., brake pads from vehicles) [6]. These metals pose significant environmental and public health risks due to their persistence in the environment and toxic effects. Nickel can harm aquatic organisms, affecting fish growth, reproduction, and survival when it accumulates in water bodies [7], [4]. Copper is an essential micronutrient for humans and other organisms; however, excessive exposure can lead to toxicity [7]. In humans, high levels of copper can cause gastrointestinal disturbances, liver damage, and, in severe cases, kidney failure. In the environment, copper is particularly toxic to aquatic organisms [4]. Elevated copper concentrations in water bodies can impair the function of fish gill tissues, leading to respiratory distress and, in extreme cases, death. Prolonged accumulation of copper in soils can also inhibit plant growth and reduce soil microbial diversity. In recent years, increased research has been conducted on the distribution of nickel and copper in urban areas, particularly regarding their presence in snow and rainwater, which act as carriers of these pollutants into urban water systems [8], [5]; [6].

The aim is to identify areas with the highest pollution levels and assess their potential contribution to stormwater pollution.

MATERIALS AND METHODS

The study was conducted in Jelgava, a city located in the Zemgale Plain in central Latvia. Jelgava is an important transportation corridor between various cities and the national capital, Riga. With a total area of 60.3 km², Jelgava is the fourth largest city in Latvia by population. According to data from the official statistics portal, from the beginning of 2017 to the start of 2023, the population of Jelgava has fluctuated from 56,026 to 54,836 and decreased yearly [9]. The city is home to 106 industrial enterprises that have declared emissions to the State Environmental Service. Snow samples were collected on January 9, 2023. The average air temperature on the sampling day was -2.48 °C, the average snow cover was 4 cm, and the amount of precipitation on the sampling day was 0 mm. Snow samples were collected after a 6-day exposure period. On January 10, 2024, snow samples were also collected after a 6-day exposure period; the average air temperature on the sampling day was 1.7 °C, the average snow cover was 2.61 cm, and the amount of precipitation on the sampling day was 0 mm. Meteorological data were obtained from the station “Jelgava,” coordinates: 56° 33′ 24.954″ N, 23° 57′ 50.679″ E [10]. Snow samples were collected from 59 monitoring points distributed throughout the city of Jelgava. Additionally, a control sampling area was established outside the city to provide comparative possibilities. This control area, free from the direct influence of urban activities, allows for a comparison of the levels of heavy metals in urban and non-urban environments. At each monitoring point, three snow samples were taken, with sampling occurring approximately 5 meters from roadways or sidewalks. The territory of the city of Jelgava is divided into various functional zones: detached housing areas, multi-story residential areas, public building areas, mixed central building areas, industrial building areas, and transportation infrastructure areas; therefore, to ensure that the collected snow

data were representative, snow sampling plots were placed to cover all functional zones. The collected snow samples were transported to the laboratory, where they were thawed at room temperature and analyzed according to the methodology described in the article by Grinfelde et al. (2021) [12].

RESULTS

Ni Concentrations

In 2023, the concentrations of nickel in snow samples collected across various monitoring points in Jelgava revealed considerable variability. Minimum concentrations recorded were as low as 0.0457 µg/L, while maximum concentrations reached up to 1.35 µg/L, highlighting significant discrepancies in Ni deposition across the city (see Figure 1).

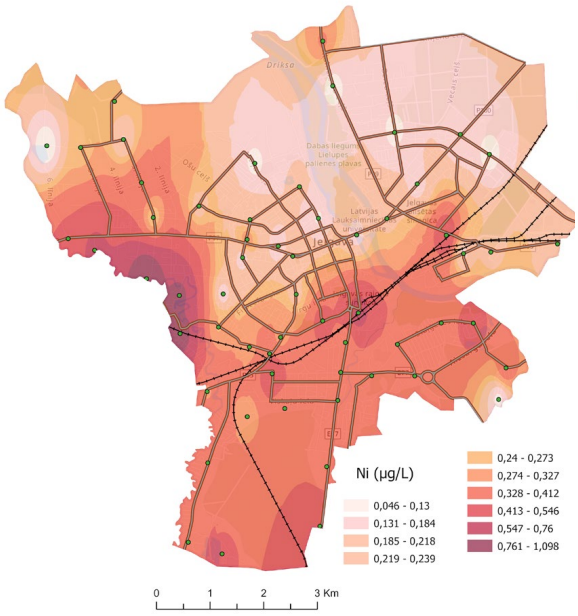


Figure 1. The distribution of nickel (Ni) in snow samples in Jelgava at the year 2023.

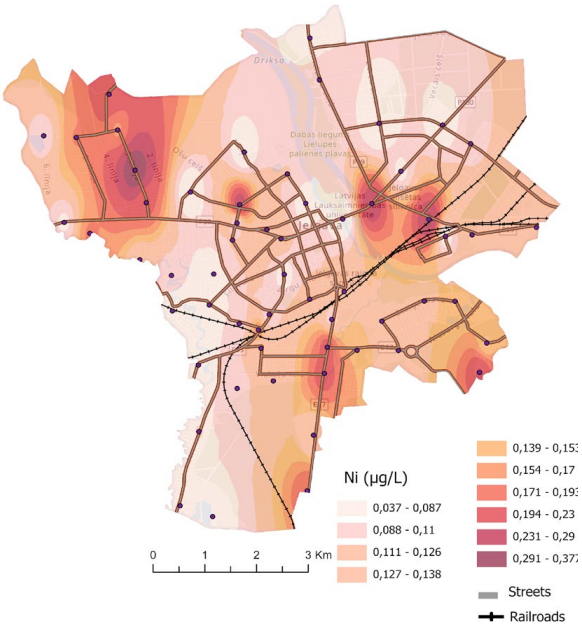


Figure 2. The distribution of nickel (Ni) in snow samples in Jelgava at the year 2024.

The range values further emphasized this variation, which spanned from a modest 0.033 µg/L to an extensive 1.24 µg/L, suggesting highly heterogeneous Ni accumulation patterns influenced by specific sources or environmental factors. Analyzing the quartile data provides additional insight into the distribution of Ni concentrations. The first quartile values ranged from 0.078 to 0.543 µg/L, indicating that 25% of concentration values fell below these thresholds across different monitoring points. The third quartile values extended up to 0.726 µg/L, illustrating a wide interquartile range. This spread implies a skewed distribution of Ni concentration data, with some areas experiencing notably higher deposition than others. The median Ni concentrations for several sites appeared lower than their respective means, underscoring the positively skewed nature of the distribution, as the higher concentrations in certain areas increased the average values. The standard deviation data supported these observations of variability, with values reaching up to 0.58 µg/L. This substantial standard deviation points to the diversity of Ni levels across Jelgava, likely reflecting localized pollution sources, variable meteorological conditions, or specific urban activities contributing to increased Ni accumulation in specific areas. Overall, the findings from 2023 depict a complex and

highly variable pattern of Ni concentrations in Jelgava's snow samples, suggesting the influence of numerous factors impacting the deposition and spatial distribution of nickel within the urban environment. In contrast to the patterns observed in 2023, the data from 2024 show a trend toward lower variability and more uniform nickel concentrations in Jelgava's snow samples. Minimum recorded concentrations in 2024 began at approximately 0.033 µg/L, with maximum levels reaching around 0.392 µg/L (see Figure 2). This reduction in maximum concentrations suggests a decline in extreme Ni deposition events compared to the previous year. The range of values, too, was smaller in 2024, with the highest range not exceeding 0.2 µg/L, indicating a narrower spread in concentrations across different monitoring sites. An examination of the quartile values further supports this trend. The first and third quartiles were closer together in 2024, averaging between 0.115 and 0.136 µg/L. This more compact interquartile range points to a reduced overall spread in the data, suggesting fewer instances of high-concentration outliers that were notable in 2023. Additionally, the alignment of the median concentration (0.120 µg/L) with the mean (0.124 µg/L) reflects a more symmetric distribution, indicating that Ni deposition across monitoring sites in 2024 was generally balanced without substantial skew. Standard deviation values in 2024 also revealed decreased variability, with the average standard deviation around 0.013 µg/L, which highlights the more consistent levels of Ni across Jelgava's snow samples. These observations collectively suggest that the factors influencing nickel deposition in 2024 led to a more even distribution across the city. Possible explanations could include changes in atmospheric conditions, shifts in local emission sources, or enhanced environmental management efforts. Overall, the data from 2024 depict a less variable and more uniformly distributed pattern of nickel accumulation, contrasting sharply with the previous year's observations and indicating evolving dynamics in urban Ni deposition in Jelgava.

Cu concentrations

In 2023, copper concentrations in Jelgava's snow samples exhibited substantial variability across different monitoring points. Minimum concentrations recorded were as low as 0.283 µg/L, while maximum concentrations reached up to 4.81 µg/L, underscoring a significant spread in Cu levels within the urban environment (see Figure 3). The range of values for copper concentrations extended up to 4.33 µg/L, revealing pronounced variation likely influenced by localized sources or environmental deposition dynamics. Analysis of quartile values provides additional insight into the concentration distribution. The first quartile ranged from approximately 0.55 to 1.57 µg/L across monitoring points, indicating that the lower 25% of Cu values in the dataset were fairly dispersed. The third quartile reached values up to 3.73 µg/L, displaying a wide interquartile range and a distribution with high variability. The median Cu concentration at most points was lower than the mean, suggesting a positively skewed distribution, where outliers or areas with elevated concentrations influenced the average. The standard deviation data, which ranged up to 1.77 µg/L, reinforces this variability, indicating diverse levels of Cu deposition across Jelgava. Such variability may reflect localized sources, specific industrial or traffic-related emissions, or differing environmental conditions affecting the accumulation of copper in snow. These findings depict a complex, non-uniform pattern of Cu concentrations in 2023, suggesting that multiple factors contribute to the spatial distribution of copper within the city. In 2024, Cu concentrations in snow showed more consistent distribution patterns with decreased variability compared to 2023. Minimum recorded concentrations began at 0.29 µg/L, with maximum concentrations peaking at

approximately 1.8 µg/L, indicating a reduction in extreme Cu levels across Jelgava's monitoring points (see Figure 4).

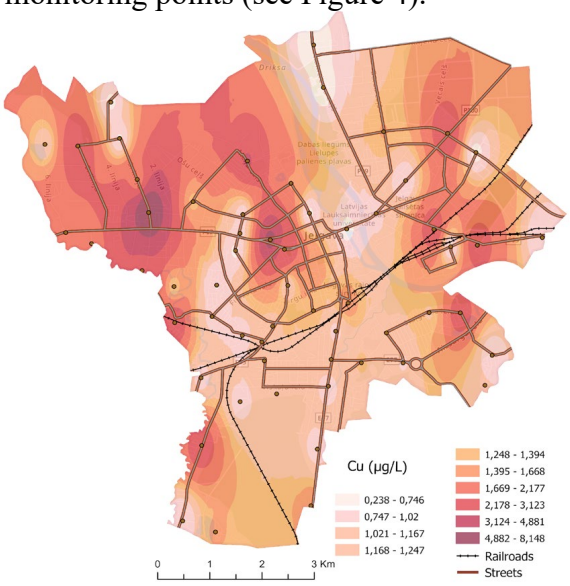


Figure 3. The distribution of copper (Cu) in snow samples in Jelgava at the year 2023.

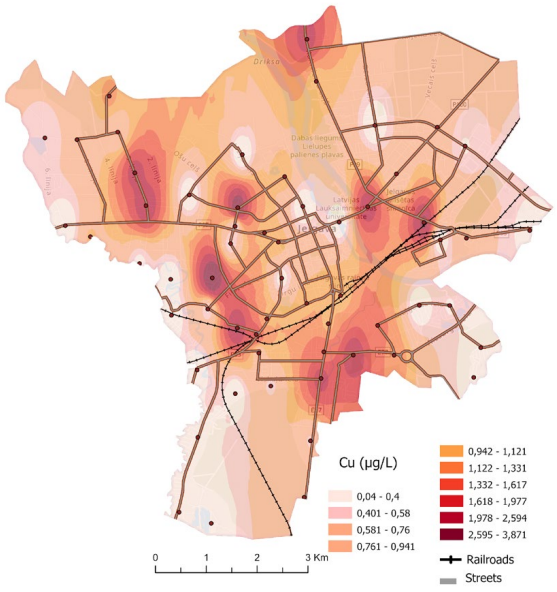


Figure 4. The distribution of copper (Cu) in snow samples in Jelgava at the year 2024.

The overall range of Cu values was smaller, typically remaining under 1.5 µg/L, which points to a more uniform concentration pattern. The quartile analysis for 2024 further supports this trend. Both the first and third quartile values were closely aligned, suggesting that Cu concentrations were more balanced across different monitoring sites, with fewer instances of extreme values. The median concentration values were close to the mean, indicating a symmetric distribution contrasting with the skewed distribution observed in 2023. This alignment suggests that Cu deposition was more homogenous across the city, without significant outliers. Standard deviation values for 2024 were lower, averaging around 0.5 µg/L, confirming that Cu levels were more stable across Jelgava's monitoring points. These findings imply that the sources or conditions influencing Cu deposition may have shifted between 2023 and 2024, resulting in a more even spread of concentrations. This trend may be attributable to reduced emissions or environmental changes that impacted the deposition of copper across Jelgava's urban landscape.

DISCUSSION

Studies conducted in Europe have shown that snow and rainwater in urban areas often contain elevated levels of nickel and copper, especially in regions near industrial sites and high-traffic areas. For example, in a study conducted in Białystok, Poland, nickel and copper concentrations in snow samples were found to be significantly higher in industrial and high-traffic areas compared to residential zones. Concentrations of heavy metals in snowmelt water were observed to be much higher than those in rainwater [1]. Similar findings have been reported in cities like Helsinki, where copper concentrations in urban snow have been associated with road traffic and building materials [13]. These studies highlight the role of precipitation in the redistribution of heavy metals in urban

environments and emphasize the importance of monitoring snowmelt and stormwater in pollution control.

The analysis of nickel (Ni) and copper (Cu) concentrations in urban snow in Jelgava over the years 2023 and 2024 reveals significant insights into the spatial and temporal distribution of these heavy metals. The data indicate that Cu concentrations consistently exceeded those of Ni across various monitoring sites in both years. This observation aligns with findings from urban environments where Cu pollution is often linked to localized sources such as vehicular wear and industrial activities, particularly those associated with traffic, including brake and tire wear [14], [4]. The higher concentrations of Cu in urban settings can be attributed to the direct impact of urbanization and industrialization, which are known to elevate heavy metal levels in the environment [4], [3]. In contrast, Ni concentrations, while variable, were generally lower than those of Cu. This disparity may be due to the more diffuse nature of Ni emissions, typically associated with fossil fuel combustion and minor industrial emissions rather than localized urban activities [15]. The variability observed in 2023, particularly the high maximum values of Cu, suggests that emissions in Jelgava may have been influenced by specific meteorological conditions or episodic pollution events, which can significantly affect the deposition of atmospheric pollutants [16]. Factors such as precipitation patterns, wind direction, and snowfall rates are critical in determining how pollutants accumulate in urban snow, as they influence the transport and deposition processes of heavy metals. By 2024, the data indicate a shift towards more uniform distributions of both metals, with reduced ranges and lower maximum concentrations. This change could reflect improvements in emission control measures, more stable atmospheric conditions, or effective urban environmental management strategies. The closer alignment of mean and median values for both Ni and Cu in 2024 suggests a reduction in extreme concentration values, indicating a more balanced deposition across monitoring points. Such consistency may point to stabilizing emission sources or enhanced pollution control efforts within Jelgava or its surrounding areas [17]. The pronounced differences in the range, maximum values, and standard deviation between Ni and Cu highlight the influence of local sources on metal deposition patterns. The higher variability and concentration range of Cu suggest that it is more sensitive to urban activities. At the same time, Ni, although influenced by local sources, likely results from smaller, dispersed emissions across multiple sources [4]. This distinction underscores the necessity of tailored pollution control strategies for each metal, considering their differing sources and behaviors in urban environments [18]. The observed trends from 2023 to 2024 indicate a potential positive trajectory towards reduced heavy metal pollution in Jelgava. If these shifts are indicative of successful pollution management efforts, they could signify progress in mitigating urban pollution. Conversely, if external factors such as weather were the primary drivers of these changes, it would emphasize the need for ongoing monitoring and mitigation strategies to ensure consistent reductions in heavy metal concentrations [19], [20]. Future research should aim to expand on these findings by incorporating detailed source apportionment studies, seasonal data, and weather factors to understand better the dynamics driving heavy metal deposition in urban areas like Jelgava.

CONCLUSION

The analysis shows that copper concentrations were generally higher than nickel concentrations in both 2023 and 2024, suggesting that local sources, likely related to

traffic wear and industrial activities, contribute more significantly to Cu pollution in Jelgava. In 2023, both Ni and Cu exhibited greater variability, with larger ranges and higher standard deviations, indicating uneven distribution across monitoring sites. This variability suggests that localized emissions or specific environmental conditions were likely more pronounced that year. By 2024, both metals displayed lower maximum concentrations and a smaller overall range, indicating a potential reduction in extreme Ni and Cu levels. This trend may reflect improved pollution control efforts, decreased emissions, or more stable atmospheric conditions. In 2024, Ni and Cu showed closer alignment between their quartile values and similar mean and median concentrations, suggesting a decrease in extreme values and a more consistent deposition pattern citywide. The broader concentration range and higher quartile values of Cu, especially in 2023, imply that copper is more heavily influenced by localized urban sources, such as vehicular wear and industrial emissions, where Ni concentrations may originate from smaller, more diffuse sources.

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CHANGE OF THE GROWING SEASON IN THE CONTEXT OF CLIMATE CHANGE IN SLOVAKIA

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ABSTRACT

Climate change significantly affects agriculture in Slovakia by altering precipitation patterns, temperatures, and the length of the growing season. Common effects include drought, more intense rainfall, higher summer temperatures, and increased pest populations, all of which influence crop production and livestock breeding. Human activities have already impacted atmospheric properties such as temperature, precipitation, CO2 levels, and ground-level ozone, and this trend is expected to continue. While warmer climates may benefit some crops, the increased frequency of droughts, floods, and heatwaves will challenge growers. In some regions, climate change may make crop cultivation unfeasible.

Farmers in Slovakia must adapt to these changes to mitigate negative economic impacts. Adaptation strategies include using climate-resilient crop varieties, improving soil and water management, and adopting innovative agricultural technologies. Expanding crop cultivation into higher elevations is possible but depends on soil suitability. However, the risk of late frosts is a concern, as an extended growing season could lead to early blooming, followed by frost damage.

Recognizing and addressing climate change's impact on agriculture is essential for ensuring sustainable production, supporting resilience, and reducing environmental harm.

Keywords: climate change, growing season, agriculture

INTRODUCTION

Phenophases are phases in the life of plants related to growth, flowering, and fruit production. Changes in these phenophases can be significant indicators of climate change. The impact of climate change on plant phenophases manifests as temperatures and climates change, affecting the biological processes of plants. Research shows that due to climate change, phenophases in many plants are occurring earlier, meaning plants are blooming and producing fruit earlier than in the past. These changes can affect ecosystem function because many plant and animal species are interdependent on the phenophases that typically follow. [1]

The impact of climate change on plant phenophases also extends to agriculture. Early plant phenophases can influence the timing of planting and harvesting, which can impact overall crop production. Additionally, plants flowering earlier may be susceptible to frost damage if temperatures drop significantly later in the season. Overall, changes in plant phenophases are one manifestation of climate change. The impact of these changes on ecosystems and agriculture can be significant and can have implications for society. Therefore, it is important to monitor and study changes in plant phenophases and take measures to adapt to these changes. [2]

In agriculture, projected climate changes will affect crop yields, livestock breeding, and production locations. The distribution of production areas may shift to more northern regions where agricultural production has not been as intensive historically. Due to the increasing probability and intensity of extreme weather fluctuations, the risk of crop failure will increase. The consequences of climate change will also affect the soil, leading to a reduction in organic matter content, which is a decisive factor in soil fertility. In the case of forests, climate change effects are likely to include changes in forest health and productivity, as well as changes in the geographic distribution of certain tree species. [3]

MATERIALS AND METHODS

Meteorological data for addressing the task (values of average monthly temperatures) for the reference time series from 1961 to 2020 were provided by the Slovak Hydrometeorological Institute in Bratislava. Onset (in spring) and end (in autumn) of the growing season are being analyzed:

• Large growing season, delimited by the onset and end of days with an average daily temperature $T \geq 5.0$ °C,

• Main growing season, delimited by the onset and end of days with an average daily temperature $T \geq 10.0$ °C.

For basic analyses of vegetation belts in Slovakia, 100 stations across the entire territory of Slovakia will be selected (see Figure 1).

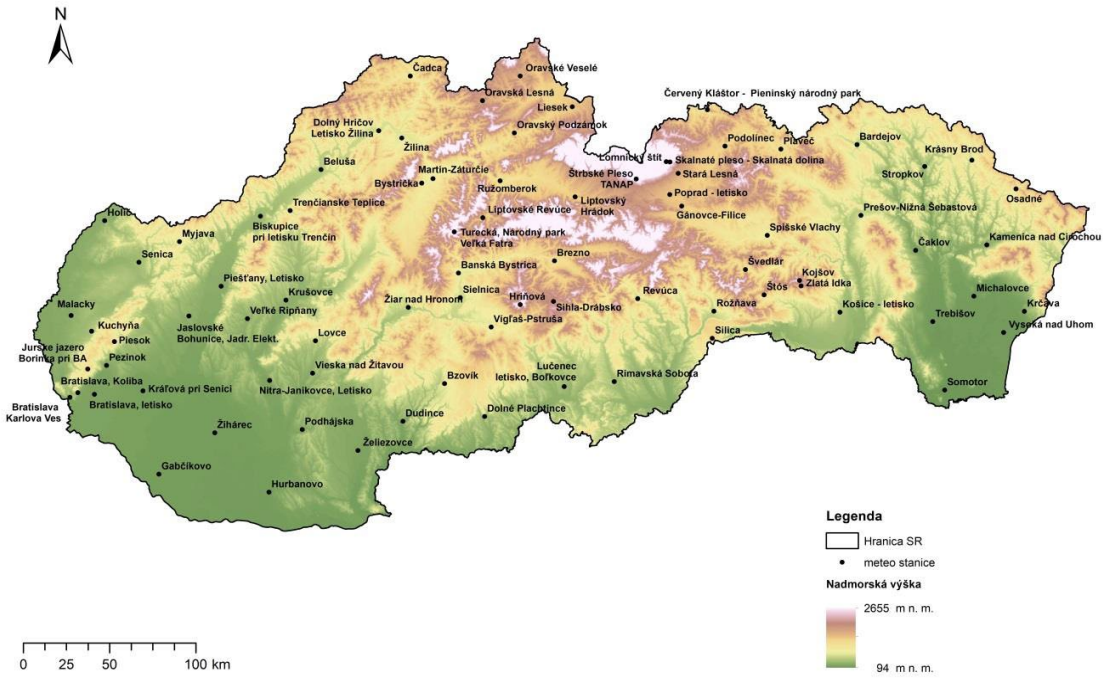


Figure 1: Network of meteorological stations provided by the Slovak Hydrometeorological Institute

The change in analyzed growing seasons (large growing season, main growing season) will be determined by calculating the onset and end of the growing season (according to equations (1), (2)) and will be analyzed from the average daily temperature for the years

1961-2020, followed by forecasts for the decades 2011-2020, 2041-2050, 2071-80, and 2091-2100 in the form of map outputs.

The onset and end of defined temperatures will be determined according to equations (1) and (2).

Onset of temperatures: $$r_v = R\frac{T_n - T_2}{T_1 - T_2}, \quad \text{(days)} \quad (1)$$

Ending temperatures: $$r_p = R\frac{T_1 - T_u}{T_1 - T_2}, \quad \text{(days)} \quad (2)$$

where:

T_n - onset temperature in °C,

T_u - termination temperature in °C,

T_1 - the nearest average monthly temperature above the starting or ending temperature in °C,

T_2 - the nearest average monthly temperature below the starting or ending temperature in °C,

R - the difference in days between the middle of months with an average temperature and an average temperature, can be expressed as an average number,

r_v - the difference in days between the middle of the month with the temperature and the date of onset of the temperature,

r_p - the difference in days between the middle of the month with the temperature and the end date of the temperature.

For the processing of map outputs, we chose the ArcGIS pro software from ESRI. This modular software is ideal for collecting, analyzing, and visualizing geographic information. [9]

The processing of map outputs was preceded by the preparation of input data. Each meteorological station had its position defined in XYZ coordinates. When loading into the ArcGis environment, the coordinates were transformed so that the resulting point vector model (*.shp) was placed in the S-JTSK coordinate system. This is how we obtained the exact location of meteorological stations in Slovakia.

When we obtained the location of these stations, it was necessary to assign to them the calculated lengths of the vegetation periods in the individual decades under investigation. We prepared the data on the lengths of the growing seasons in the MS Excel environment and then assigned them to the individual meteorological stations according to the serial number.

Since the location of meteorological stations mostly forms an irregular network, it was necessary to find out data for the entire territory of Slovakia. Because of this, we proceeded to interpolation. To interpolate unknown values, we used the Topo to Raster interpolation method. This method is based on ANUDEM version 4.6.3. This interpolation method combines IDW, Kriging and Spline interpolation methods. By

interpolation, we obtained data for the entire territory of Slovakia and for each examined decade. [10]

Subsequently, according to the histogram for each period, we reclassified the individual categories of the length of the growing seasons. From the values reclassified in this way, we obtained the differences in the lengths of the growing seasons.

Since the goal was to find out the differences in the lengths of the growing seasons in the individual investigated decades on the agricultural land, it was necessary to eliminate from the obtained data positions that would negatively distort the resulting values. Therefore, we used a digital relief model to delineate the areas whose altitude was higher than 800 meters above sea level. Subsequently, these areas were not even included in the calculations and form empty areas in the resulting map outputs.

When we had all the data processed into a graphic form, we used the print view to assign a scale, northing and a legend to the maps, where the individual categories shown in the maps are defined. We exported the resulting map assembly to JPEG format.

The resulting map set shows the changes in the length of the growing seasons in Slovakia for the horizons of 2041 – 2050, 2071 – 2080 and 2091 – 2100.

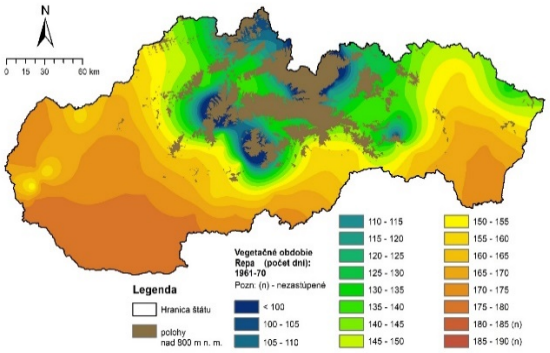


Fig. 1: Vegetation period delimited by the onset and termination days with an average daily temperature (3,0 – 7,5 °C) for the years 1961 - 1970

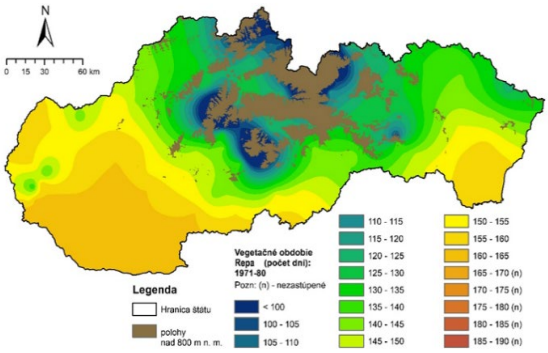


Fig. 2: Vegetation period delimited by the onset and termination days with an average daily temperature (3,0 – 7,5 °C) for the years 1971 - 1980

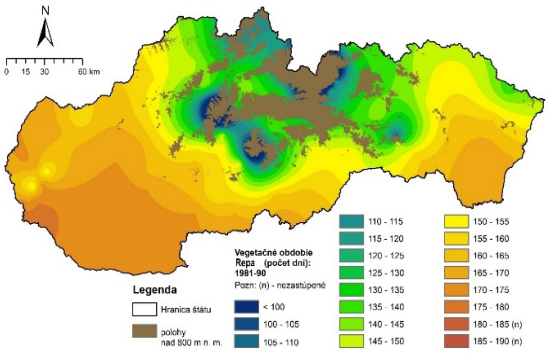


Fig. 3: Vegetation period delimited by the onset and termination days with an average daily temperature (3,0 – 7,5 °C) for the years 1981 - 1990

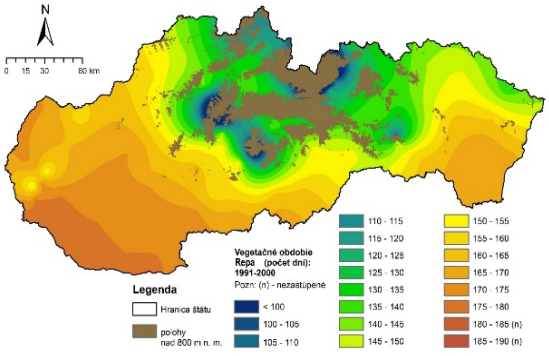


Fig. 4: Vegetation period delimited by the onset and termination days with an average daily temperature (3,0 – 7,5 °C) for the years 1991 - 2000

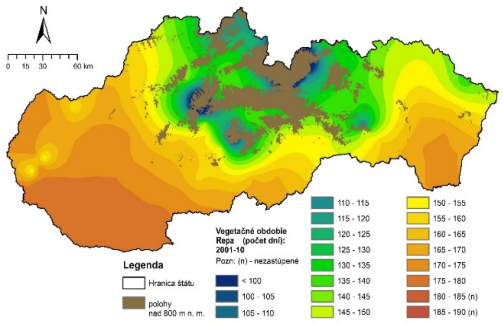


Fig. 5: Vegetation period delimited by the onset and termination days with an average daily temperature (3,0 – 7,5 °C) for the years 2001 - 2010

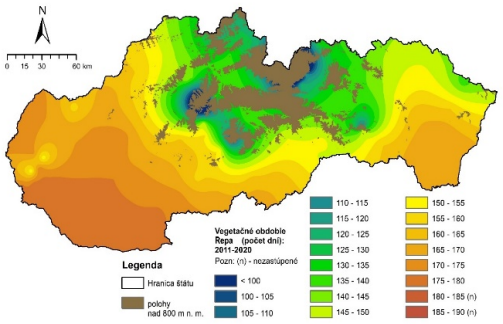


Fig. 6: Vegetation period delimited by the onset and termination days with an average daily temperature (3,0 – 7,5 °C) for the years 2011 - 2020

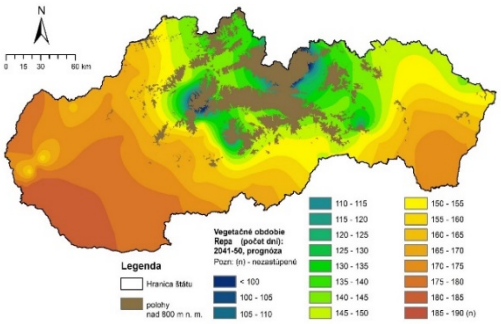


Fig. 7: Vegetation period delimited by the onset and termination days with an average daily temperature (3,0 – 7,5 °C) for the years 2041 - 2050

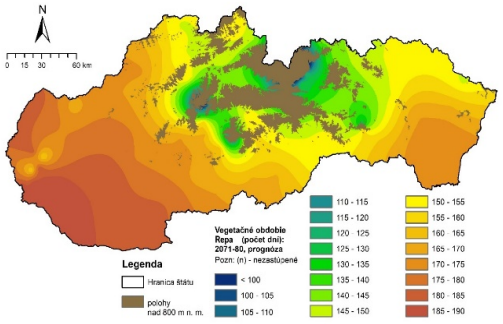


Fig. 8: Vegetation period delimited by the onset and termination days with an average daily temperature (3,0 – 7,5 °C) for the years 2071 - 2080

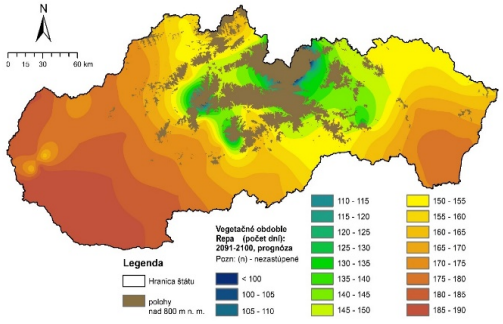


Fig. 9: Vegetation period delimited by the onset and termination days with an average daily temperature (3,0 – 7,5 °C) for the years 2091 - 2100

RESULTS

Climate change is a global issue and Slovakia is no exception. One of the most significant manifestations of climate change in Slovakia is rising temperatures. Temperatures in Slovakia have been gradually increasing over the past decades, with a prevailing warming trend. This trend also affects changes in precipitation patterns, which have been very unstable recently. There are changes in precipitation patterns leading to frequent dry periods and torrential rains. These extreme weather changes can lead to floods and

inundations. The increasing temperatures in Slovakia in recent years also affect the onset and duration of various phenological phases of plants. These changes in phenological phases may have a negative impact on plants and animals that depend on them.

The presented article provides a comprehensive overview of climate change and its impact on changes in the vegetation period and forecasts further development up to the horizon of the years 2090 - 2100. The results suggest that compared to the decade (1971 - 1980), which represented the coldest decade, it is anticipated that the vegetation period in the Danube Lowland will increase on average by up to 25 - 30 days. This could pose a significant problem in the future for the cultivation of native plant species.

Therefore, it is important to monitor changes in phenological phases and adapt to new conditions. This may include selecting plant species adapted to the new climate conditions and improving soil management and production processes. Additionally, it is important for us to realize the significance of climate change and its impact on our environment and take steps to mitigate its negative consequences.

DISCUSSION

Climate change has a significant impact on agriculture in Slovakia, particularly through rising temperatures, changing precipitation patterns, and the increasing frequency of extreme weather events. As temperatures rise, the growing season in regions like the Danube Lowland is projected to increase by 25-30 days compared to the 1970s. While a longer growing season may benefit some crops, it also increases the risk of frost damage due to earlier blooming and fruiting, as well as the potential for greater pest pressures.

Changes in plant phenology, such as earlier flowering and fruit production, are important indicators of climate shifts and can affect crop yields. While longer seasons may provide more time for crops to mature, they also expose plants to late frosts and pest outbreaks, which can negatively impact agricultural productivity. As such, monitoring these phenological changes is essential for understanding their effects on crop production and ecosystem functioning.

Adaptation strategies for Slovak farmers are crucial to mitigate the negative effects of climate change. These include selecting crop varieties better suited to warmer conditions, improving soil and water management, and adopting more sustainable farming practices. Technological innovation in agriculture will also play a key role in reducing the vulnerability of farming to extreme weather events like droughts and floods.

CONCLUSION

Climate change is a significant challenge for agriculture in Slovakia, with rising temperatures, changing precipitation patterns, and an increased frequency of extreme weather events. These changes have direct implications for crop production, plant phenology, and ecosystem stability. The lengthening of the growing season, particularly in the Danube Lowland, could provide some benefits by extending the time available for crops to mature. However, these benefits are tempered by the risks of earlier flowering and fruiting, which may expose plants to late frosts and greater pest pressures.

As climate change affects the timing of plant growth and flowering, it is crucial to monitor these phenological shifts and adapt agricultural practices accordingly. Early blooming and altered harvest times can have significant implications for crop yields, particularly

considering increased vulnerability to late frosts and extreme weather events. To mitigate these risks, Slovak farmers must adopt adaptive strategies, such as selecting crop varieties that are better suited to warmer climates, improving soil health, and optimizing water management. Furthermore, integrating sustainable agricultural practices and embracing technological innovations will be key to enhancing resilience against climate-related challenges.

The projected changes in temperature and precipitation patterns indicate that some regions in Slovakia may become less suitable for certain crops, while other areas could become more favorable for agriculture. Therefore, proactive measures are necessary to ensure that Slovak agriculture remains resilient in the face of an uncertain climate future. Through adaptation, innovation, and a commitment to sustainability, Slovak agriculture can continue to thrive despite the challenges posed by climate change.

ACKNOWLEDGEMENTS

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EFFECTS OF TILLAGE SYSTEMS ON METHANE ASSIMILATION IN *CAMBIC CALCISOL* AND IMPLICATIONS FOR CLIMATE CHANGE MITIGATION

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ABSTRACT

Well-aerated soils are essential for methane (CH_4) uptake from the atmosphere, acting as significant sinks for this greenhouse gas, which has a global warming potential 25 times greater than that of carbon dioxide (CO_2). These soils contain methanotrophic bacteria, which oxidize CH_4 and thereby reduce atmospheric methane concentrations. The potential of soils to assimilate CH_4 depends on factors such as soil type and moisture regime. This study investigates the ability of clay soil *Cambic Calcisol* to assimilate CH_4. Measurements were conducted at an experimental site with two tillage systems and two crop rotations from 2018 to 2023, with observations taken every two weeks from April to October. Experimental plots under conventional tillage demonstrated a higher rate of CH_4 assimilation compared to reduced tillage plots (-4.1 g CH_4 ha^{-1} day^{-1} and -3.5 g CH_4 ha^{-1} day^{-1}, respectively). CH_4 uptake by soils plays a vital role in regulating methane emissions, making soil management practices a key factor in climate change mitigation efforts. Understanding the variables influencing CH_4 assimilation is crucial for optimizing land-use strategies to enhance greenhouse gas mitigation.

Keywords: conventional tillage, reduced tillage, agriculture, GHG emissions, Picarro G2508, soil

INTRODUCTION

Well-aerated soils play a crucial role in absorbing methane (CH_4) from the atmosphere, serving as important sinks for this greenhouse gas, which has a global warming potential 25 times that of carbon dioxide (CO_2). These soils host methanotrophic bacteria that oxidize CH_4, thereby lowering its levels in the atmosphere. The capacity of soils to absorb CH_4 is influenced by various factors, including soil type and moisture conditions. For instance, Hansen et al. (2024) found that well-drained sandy soils with lower bulk density in Denmark have higher CH_4 uptake rates compared to coarse sandy soil and the loamy soils [1]. Additionally, Rafalska et al. (2023) suggest that grasslands affected by warming and drought conditions may enhance their CH_4 absorption, primarily due to reduced soil moisture and increased gas diffusivity [2]. Furthermore,

Guckland et al. (2009) observed that CH4 uptake in the forest soils of deciduous mixed forests in Germany significantly increased during the main growing season (May to September) as precipitation rates declined. Their findings indicate that climate change is likely to result in higher CH4 uptake rates in this region due to the anticipated trend of drier summers and warmer winters [3].

Although the factors influencing CH_4 uptake in soil have been extensively researched, the complex interactions among these elements highlight the necessity for more site-specific field measurements of CH_4 uptake rates. Therefore, the aim of this study is to investigate the capacity of *Cambic Calcisol* clay soil to assimilate methane (CH_4), by comparing CH_4 uptake rates under different tillage systems and crop rotations from 2018 to 2023, thereby highlighting the significance of soil management practices in regulating methane emissions and contributing to climate change mitigation efforts.

MATERIALS AND METHODS

The research was conducted at the Peterlauki Research and Study Farm, part of the Latvia University of Life Sciences and Technologies, situated in the central region of Latvia, Northern Europe (56°30.658`N and 23°41.580`E) (Figure 1).

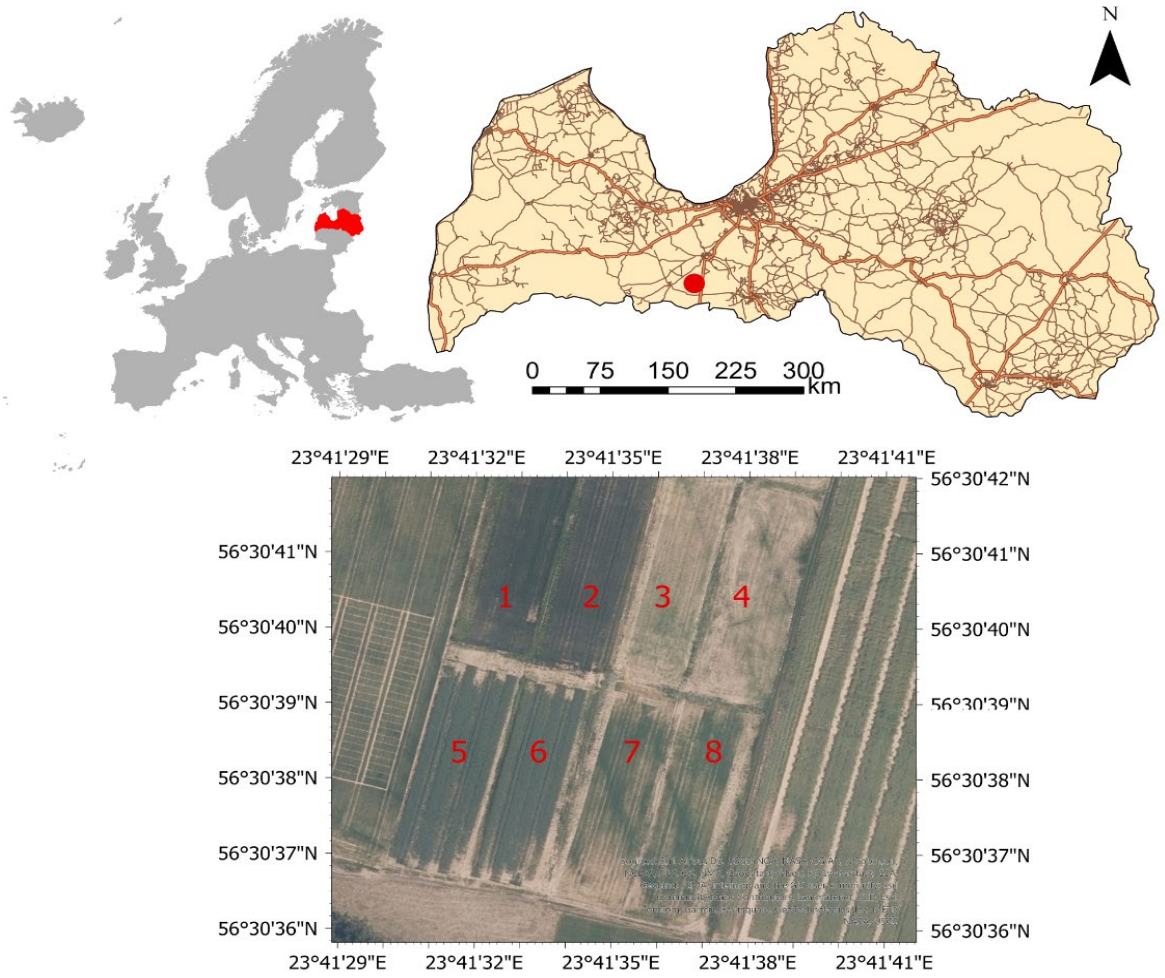


Figure 1. Location of monitoring site Peterlauki (56.510932, 23.692988). Numbers represent experimental plots were measurements were conducted.

This research was conducted as part of a comprehensive field experiment initiated in 2009, comparing two tillage practices: conventional tillage (CT) and reduced tillage (RT). Conventional tillage involved mould-board ploughing to a depth of 22–24 cm, while reduced tillage utilized disc harrowing to a depth of 10 cm. The soil at the study site is classified as *Cambic Calcisol*. For more details on soil characteristics and agronomic practices, refer to Valujeva et al. (2022) [4]. Greenhouse gas (GHG) measurements were done on eight experimental plots, each measuring 24x100 m, covering an area of 0.25 ha per plot [4]. To monitor soil fluxes of CH4 measurements were conducted biweekly between 10 AM and 2 PM during the growing seasons (April to October) from 2018 to 2023. Since 2013, the trial fields have followed two crop rotations: a three-year rotation of winter rapeseed followed by two years of winter wheat (WR–WW–WW), and a four-year rotation consisting of field beans, winter wheat, winter rapeseed, and spring barley (FB–WW–WR–SB). Prior to this, from 2009 to 2013, four crop rotations were used. Further details can be found in Valujeva et al., 2022 and 2023 [4,5].

CH_4 concentrations were measured using a Picarro G2508 mobile spectrophotometer, with a total of 1197 measurements, each lasting 400 seconds. A detailed explanation of the equipment and data processing can be found in Valujeva et al., 2022 and 2023 [4, 5]. The measured gas concentrations were used to calculate soil flux rates using a linear model [6] within the Soil Flux Processor (SFP) software by Picarro Inc., and all flux rates were converted to grams or kilograms per hectare per day.

The data distribution was assessed using the Shapiro-Wilk test in IBM SPSS Statistics version 22. Since the data did not follow a normal distribution, the non-parametric Mann-Whitney U test ($p < 0.05$) was employed to compare conventional and reduced tillage. The Kruskal-Wallis test ($p < 0.05$) was applied to evaluate differences between tillage treatments, years, months, and crops, followed by Dunn's post hoc tests ($p < 0.05$) for pairwise comparisons.

RESULTS

Conventional tillage demonstrates a significantly higher mean CH_4 assimilation (-4.1 g CH_4 ha^{-1} day^{-1}) compared to reduced tillage (-3.5 g CH_4 ha^{-1} day^{-1}) ($p=0.034$), but also displays greater variability, with a higher standard deviation (5.6 for conventional tillage and 5.0 for reduced tillage, respectively) and a wider range of values (-32.4 to 13.5 for conventional tillage, compared to -29.3 to 4.9 for reduced tillage). Additionally, the median CH_4 emissions are lower in conventional tillage (-2.2 g CH_4 ha^{-1} day^{-1}) compared to reduced tillage (-1.9 g CH_4 ha^{-1} day^{-1}), indicating overall greater methane uptake in the conventional system.

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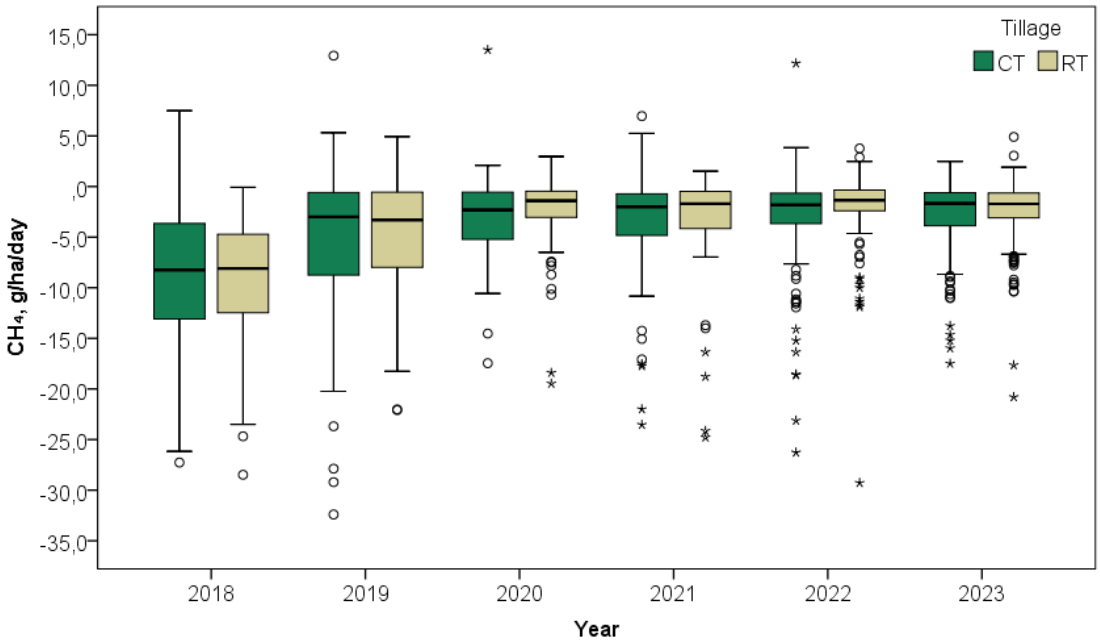


Figure 2. CH_4 emissions for two tillage systems in the period from 2018 to 2023.

The CH_4 assimilation in conventional tillage shows significant differences between mid-season months (May to August) and both early spring (April) and autumn (September and October), with peak assimilation in June (-5.8 g CH_4 ha^{-1} day^{-1}). For reduced tillage, CH_4 assimilation significantly differs between May, July, and August compared to April, September, and October, with June showing the highest uptake (-5.3 g CH_4 ha^{-1} day^{-1}) and October the lowest (-0.6 g CH_4 ha^{-1} day^{-1}) (Figure 3).

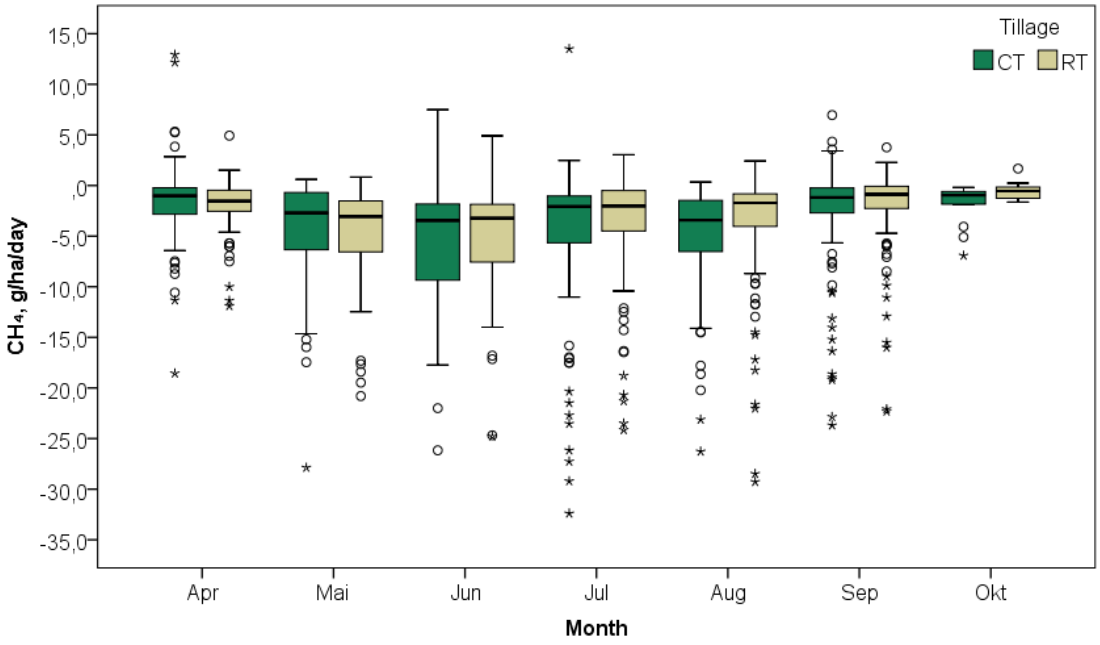
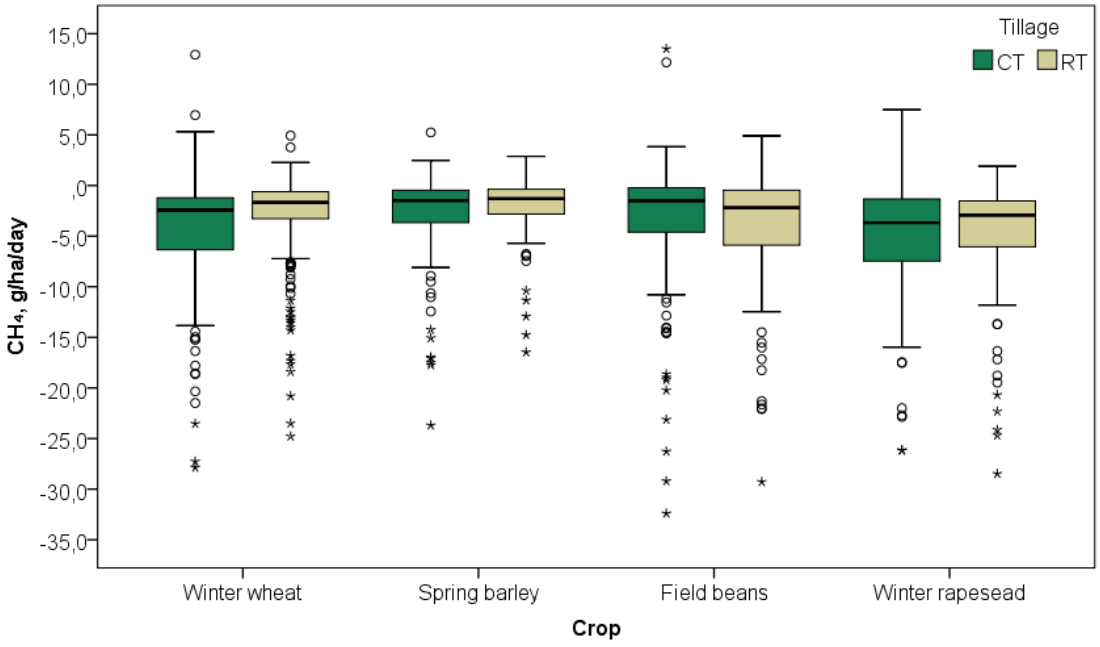


Figure 3. CH_4 emissions for two tillage systems from April to September in the study period from 2018 to 2023.

The Kendall correlation analysis for both tillage systems shows notable differences in the relationships between CH_4 assimilation, soil temperature, and soil moisture. In conventional tillage, CH_4 assimilation show a weak negative correlation with soil temperature ($r=-0.155$, $p < 0.01$) and a moderate positive correlation with soil moisture ($r=0.299$, $p < 0.01$). Similarly, reduced tillage also shows a negative correlation between CH_4 emissions and soil temperature, though weaker ($r=-0.095$, $p < 0.01$), and a moderate positive correlation with soil moisture ($r=0.268$, $p < 0.01$). In both systems, soil temperature and moisture are weakly and negatively correlated, but the relationship is slightly stronger in conventional tillage ($r=-0.204$ vs. -0.151). Overall, CH_4 assimilation are more influenced by soil moisture in both tillage systems, with conventional tillage showing slightly stronger correlations overall.

In both tillage systems, CH_4 assimilation varies across crops, with winter rapeseed consistently showing the highest methane uptake (-5.3 g CH_4 ha^{-1} day^{-1} for conventional tillage and -4.7 g CH_4 ha^{-1} day^{-1} for reduced tillage, respectively) and spring barley the lowest (-3.0 g CH_4 ha^{-1} day^{-1} for conventional tillage and -2.1 g CH_4 ha^{-1} day^{-1} for reduced tillage, respectively). Under conventional tillage, the overall mean CH_4 assimilation is slightly higher (-4.1 g CH_4 ha^{-1} day^{-1}) than under reduced tillage (-3.5 g CH_4 ha^{-1} day^{-1}). Additionally, conventional tillage shows more variability in assimilation rates across crops, particularly for winter wheat and spring barley, while reduced tillage demonstrates greater variability in methane uptake for field beans and winter rape. Overall, conventional tillage appears to promote slightly higher CH_4 assimilation across all crops.



DISCUSSION

Given that crop rotation and management practices have remained consistent, the decline in CH_4 assimilation rates in Latvia from 2018–2019 to 2023 could primarily be attributed to differences in weather conditions, such as drier and warmer conditions in 2023, which may have negatively impacted soil moisture levels. Additionally, other

environmental factors, such as shifts in soil health or long-term climate change effects, could further explain the observed reduction in methane uptake.

It is essential to recognize that the estimates in this study focus exclusively on methane assimilation during the vegetation period, leaving out year-round assimilation or emissions. When comparing the methane uptake rates calculated here (-1.48 kg CH_4 ha^{-1} day^{-1} for conventional tillage and -1.28 kg CH_4 ha^{-1} day^{-1} for reduced tillage) with the values reported by Dutaur and Verchot (2007) for temperate forests (-4.28 kg CH_4 ha^{-1} day^{-1}) and grasslands (-1.74 kg CH_4 ha^{-1} day^{-1}) [7], a clear decline in methane assimilation is evident. This difference suggests that the current study reflects a lower methane uptake capacity, possibly due to the limited time frame of data collection, along with potential changes in ecosystem conditions or management practices that could be influencing methane dynamics. Further research encompassing a full year's cycle and a broader environmental context is needed to better understand these fluctuations and develop more accurate estimates of methane assimilation.

CONCLUSION

In conclusion, this study demonstrates that conventional tillage practices yield significantly higher mean CH_4 assimilation rates compared to reduced tillage, despite showing greater variability. The peak CH_4 uptake was observed during the mid-growing season, highlighting the importance of timing in management practices to optimize methane absorption. Notably, the strong positive correlation between CH_4 assimilation and soil moisture in both tillage systems suggests that moisture management is crucial for enhancing methane uptake. Additionally, crop type influences CH_4 assimilation, with winter rapeseed showing the highest uptake across both tillage methods. The variability in CH_4 emissions and assimilation between the two tillage systems indicates that while conventional tillage may provide overall better CH_4 uptake, the variability and environmental conditions, including soil temperature and moisture, play significant roles in determining methane dynamics. These findings underscore the potential of soil management practices in mitigating greenhouse gas emissions, emphasizing the need for targeted strategies to enhance CH_4 assimilation in agricultural systems as part of climate change mitigation efforts.

ACKNOWLEDGEMENTS

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FUNCTIONALITIES OF GEOINFORMATIC SYSTEMS IN CRISIS EVENTS CAUSED BY CLIMATE CHANGE

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ABSTRACT

As the climate changes, the EU is experiencing heavier rainfall, harsher storms and rising sea levels. According to the European Environment Agency (EEA), the consequences of fluvial, pluvial and coastal floods in Europe will overall worsen as a result of local and regional increases in intensity and frequency of flooding [1]. The article concerns the indication of the functionality of the available QGIS software in the identification of critical infrastructure objects in Poland and the Czech Republic along with the risk analysis.

The research aims to showcase the capabilities of QGIS software in mapping critical infrastructure and utilizing geoprocessing tools to create buffers, or protective zones, around these infrastructures. The study highlights that QGIS provides broad access to spatial data. With the rapid advancement of technology, we can anticipate significant growth in mobile-GIS, enhancing access to GIS databases via mobile devices for real-time data acquisition, management, and updates. The diverse technical and organizational GIS solutions underscore the necessity for universal standards and norms in this field. This article illustrates the use of GIS in security engineering, such as aiding decision-making in public administration and agencies responsible for public safety or emergency management. Properly chosen GIS software, based on prepared data, can address numerous security engineering challenges by facilitating the decision-making process. The study identifies potential critical infrastructure, maps their locations, and generates security buffers with assigned risk classifications. These tools can be instrumental in decision-making during crises like pandemics. Each risk zone can be linked to specific anti-crisis measures and define actions for emergency services, such as access control or disinfection. QGIS maps offer a comprehensive operational view, enhancing the efficiency of decision-making processes.
Keywords: geomatics, crisis management, critical infrastructure.

INTRODUCTION

Among other things, long-term and significant changes in average atmospheric conditions in a specific region or around the world observed in recent decades are referred to as the concept of climate change. The European region is also affected by a number of negative consequences caused by various types of natural disasters resulting from dynamically changing weather conditions. Over the last 30 years, Europe has seen an increase in the

frequency and intensity of disasters caused by climate change. Many regions in Europe experienced increasingly frequent and intense heatwaves. An example is the heat wave in Europe in 2003, which caused a significant number of deaths and health problems. Increased rainfall and severe storms may lead to flooding. An example is the flood in Central Europe in 2021 and 2024, which caused significant damage and death of many people [2]. Some regions in Europe are experiencing increasingly longer and more intense periods of drought, with negative impacts on agriculture, access to drinking water and ecosystems. Accelerated melting of glaciers and climate change are contributing to rising sea levels, increasing the risk of flooding of low-lying coastal areas [3]. Strong winds, hurricanes and other extreme weather events can cause significant infrastructure and human damage [4]. Changes in vegetation and ecosystems: Climate change can affect the spread of plant and animal species and the structure of ecosystems.

These changes have serious consequences for people, local economies and the natural environment. Europe, like other regions of the world, faces the challenge of adapting to changing climate conditions and reducing greenhouse gas emissions to reduce the effects of climate change. In this research, the authors focused their attention primarily on the flood risk, which is constantly growing and has very negative consequences, especially for urbanized areas. The Floods Directive adopted by European Union in 2007 is very important in the management of flood events [5]. The research included observations of selected events in Poland and the Czech Republic. The work characterizes the process of managing disaster situations using the available and free QGIS software [6]. Selected functionalities enabling the creation of maps and analysis of data from the studied geographical areas were presented. The results of the analyzes may be a useful tool in preparing action plans and scenarios for anti-crisis services.

NEGATIVE EFFECTS OF CLIMATE CHANGE IN THE STUDIED AREAS

The study covers the area of Poland and the Czech Republic. Both countries have experienced natural disasters in recent years caused by heavy rains, causing major damage to the infrastructure of urban areas. Poland experienced extreme downpours in various regions of the country [7]. Examples include the Małopolska region, where in May and June 2010 intense rainfall caused floods. The greatest losses were in cities such as Kraków, Tarnów, Nowy Sącz and Wieliczka. Water flooded houses, roads and bridges [8]. Area. At the same time, Podkarpackie experienced floods as the Wisłok and San rivers overflowed. The towns that suffered the most were Rzeszów, Łańcut, Przemyśl and Krosno. Then the Vistula River exceeded its alert levels, flooding large areas of the country's capital and adjacent areas. Similar events also took place in July 2020 [9]. In July 2001, Gdańsk experienced one of the heaviest downpours in its history, which caused floods and significant damage to the city. Streets, residential buildings and infrastructure were flooded [10, 11]. Extreme downpours in Poland are becoming more frequent, which is related to climate change [12]. They cause serious problems for local communities, infrastructure and the economy of the regions affected by them. Predicting sudden weather breakdowns is very difficult, but active local activities should be carried out to enable technical security of the most important critical infrastructure located in urban areas.

In recent years, several significant flood events have also occurred in the Czech Republic, which can be attributed to climate change [13]. In August 2002, there was a flood that was one of the largest in the history of the Czech Republic. Water from rivers such as the

Vltava and Elbe flooded large areas, including the center of Prague. The flood caused the death of several people and huge material losses, estimated at billions of Czech crowns. Prague and other cities were severely damaged, requiring long-term reconstruction. However, in March and April 2006, intense rainfall and melting snow caused floods throughout the Czech Republic [14, 15]. The areas along the Elbe and Vltava rivers were most affected, causing significant disruption to the lives of thousands of residents.

Similar disasters occurred in these areas in 2010, 2013 and 2020 [16]. Floods resulted in the death of several people, thousands of people were forced to evacuate from endangered areas, and significant damage to infrastructure was recorded. These extreme flood events in the Czech Republic are becoming more frequent and more intense, which is consistent with climate change projections. Rising global temperatures lead to more frequent and intense rainfall, which increases the risk of flooding. This phenomenon has serious consequences for people, infrastructure and the economy in the Czech Republic.
In Poland and in Czech Republic, a number of actions have been taken to prevent the consequences of floods resulting from climate change [17]. First of all, implemented projects related to technical protection of areas exposed to flooding. These projects included, among others, the construction and modernization of flood protection infrastructure. Many new flood embankments were built and existing ones were strengthened. The most important investments in this area were located along the main rivers, i.e. the Vistula, Odra, Bug and San, and concerned cities most exposed to flooding. Another initiative aimed at minimizing flood losses is the construction and modernization of retention reservoirs, which help control water flow and reduce the risk of flooding [18, 19]. Construction of pumping stations and polders that allow controlled flooding of areas to protect more populated and valuable areas. Water level monitoring systems are also of key importance in optimizing crisis management activities. Secondly, numerous government programs and risk management plans are created, which may be of key importance in the effectiveness of rescue operations in a sudden crisis situation.

RISK ASSESSMENT METHODOLOGY

Emergency management focuses not only on the proper identification of key facilities, but also on the identification of IT tools to support this area. GIS tools are commonly used. The most noteworthy is the free Quantum GIS software. Its advantage over ArcGIS is its widespread availability and simplified use [20]. These programmes allow for cartographic imaging of up-to-date information on the current location of emergency events. This allows for effective management actions to be taken during an incident and for future prevention planning [21, 22, 23, 24].

This paper presents the use of the PHA (Preliminary Hazard Analysis) method to identify the level of flood risk using hydrological maps [25]. The following steps of determining the R (risk) level can be distinguished:

- identification of flood risk areas in the study area,
- selection of key critical infrastructure in the study area,
- identification of buffer zones around the selected objects,
- a flood risk assessment of the critical infrastructure facilities in the study area in three steps:
  - compilation of a list of identified hazards,
  - Assessment of the impact of the hazards (severity),
  - determination of the probability of an event for the objects,
- development of flood risk management maps for the study area.

This paper presents examples of facilities in the city of Gliwice, Poland.

On the basis of the completed flood risk maps, it is possible to prepare the risk level using QGIS software. Using this tool, risk zones can be determined for selected critical infrastructure objects. In the presented examples, the quick search tool was first used to select a layer containing sewage treatment plants, railway stations and other highlighted objects (fig. 2-5) located in the study area. It was then possible to determine the level of flood risk for these facilities.

In QGIS software, the Qgis2web plug-in can be used to generate map files. It increases the functionality of the active web maps in context to the simple views created in PDF, JPG and other files.

Fig.1 presents an example of a risk level valuation matrix using the PHA (Preliminary Hazard Analysis) method.

A five-point scale can be used to determine severity: 1 - negligible impact; 2 - low impact; 3 - medium impact; 4 - high impact; 5 - catastrophic impact.

The assumed degrees of probability (likelihood L) are: A (1) - very rare event; B (2) - rare event; C (3) - possible event; D (4) - probable event; E (5) - very likely event,

The risk indicator is determined from equation (1):

$$R = S \times L \qquad (1)$$

where:
S - severity of possible losses,
L - likelihood of an event,
R - risk indicator.
Table 1 presents R calculations for selected critical infrastructure facilities in the City of Gliwice presented in figs. 2-5. The highest level of risk was set for the hospital and water plant (Table 1). This allows emergency procedures to be built and protective mechanisms to be established.

Floods cause enormous damage to property, as they are often accompanied by off-stream runoff such as water from hillsides, mudslides, groundwater, etc. The recent torrential floods in the Czech Republic and Poland, as well as many other flood-prone regions, demonstrate the challenge society faces in adapting to a changing climate. Therefore, research and preventive measures in this area are crucial to meeting such challenges.

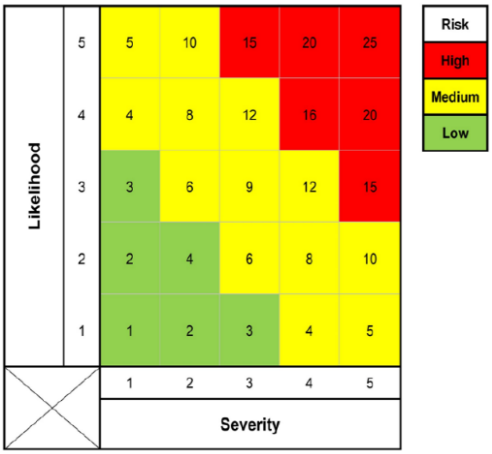


Fig 1. PHA method for risk assessment [based on 26]

Object (example)	Rank (1-5) (S)	Likelihood (L)	PHA (SxL)
Hospital	3	5	15
Water plant	4	4	16
Heating plant	2	2	4
Food wholesale	2	5	10



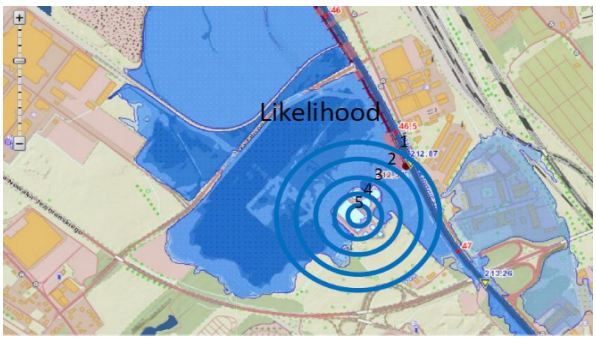


Fig 2 and 3. Flood hazard map of oncology hospital and water plant in Poland
Source: own elaboration in QGIS

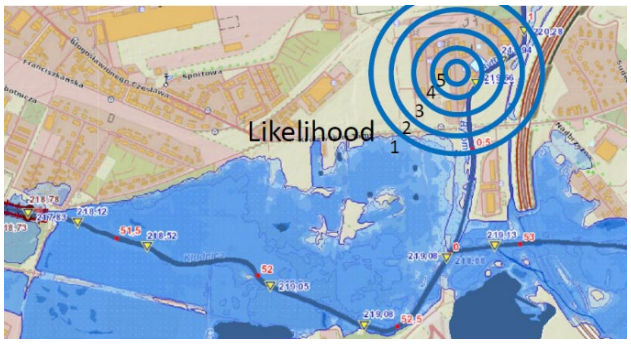




Fig 4 and 5. Flood hazard map of heating plant and food wholesale (social welfare)
Source: own elaboration in QGIS

Research and activities include continuous monitoring and assessment of the impact of climate change on precipitation patterns, snow melt rates and river flow. This is essential to predict how flooding in the Czech Republic and Poland may evolve in the future.

SUMMARY

Cooperation between authorities and emergency services requires inter-state agreements and regional arrangements. Much has changed in this area in recent years, with opportunities for cooperation and new threats identified. However, these activities require constant monitoring. Improving cooperation at the executive level requires integrating the activities of the various actors.

Cross-border cooperation should be an important element of the European Union's (EU) ‘open borders’ policy, together with the elimination of the negative impact of national borders on social and economic life, especially in border areas. A common system should be created to protect the life and health of citizens and national assets from the effects of

natural disasters and technical failures. Through cooperation, coherent road and critical infrastructure can be built. Through joint plans for responding to and preventing natural disasters caused by floods or natural catastrophes in border regions, better use can be made of the tools and technical facilities available. More cross-border disaster management initiatives are now being implemented, both at local authority and NGO level.

The preparation of a digital map in the area of critical infrastructure and the determination of the level of flood risk on it can be effectively used by the emergency management services to determine strategic and operational actions in the selected area. The preparation of various flood risk maps together with the determination of vulnerability is the basis for determining the directions of spatial planning for flood mitigation [27]. The cross-border nature of many rivers in the Czech Republic and Poland and the experience of the 1997, 2010 and 2024 floods show that neighbourly cooperation is essential for comprehensive management during floods and other disasters [28]. Public participation in building the resilience of critical infrastructure is important for preparedness and response to floods in cross-border zones.
Flooding caused by climate change, among other factors, requires full action at all levels of management - municipalities, cities, provinces, the country and the borderland. The publication presents the possibility of using a free tool to determine the risk level of selected sites for action planning. Reducing activities that affect climate change should be addressed comprehensively. The coordination of activities in this area is crucial, the authors have discussed this in other publications [29-32]. At the same time, it is apparent that the observed climate change is forcing the mobilisation of investments for flood risk management.

ACKNOWLEDGEMENTS

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MOBILE TETHERED UNMANNED AERIAL VEHICLE (UAS) FOR CONSTANT AIR QUALITY MONITORING

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ABSTRACT

Since the drone industry is more and more frequently used on a large scale, it is desired to obtain autonomous drones for the fulfillment of as many different missions as possible. Thus, within this project it presented the design of a mobile tether system for a rotary-wing UAV, with the aim of detecting changes in air quality, especially in areas around cities where illegal waste burning is frequently reported or in highly industrialized areas. Mobility is one of the important features of the proposed tether system, as it can be transported as permanent equipment for the environmental protection service. Also, the air quality sensors on board can detect air changes over long periods of time when the UAV is anchored to the rolling / unrolling system on the ground or can detect the air quality when the UAV is disconnected from the ground system, over short periods of time, at higher altitudes. In this paper, both the hardware and software component of the tether system were designed and the capabilities of this system were tested through the simulation of a generic reconnaissance mission and a dynamic mission, both under the laboratory conditions.

Keywords: oil and gas, environmental protection, UAV, photogrammetry, sensors.

INTRODUCTION

Tethered Unmanned Aerial Vehicle (UAV) systems are increasingly used for air quality monitoring due to their unique capabilities. These systems consist of drones connected to a ground station by a tether, which provides continuous power and data transfer. Unlike traditional UAVs that rely on limited onboard batteries, tethered systems can operate for extended durations, making them well-suited for long-term environmental monitoring missions. Tethered UAVs are equipped with sensors to measure various air quality parameters, such as particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2), and ozone (O_3). They are particularly valuable in applications requiring stationary or semi-stationary monitoring, such as assessing pollution near industrial sites or during large-scale public events. Their tether ensures uninterrupted data transmission and allows them to hover stably in challenging weather conditions, often at heights that optimize pollutant detection [1]-[2].

These systems are advantageous in scenarios where access to conventional ground-based monitoring stations is limited or where real-time, high-resolution atmospheric data is needed. For example, tethered UAVs have been used for urban pollution studies, detecting pollutant dispersion patterns, and assessing the impact of vehicular and

industrial emissions [3]-[4]. Despite their benefits, tethered UAVs have limitations, including restricted mobility compared to free-flying drones and the need for a reliable ground station setup. However, their ability to carry sophisticated sensor payloads, combined with their operational stability, makes them an efficient tool for atmospheric monitoring.

The tether system discussed in this article is designed to automatically rolling or unrolling the cable onto a spool based on the drone's vertical flight coordinates (altitude). When the drone is on the ground, the cable remains fully rolled on the spool. However, as the drone ascends, the tether system automatically unrolls the cable to ensure the drone experiences no resistance during its vertical movement. Also, Unmanned Aerial Vehicle (UAV) serve as versatile tool for environmental monitoring, enabling the sampling of vertical air columns across diverse pollution scenarios to facilitate 3-D mapping and pollutant modeling [5]-[7]. Additionally, UAVs are employed to detect and pinpoint sources of fugitive emissions, enhancing the ability to localize and address pollution at its origin [8].

SYSTEM ARCHITECTURE AND IMPLEMENTATION METHOD

The next section explores a more advanced tethered drone control system, illustrated in Figure 1. This system integrates multiple interconnected components that work together to ensure seamless control and communication. It consists of several distinct subsystems, including a power supply unit, the drone's electronic control and operational framework, and a tether management subsystem. The tether subsystem is responsible for both power distribution and bidirectional communication, ensuring efficient and coordinated functionality across the entire system.

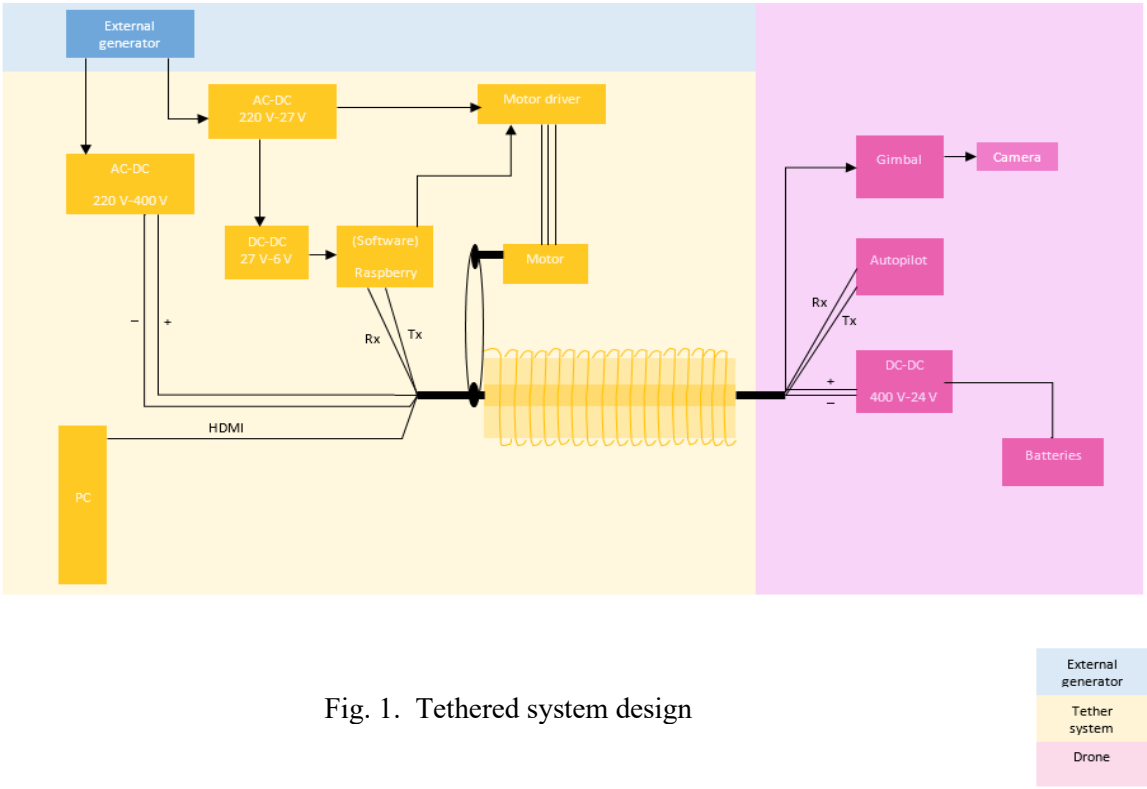


Fig. 1. Tethered system design

The proposed system integrates multiple interconnected components that work together to ensure reliable drone control and seamless communication. It is structured into distinct subsystems, including a power supply module, the drone's electronic framework for operational control, and a tether management subsystem designed to enable two-way communication and efficient power delivery.

As shown in fig. 1, the power is delivered by an external generator, serving as the primary energy source for principal components. The drone subsystem includes electronic elements essential for its operation, such as the camera gimbal and air quality sensors, an autopilot system, onboard batteries, and a voltage converter (400 VDC to 24 VDC). The tethered system control incorporates multiple power converters, including 2 AC-DC convertors (220 VAC to 400 VDC, respectivelly 220 VAC to 27 VDC) and a step-down converter (27 VDC to 6 VDC). It also comprises a stepper motor, motor driver, microcontroller, and a cable drum. This subsystem plays a dual role: providing power to the drone's electronic system and facilitating two-way communication between the ground control station and the drone's onboard autopilot system.

The selection of a 400V voltage for the tethered system is primarily motivated by the drone's high power requirements, ranging between 2.5 and 3 kW. Operating at a higher voltage allows for a significant reduction in the current carried by the tether cable. This is because electrical power is the product of current and voltage ($P = IV$), and in this configuration, an increase in voltage enables a proportional decrease in current. This relationship minimizes energy losses due to resistance in the cable, enhancing the system's overall efficiency. Also, as the voltage increases, the resistance on the wire decreases, the thickness of the wire and implicitly its weight decrease, leading to a decrease in the UAV motors speed and an increase in the reliability of the UAV system.

On the drone side, a DC-DC step-down converter reduces the voltage from 400V to 24V, a level suitable for powering the drone while increasing the current to meet its operational demands. For the tether winding and unwinding system, an additional AC-DC conversion is required at the generator output. This is accomplished using the RSP-150-27 power supply, which converts 220V AC to 27V DC and delivers a maximum current of 5.6A. This output powers the stepper motor's driver, which controls the motor's movements, and the control system, which includes a Raspberry Pi. The Raspberry Pi processes serial data received from the drone's autopilot system, enabling coordinated operation and precise control.

For the development of this project, the Python programming language was chosen due to its simplicity and versatility, which made it ideal for interacting with UAV systems. Alongside Python, the Mavlink protocol was integrated with Ardupilot and used through the Dronekit library to enable effective communication between the various components of the UAV system. Communication between the drone's autopilot system, which records altitude values, and the motor control system, managed by the Raspberry Pi, will be conducted via the tether system's cable. The communication protocol used for this connection is UART (Universal Asynchronous Receiver/Transmitter), which requires two wires for bidirectional communication: RX (receive) and TX (transmit). In addition to these communication lines, power and ground (GND) connections will also be established to ensure the proper functioning of both systems.

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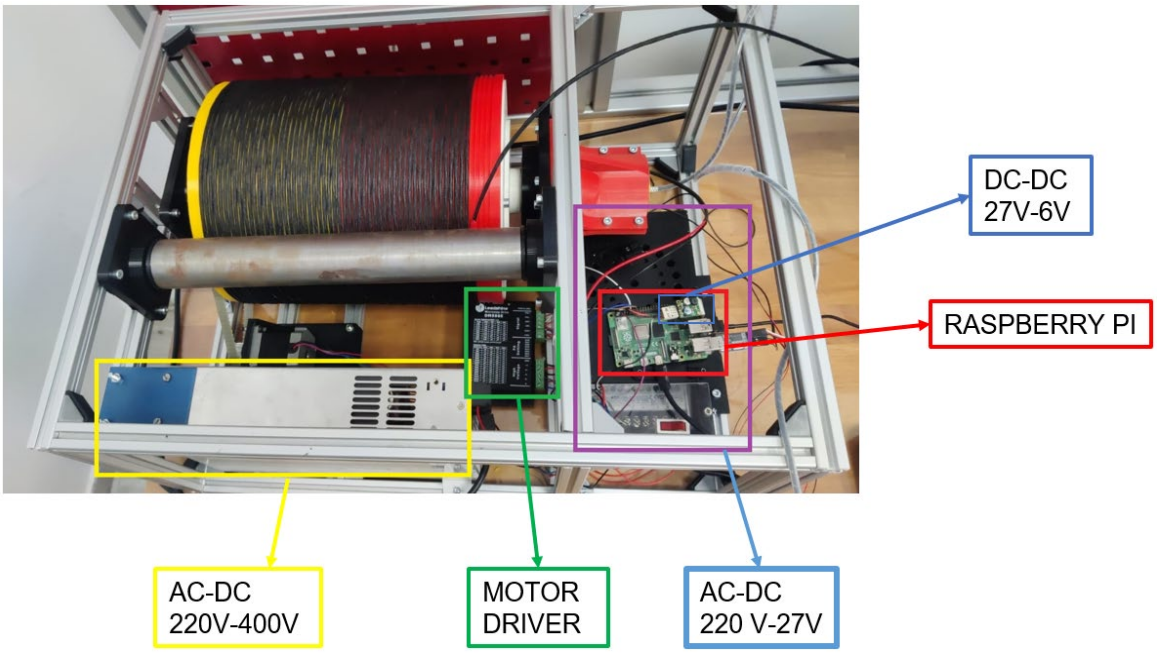


Fig. 2. Ground component of the tether system

ANALYSIS OF THE TRANSMISSION MECHANISM OF THE TETHER SYSTEM

The transmission of motion from the NEMA23 motor to the main cylinder shaft is achieved through a gear assembly consisting of two gear wheels and a transmission belt. A smaller gear is mounted on the NEMA23 motor shaft, while a larger gear is secured with screws at the left shaft end cap. The gear ratio between the small and large gears is determined by the ratio of their radii, as given in the following equation:

$$\text{Gear Ratio}=R_2/R_1 \tag{1}$$

where R_2=152 mm, is the radius of the large gear and R_1=25 mm is the radius of the small gear. This results in a gear ratio of 6:1, meaning the small gear will rotate six times for each rotation of the larger gear. These details are illustrated in Figure 3 and further clarified in the following formulas.

$$|\overline{v_1}| = R_1\omega_1 \tag{2}$$

$$|\overline{v_2}| = R_2\omega_2 \tag{3}$$

$$R_1\omega_1 = R_1\omega_1 \tag{4}$$

$$v_2 = v_1\frac{R_2}{R_1} \tag{5}$$

This gearing setup is commonly used in mechanical systems requiring efficient motion transmission with a reduced load on the motor, allowing the system to achieve higher torque and slower speed at the output.

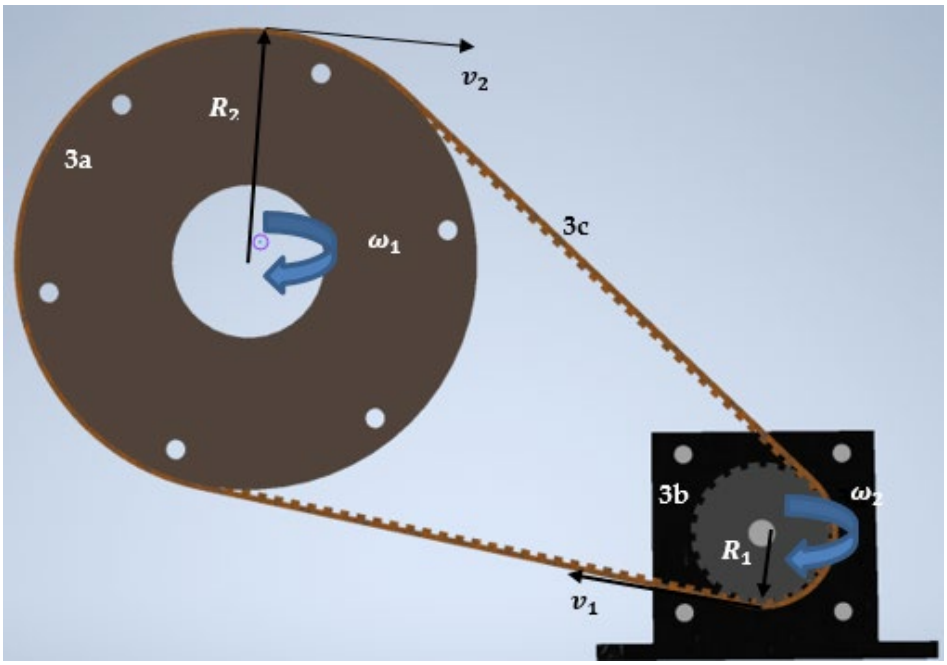


Fig. 3. The gear wheel and transmission belt mechanism. (3a) - Large gear wheel attached to the left shaft end cap. (3b) - Small gear wheel attached to the NEMA23 motor shaft. (3c)

SYSTEM BEHAVIOR IN THE LABORATORY CONDITIONS

The scenario involved simulating the drone's flight profile, which began with a controlled ascent at a maximum vertical speed of 0.5 meters per second. This ascent was carefully managed to ensure smooth and stable performance, allowing the drone to gradually reach its designated operational altitude. Upon reaching the required height, the drone maintained a constant altitude for an extended period, providing a stable platform for mission-specific data collection.

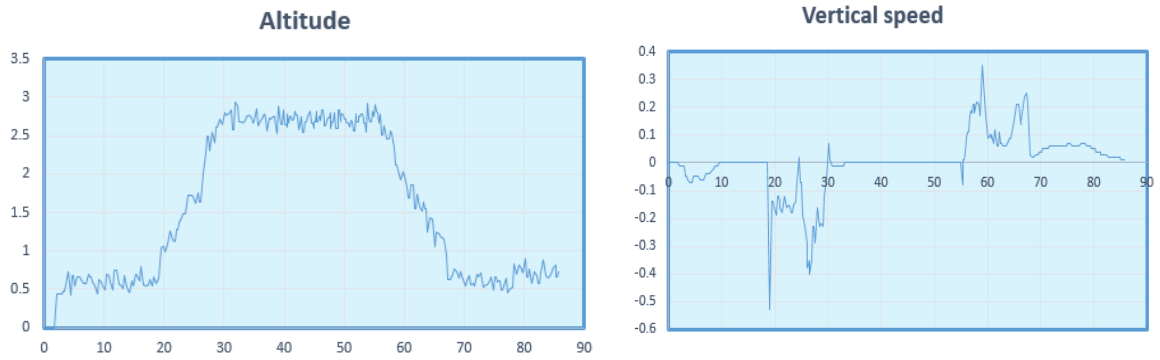


Fig. 4. Corellation between altitude and vertical speed of the UAV

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An interesting observation from the previous images is that the vertical speed is negative during ascent and positive during descent, which may seem counterintuitive. This behavior is closely tied to the autopilot's design, a factor carefully considered during the software development phase.

In the figure 5, a comparison with the altitude values reveals that the stepper motor rotations vary in response to changes in altitude, reaching a maximum value of approximately 7.8 when the successive altitude difference is initially at its peak. To further illustrate this relationship, a table will follow, presenting key altitude-related data. This includes the altitude differences between two successive time points, clearly showing how the rotation values depend on these altitude variations.

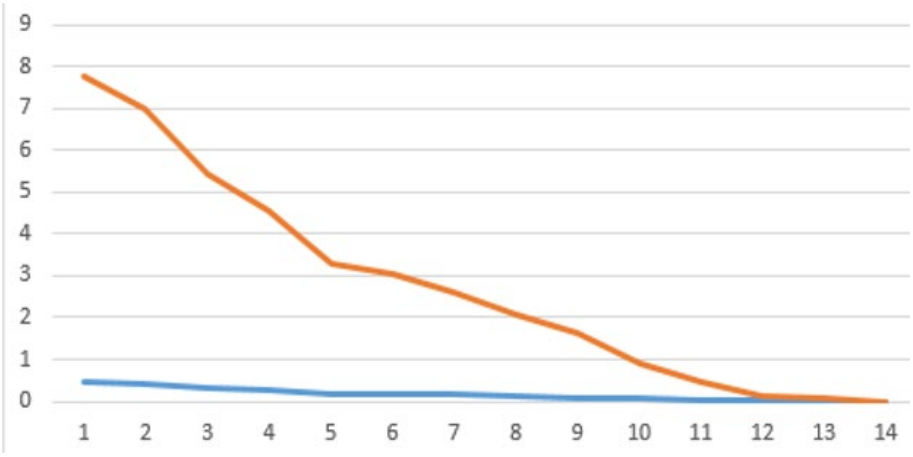


Fig. 5. The variation of rotations with the altitude difference

A table is presented next, detailing various altitude-related data, specifically the differences in altitude between successive time points, to emphasize the relationship between rotation values and altitude changes.

Nr. crt.	Altitude		The altitude difference module	Number of rotations
1	0	0.443	0.443	7.782
2	0.683	1.034	0.396	6.992
3	0.733	0.426	0.307	5.411
4	0.426	0.686	0.260	4.560
5	0.437	0.624	0.187	3.283
6	0.562	0.734	0.172	3.040
7	0.690	0.539	0.151	2.614
8	0.573	0.692	0.119	2.067
9	0.469	0.562	0.093	1.641
10	0.632	0.579	0.053	0.912
11	0.443	0.469	0.026	0.486
12	0.593	0.601	0.008	0.121
13	0.658	0.655	0.003	0.060
14	1.715	1.715	0	0

Fig. 6. Obtained parameter value

CONCLUSION

The tethered system that was designed for air quality monitoring offers a unique and effective approach to capturing real-time atmospheric data with several key advantages and implications as consistent power supply, stability and controlled altitude, real-time data collection and transmission, reduced operational costs, environmental impact.

Laboratory tests were conducted to evaluate the response of the tethered reelin/reel-out system to changes in UAV altitude. During these tests, the system's performance was monitored as it adjusted to controlled increases and decreases in altitude, assessing the tether's response time, stability, and reliability. These controlled conditions provided valuable insights into the system's ability to maintain optimal tether tension and support UAV positioning under varying altitude demands, ensuring smooth operation and safe deployment in real-world applications.

In conclusion, the tethered system designed for air quality monitoring present a robust and efficient solution, with the potential to improve the accuracy and consistency of environmental data. This technology supports proactive measures for environmental health, contributing to a deeper understanding of air pollution patterns and more effective regulatory responses.

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SOME ECOLOGICAL SERVICES OF THE FIRST, 4-YEARS OLD, HUNGARIAN MIYAWAKI-FOREST IN TABÁN, BUDAPEST

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ABSTRACT

Miyawaki-forest is a well-known method to create small forest quickly in urban conditions. It works with native woody species that are densely (4-5 pcs/m^2) planted together after topsoil changing in a quite small area. The first Hungarian Miyawaki-forest was introduced in Taban, 2021. It planted with 9 native species (*Acer platanoides, Acer campestre, Carpinus betulus, Crataegus monogyna, Euonymus europaeus, Pyrus pyraster, Ulmus laevis, Sorbus torminalis* and *Quercus robur*). The area is 40 m^2. Soil was changed up to 50 centimeters before planting. 120 individuals were planted and the surface was mulched with straw about 20 cm thick to retain water in the soil. This planting arrangement provides an excellent opportunity to study the ecological services of Miyawaki forests, including the capabilities of species under low maintenance conditions. We examined some ecological services such as CO_2-fixation (daily maximum photosynthetic activity), evaporation (water vapor emission) and dust deposition (mg/m^2 leaf area) for more or less 4 years. Daily maximum photosynthetic activity (g CO_2/m^2 leaf area) and water vapor emission (l/m^2 leaf area) were measured on trees twice a year in 2021, from 2022 to 2024 mostly monthly from May to October with a portable infrared gas analyzer. The data were recorded between 11 and 13 h. From 2022, dust deposition is also measured on each species. Leaf samples were collected, washed with distilled water and scanned for leaf area. The CO_2-fixation and evaporation show seasonal and species changes. Dust deposition mostly influenced by weather.

Keywords: Miyawaki-forest, CO_2-fixation, water vapor emission, dust deposition, ecological services.

INTRODUCTION

Urban trees and forests are invaluable and essential in the crowded, built-up urban environment. The ecological services are necessary for citizens [1, 2, 3, 4, 5, 6, 7]. The urban trees need to match the standard in cities, it means that they need to be 2- or 3-times transplanted with 2.5-meter-high trunk and of course standard looking [8]. This is why they are propagated by vegetative methods. However, these methods decreased the genetic background [9] that decreased the adaptation capacity of species. We can fight against the genetic degradation using native seedling [10].

Miyawaki-forest is a well-known method to create small forest quickly in urban conditions. Akira Miyawaki is a Japanese botanist and professor, who invented the

Miyawaki-forest technique worldwide. In the concept, (a) they use as many native species as possible, (b) change top soil (min. 20 cm topsoil) and (c) plant the young plants randomly together in a slightly small area (4-5 pcs/m^2), (d) use seedlings or sow seeds directly into area. To protect against drought, cover the soil with thick mulch-layer [11,12]. This method takes its inspiration from nature. The trees that are planted in this way grow faster because they compete for light and nutrients [11,12]. The aim is not to alive all the individuals, the succession is a natural process where those individuals reach high age, which adopt to the given environment as much as possible.

To monitoring trees utilities, we can measure carbon sequestration in different ways [13, 14, 15]. Calculating of carbon sequestration in a Miyawaki-forest can be different [16, 17, 18]. Researchers at Wageningen University use forestry methods [16, 18] calculating the biomass changing. All the researchers agree that the trees and shrubs in Miyawaki-forest will increase their ecological services with their age [11, 12, 17, 18].

MATERIALS AND METHODS

The first Hungarian adaptation of Miyawaki-forest was introduced by the BKM (Budapest Public Services) FOKERT division (green infrastructural management company of Budapest) in Taban (district in Budapest) on 20th May 2021.

Forest planted with nine tree species, which are the follows *Acer platanoides* (Norway maple), *Acer campestre* (field maple), *Carpinus betulus* (common hornbeam), *Crataegus monogyna* (common hawthorn), *Euonymus europaeus* (common spindle), *Pyrus pyraster* (European wild pear), *Quercus robur* (common oak), *Ulmus laevis* (European white elm), *Sorbus torminalis* (wild service tree). Soil was changed in the area up to 50 centimeters before planting. The area of current forest is 40 m^2. 120 trees were planted to the area and after planting the surface was mulched with straw about 20 cm thick to retain water in the soil.

In this article, we examined and summarized four years of young trees. We monitored some ecological services such as CO_2-sequestration (daily maximum photosynthetic activity), evaporation (water vapor emission) and dust deposition (mg/m^2 leaf area) for more or less 4 years. Daily maximum photosynthetic activity (g CO_2/m^2 leaf area) and water vapor emission (l/m^2 leaf area) were measured on trees twice a year in 2021, from 2022 to 2024 mostly monthly from May to October with a portable infrared gas analyzer (BioCID CI-340, USA). The data were recorded between 11 and 13 h. The device works by calculating the photosynthetic activity and the water vapor emission from difference between atmospheric carbon dioxide and the carbon dioxide measured in the chamber clipped to the leaf. 10-10 data were recorded per species. It counts automatically the photosynthetic activity in μmol/m^2×sec and evaporation in mmol/m^2×sec what calculated to g/m^2 and l/m^2 in a two-hours period.

From 2022, dust deposition is also measured on each species. Leaf samples were collected (3-3 pcs in 4 repetitions per species), washed with 50 ml distilled water. The water was evaporated from the solution in an oven (at 115°C for 8 hours). The weight of beakers with dust was measured back. The difference between starting and dusted weight gave us the dust weight of samples. The sample leaves were scanned for leaf area by a leaf scanner (ADC Bioscientific Ltd., UK). We only measured the TSPs (total suspended particulates), which contain all the dust and other dirt on leaves in mg/m^2 leaf area.

According to Hungarian Meteorological Institute the weather in 2021 was hot and relatively humid with multiply heat alarms. In 2022, the weather was hot and dry. Only in April and May was precipitation in this year during vegetation period. In 2023, the weather was very hot, with many heat alarms, but more it rained every month. In 2024, the weather was the hottest without rain from May to August, then in September came two months' dose of rain. The atmospheric drought was so high every August.

All data were statistically analyzed by ANOVA using the statistical package IBM SPSS Statistics 29.0.1.0. Means were separated by Duncan-test at level p = 0.05. Different letters in the same column of the tables and graphs indicate significant differences at p = 0.05 by species and by months. Standard deviations are also shown in tables and graphs. Our aims were to search differences between species by months. We did not calculate seasonal changing in this study.

RESULTS

The maximum daily photosynthetic activity in 2021 (fig. 1. left) shows that most species showed lower photosynthetic activity in July 2021, except for *Sorbus* and *Ulmus*. In September 2021, most of species increased its own activity to fix carbon dioxide except for *Quercus* and *Sorbus* (fig 1.). *Pyrus* was the most active in September, this was followed by *Crataegus monogyna*. *Acer platanoides* shows the lowest activity in both months in 2021. In parallel with photosynthetic activity, evaporation also mostly follows the photosynthesis (fig. 1. right).

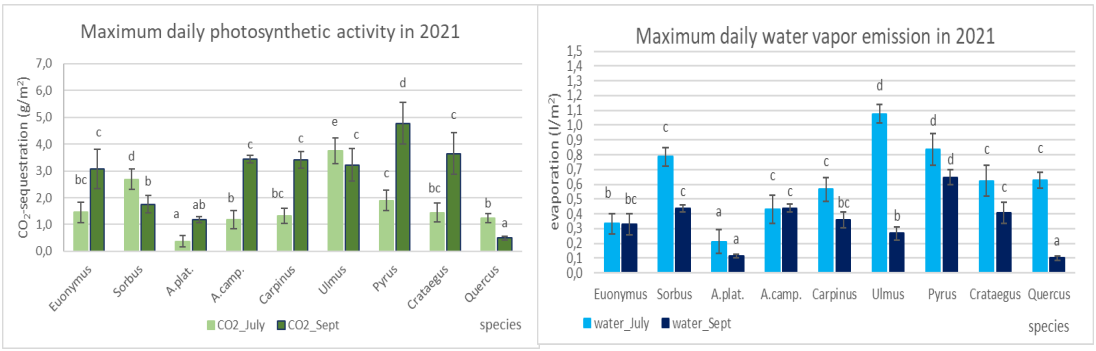


Figure 1. Maximum daily photosynthetic activity in g/m^2 leaf area (left) and maximum daily water vapor emission in l/m^2 leaf area (right), Budapest, 2021.
The columns of graphs show the standard deviation and the sign of statistical analysis. Means are separated by Duncan-test, different letters on the same column indicate significant differences at p = 0.05 by months and species.

In 2022, most species increased its maximum daily photosynthetic activity until July, after that in August it decreased (fig. 2.). *Sorbus* and *Carpinus* increased their activity through August instead of the other species. In October 2022, all species increased their maximum daily photosynthetic activity, except for *Quercus*, that showed weak activity all season.
Maximum daily water vapor emission in 2022 also followed the photosynthetic activity of species (fig. 2.). Most of the species could increased the evaporation until July, after that decreased. In October 2022, evaporation showed increasing tendency at all species. *Carpinus, Ulmus, Pyrus* and *Crataegus* gave the highest water vapor emission values in

May 2022. *Quercus* species disappeared from the Miyawaki-forest by the autumn of 2022.

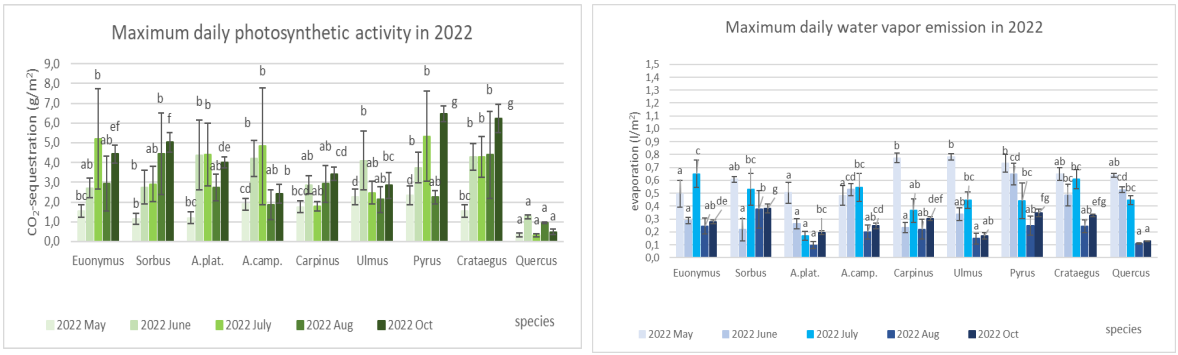


Figure 2. Maximum daily photosynthetic activity in g/m^2 leaf area (left) and maximum daily water vapor emission in l/m^2 leaf area (right), Budapest, 2022.

The columns of graphs show the standard deviation and the sign of statistical analysis. Means are separated by Duncan-test, different letters on the same column indicate significant differences at p = 0.05 by months and species.

In 2023, the maximum daily photosynthetic activity (fig. 3.) showed the same tendency like in 2022 (fig 2.). In this year the activity increased until June, in July decreased and in September increased again. Maximum daily vapor emission in 2023 showed a tendency that evaporations increased until June and then gradually decreased for each species (fig. 3.).

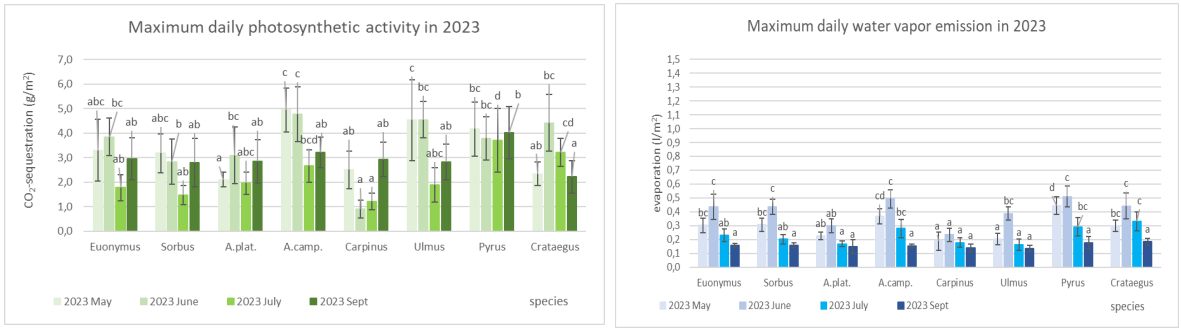
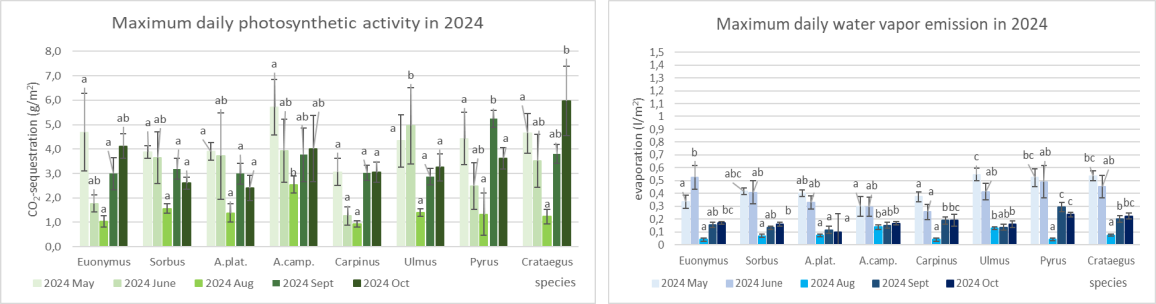


Figure 3. Maximum daily photosynthetic activity in g/m^2 leaf area (left) and maximum daily water vapor emission in l/m^2 leaf area (right), Budapest, 2023.

The columns of graphs show the standard deviation and the sign of statistical analysis. Means are separated by Duncan-test, different letters on the same column indicate significant differences at p = 0.05 by months and species.

In 2024, the maximum daily photosynthetic activity of species (fig. 4.) started with high volumes in May, after that they decreased until August, and increased again in September and October. This year the highest values were in October. *Pyrus* and



Crataegus had the highest photosynthetic activity in September and October. The maximum daily water vapor emission in 2024 (fig. 4.) started also with high volumes that kept in June, too. From August 2024 the evaporation greatly declined. Only *Pyrus* and *Crataegus* could increase the water vapor emission significantly in September and October 2024.

Figure 4. Maximum daily photosynthetic activity in g/m^2 leaf area (left) and maximum daily water vapor emission in l/m^2 leaf area (right), Budapest, 2024.

The columns of graphs show the standard deviation and the sign of statistical analysis. Means are separated by Duncan-test, different letters on the same column indicate significant differences at p = 0.05 by months and species.

The dust deposition of species is shown in fig. 5. We have plotted the data by time, so that the effect of the weather can be better perceived. We can see, that in 2022 was the highest values of TSPs for all species. In 2023, the dust volume was lower. In 2024, we can see, that in case of the lower species (*Crataegus, Pyrus, Carpinus, Euonymus*), the amount of dust on the leaves is higher.

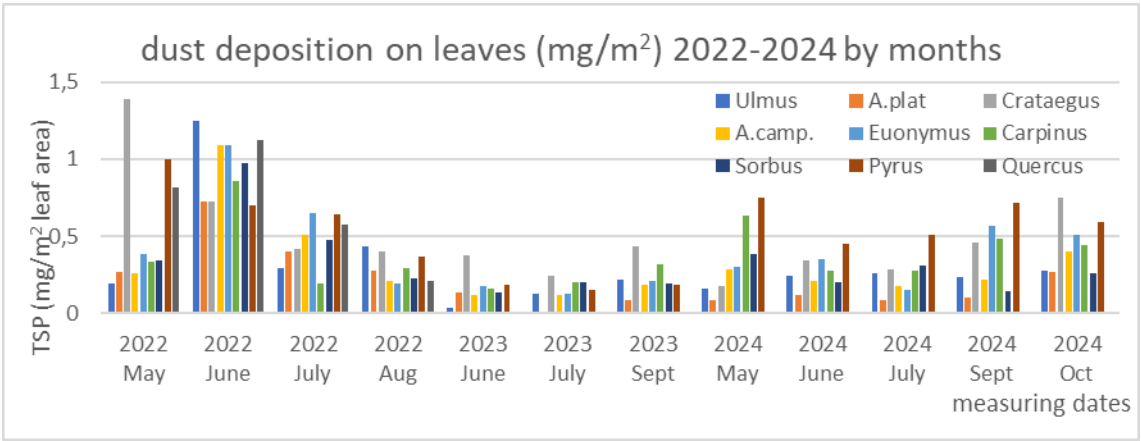


Figure 5. Dust deposition on leaves in mg/m^2 leaf area by measuring dates.
In this case, we omitted the representation of the statistical evaluation in order to avoid crowding.

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DISCUSSION

Monitoring the maximum daily photosynthetic activity from year to year, we can see that performance fall back significantly in the middle of summer (July-August). This is due to the atmospheric drought and rainless period, that caused a stressful state. In 2022 and 2023 (fig. 2. and 3.), this is less visible, but in 2024 there was extreme drought throughout the summer, followed by extreme rainfall (fig. 4.). Species that are drought tolerant (*Pyrus, Crataegus, Acer campestre, Ulmus*), will better endure the severe conditions. They can increase their photosynthetic activity significantly (fig. 4.).

In most years, the spring started with a higher amount of precipitation, this is clearly visible in the evaporation graphs of all four years (fig. 1.-4.), but after that, due to the increasing heat and lack of precipitation, the species significantly reduced evaporation. Unfortunately, the thin-skinned species (*Acer platanoides*, *Carpinus, Sorbus, Euonymus*) coped less well with these stressful periods, and their rate of evaporation did not increase even during the late summer and early autumn rainfall. However, the *Pyrus* has thin-skinned leaves, it can renew its water balance after rainfall.

In some years, in the stressful state of summer, the differences between the species were difficult to detect with statistical analysis, because the standard deviation in the data was large. This could be due to the extent to which the individual examined leaves were exposed to stress. Furthermore, this could also have been caused by how the individuals of the species adapted to their environment.

Based on our four years of research, we can say that the best adopted species are *Pyrus, Crataegus, Ulmus, Euonymus* and *Acer campestre*. *Acer platanoides* grows fast but its leaves are sensitive to sunburn. By the end of 2022, they dried back up and lost their leaves early, which can be seen mostly in the evaporation graph (fig. 2.). However, by 2023, this species had already learned how to work in a hot, droughty period. This is due to the fact that seedlings have more genetic background and are more adaptable [9, 10, 11, 12].

Although we did not examine it in this study, we confirm Lerink's [16], Cárdenas's [17] and Ottburg's [18] statement that the ecological services of mini-forests will increase with age. The maximum daily photosynthetic activity and maximum daily water vapor emission show that the individuals have adapted to their environment and this helps them survive. At the same time, Miyawaki [12] warns that the goal is not the survival of individuals. We saw this when the oaks were disappeared from the mini-forest by the end of 2022. In the race for the light, they fell short.

In terms of the dust deposition capacity of the species, the standard deviation is large, so it is difficult to show a statistical difference. The reason for this is that the location of the leaves greatly affects dust deposition. Short individuals have more dust because they are closer to the ground. It can be assumed that the stirred-up dust deposit on the leaves. Dust from the air is captured by taller plants.

CONCLUSION

The Miyawaki-forest is an innovative solution for replacing lost natural plants in cities. The use of native species ensures long-term settlement in the area. Seedlings have mor genetic pool, so they can adapt better. The most adaptable remain in the field.

The first Miyawaki-forest in Taban, Budapest showed us the opportunity to examine the species in the same area at the same time. This makes it possible for us to compare the behavior of individual species in an urban environment, even for young individuals.

From our four years of research, we can see that species adapt to weather conditions in different ways. The fast-growing species can protect the lower ones as an umbrella, but the lack of light can also be a disadvantage (see *Quercus*).

We believe that our research can provide even more information about the development of the mini-forest in the long term. Our further plans include comparing maximum daily photosynthetic activity and maximum daily water vapor emission with serious statistical analyzes in order to obtain more detailed information about the relationships. Examination of the soil's carbon dioxide and water content may show further correlations. By filtering the amount of dust during dust capture, it can be shown how much of the total dust belongs to the PM10 and PM2.5 ranges, which pose a serious health risk.

The measurement of carbon dioxide sequestration, evaporation and water retention reported in international literature [11, 17, 18] requires further research and contact to be able to compare our data.

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THE ECOLOGICAL IMPORTANCE OF USING EXPLOSIVE MATERIALS FOR OBTAINING LAYERED STRUCTURES

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ABSTRACT

The paper presents an ecological technology regarding the use of explosive materials in obtaining unconventional layered structures. It is emphasized that the use of the presented method contributes substantially to the minimization of the action of toxic factors on the environment compared to classic welding technologies. The reduction of harmful effects on the environment is due to the extremely short duration of the process, the entire amount of explosive material being consumed almost instantly. The subject of the paper focuses on those parameters that must be taken into account as a result of the detonation of the explosive charge in order to obtain the most effective results in terms of environmental protection. Experimental results regarding the development and testing of such structures are also presented in the article. In this regard, the obtaining of layered metal structures based on aluminum with a stainless steel texture was studied. The technology presented is of the latest generation, with applicability in the chemical industry, but also in the production of civil protection equipment. The paper begins with a short introduction on the advantages of obtaining such materials, continuing with a theoretical presentation and a numerical simulation of the process, so that at the end the results of the experimental tests carried out on the structures thus obtained are exposed.

Keywords: unconventional layered structures, ecological welding technology, explosive materials.

INTRODUCTION

The development of the technique has imposed the increase of the requirements in the choice of special purpose materials. The problem of the survival of a certain category of technique requires to be defined by a package of systems characterized by the nature of the required performance, forming a complete ensemble, capable of increasing the degree of protection, and, that is to reduce its vulnerability. These are frequently mentioned in the literature, by considering each as unique, de-sustaining elements [1], [2], [3]. This creates the possibility to approach a certain category of special technique as part of a dependent, interactive, total system.

In order to increase the puncture resistance, armor from structures of type "sandwich" is made, to which the outer layer is of high-strength steel, and the inner layer, of titanium alloy, is made, aluminium, vanadium or chromium. Between the two steel plates a plate made of ceramic materials or plastic materials reinforced with glass fibre [4].

As the cost of manufacturing ceramic armor prevents their expansion, the prospect is to develop new types of alloys such as titanium alloys, obtaining high-strength steels or using composite fiber materials.

The production of explosion-welded blanks, a process used to obtain special purpose structures, is based on the well-known 1964 patent of the company Du Pont Company from USA [5]. According to him, the metal plates to be welded are initially kept in a parallel position, between them being a predetermined distance, well determined, the explosive used being chosen based on its detonation speed.

MATERIALS AND METHODS

As it is known from the literature, in order to weld by explosion two metal parts, they must undergo a process of oblique collision with jet formation.

Practical experience has shown that due to the peculiarity of the process, only simple geometric configuration parts can be joined due to the difficulties of placing explosive components and load, but especially due to the voltages that would it appears in areas with section variations, voltages that would lead to the destruction of the component parts.

After the geometric shape of the blanks we can distinguish the following situations: welding after flat surfaces and welding after cylindrical surfaces.

Explosion welding can be defined as the process of joining two or more metal materials, as a result of the controlled action of the shock waves produced by the detonation of explosives.

The role of detonation is to accelerate and propel the metal input component to the welding component in order to obtain an oblique collision with the realization of an atomic bond between the two plates.

In **fig.1** is schematically shown the fitting required for the explosion plating operation [6], [7]:

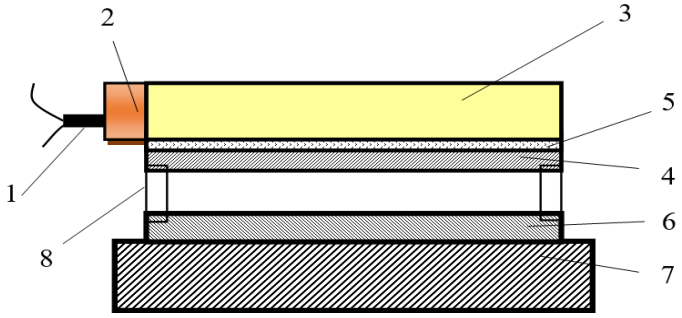


Fig. 1 The installation required for the welding operation by explosion: 1. detonator; 2. booster; 3. explosive charge; 4. mobile plate; 5. attenuator; 6. motherboard; 7. bracket; 8. Spacer

Starting from the qualitative explanations of the welding process and mechanism, for explosion welding to take place, the following basic requirements must be met [1]:

1. appearance a jet at the interface;
2. obtaining a contact pressure – associated with the kinetic energy dissipation of the propelled component – of sufficient level and for an appropriate time, so that stable interatomic connections are made. In this case the pressure is

caused by the impact with a certain speed, and the available time for welding is given by the speed of the collision point (welding).

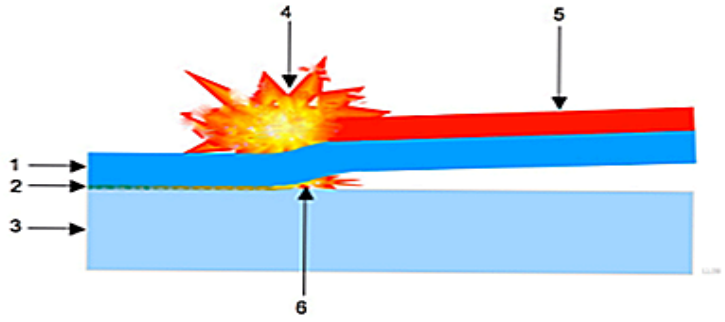


Fig. 2 Schematic representation of explosion welding process: 1. movable plate; 2. welded interface; 3. motherboard; 4. detonated explosive; 5. non-consumed explosive charge; 6. the appearance of the jet at the interface.

In **fig.2** is represented schematically the actual realization of the explosion cladding process being explained the steps taken.

Thus, it can be seen how the detonation of the explosive chamber located on the surface of the movable plate has the immediate effect of the appearance of the jet at the interface, a determining factor in the relalization of the welding process.

In essence, mastering the intimate processes that take place during propulsion and collisions between the welding parts allows the correct choice of the parameters that constitute the variables of the welding process, namely:

- detonation speed D;
- propulsion speed Vp;
- collision speed Vc and dynamic angle β.

Schematically, the link between the parameters of the detonation process, lateral deformation, propulsion and collision phenomena, is represented in **fig.3** and the relations (1÷4), as follows:

- dynamic collision angle (welding):

$$\beta = \alpha + \varphi \qquad \textbf{(1)}$$

- propulsion speed:

$$V_c = 2D \cdot \sin\frac{\varphi}{2} \qquad \textbf{(2)}$$

- collision speed:

$$V_c = \frac{V_p}{\sin\beta} \qquad \textbf{(3)}$$

- the relationship between the welding speed and the detonation speed:

$$V_c = D\frac{\sin\varphi}{\sin(\alpha+\varphi)} \qquad \textbf{(4)}$$

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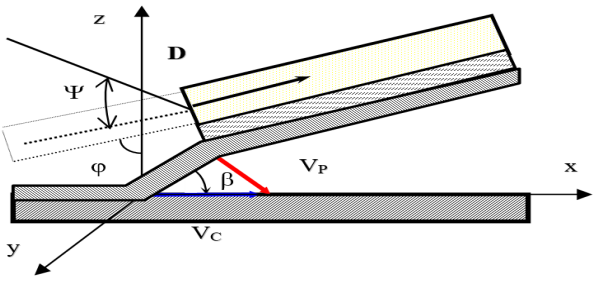


Fig. 3 Schematic representation of the influence of the detonation process parameters on the welding process

It is assumed that the detonation of the explosive is carried out at a constant *D*-speed. The shock wave front launched into the air makes an angle Ψ with the initial position of the outer surface of the explosive charge.

As a result of the accumulation of shocks, the intake plate (disposed into contact with the explosive) is deformed and propelled laterally with the *Vp* propulsion speed and at an angle φ (the angle between the initial and final positions of the movable plate). The pressures in the welding materials are so high (at least an order of magnitude from the flow limit) that they can be considered as liquid blades [8].

The experimental results indicate that there are, however, certain critical values, both for the parameters of the collision process and for the geometric ones, parameters that must be observed in order to achieve a proper welding. They can be summarized hereinafter:

1) Since it is necessary to have a jet in the collision region, it is necessary to overcome a certain minimum dynamic collision angle β_{min}. For a given metal, the value of such an angle is depending on the speed of collision. Critical values of β were calculated according to the collision speed and the metal status equation [4].

2) The collision speed *Vc* and the impact speed *Vp* shall be less than the speed of sound in the metal components to be welded.

3) A minimum impact pressure limit value (thus a minimum value of the plate speed *Vp*) shall be exceeded in order to ensure that the impact energy is sufficient to produce welding.

4) An initial distance *S* between the plates must be ensured so that the movable plate can be accelerated to the required impact speed *Vp*.

In order to study the phenomena that take place during the explosion plating process, using the Finite Element Method, the mechanical model of the process, was designed with the help of the COSMOS program, model based on the characteristics of the elements used to perform the experiment itself. This model, designed in a two-dimensional space, consists of the following elements [9]:

1- mobile board;
2- motherboard;
3- attenuator;
4- explosive.

In this model it is assumed that the detonation is initiated on the left edge of the explosive, simultaneously with all the thickness.

It was found that the explosion cladding process can be controlled by two important parameters, namely: the impact speed and the collision angle.

The mechanical model adapted for the process of explosion cladding does not appeal to simplifying assumptions, which makes it apt for a more accurate analysis of the quantities that intervene in the process.

Because the properties of explosives used in explosion cladding are known, as well as the laws governing the phenomenon of their transformation into detonation products in plasma-containing gaseous form and then release of energy through relaxation, relaxation, from the thermodynamic study of the problem, only the isotropy of the detonation products was retained, this being expressed by "law gamma" in the form [10]:

$$p = p_0\left(\frac{v_0}{v}\right)^{\gamma} \qquad \textbf{(5)}$$

in which p_0 and v_0 are the state quantities (pressure and specific volume) of gases at the moment of detonation, and p and v are the state sizes at a given moment.

For the γ exponent, a linear variation was adopted that starts from the adiabatic index value of 1.4 to the ambient pressure and reaches the maximum value for the detonation pressure.

The finite elements are interconnected in points called nodes and whose complexity is given by the number of the latter. Each node is associated with an interpolation function whose properties can be synthesized as follows:

- in the node to which it is associated it has the value 1;
- it has the value of zero in the other nodes;
- is defined null on all elements that are not connected in the node considered.

The simulation of the realization of the welded joint was made by introducing at the interface special elements of capture, and, which become active when a node on the lower surface of the movable plate contacts an element on the upper surface of the motherboard and has a higher speed than minimum welding speed. Otherwise, although the contact between the two plates is made at that point, the connection between the two materials is not established.

The main working parameters of the explosion plating process followed in numerical simulation using the finite element method were limited to:

- the speed of the mobile board on impact;
- angle of collision;
- pressure on the mobile plate.

The second important condition for the realization of welding is related to the angle of collision. For the combination chosen in this paper it is assessed by comparison, that the minimum value of the collision angle is 7^0 [11].

From the numerical solution obtained by simulating the explosion plating process using the Finished Elements Method, the distorted shape of the movable plate (**fig.4**) on which the slopes are determined on the intervals can be retained.

Since in the vicinity of the impact point the calculated slope (the collision angle) is $17,5^0$, it can be concluded that the condition of the minimum collision angle is also satisfied. The slope was appreciated by the average value of the slopes on the intervals adjacent to the collision point.

Having the two determined sizes, the impact speed with the value of 600...700m/s and the collision angle with the value of $17,5^0$ can also be approached the condition of the maximum welding speed, the, limited to the speed of sound.

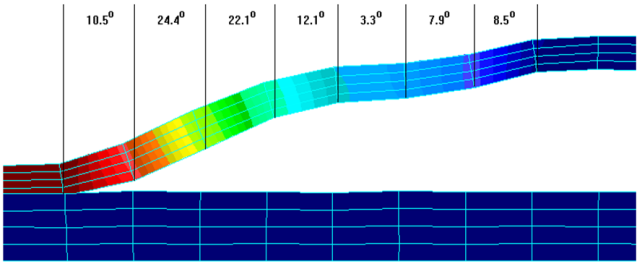


Fig.4 Moving of the movable plate and dynamic collision angle

Another parameter that influences the quality of the joint is the maximum pressure and its evolution over time at the level of the surface of the movable plate.

In **fig.5** [9] is represented the pressure field in detonation products at a certain time after reaching the stationary regime.

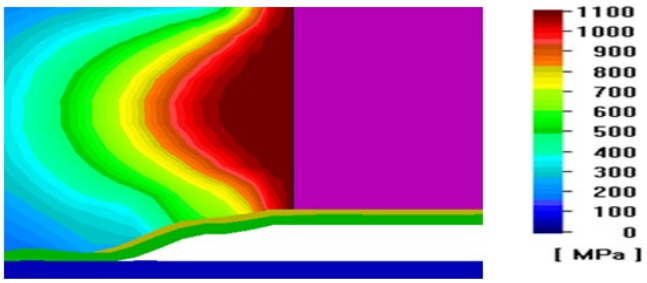


Fig.5 Pressure field in detonation products

RESULTS

The experimental technological system with the main components prior to their installation in order to obtain the assembly necessary to perform the explosion plating operation is presents in **fig.6.** Thus, on the figure can be identified the detonating staple, spacers made of granular colloidal powder, the assembly of the explosive charge, the attenuating plate as well as the base plate.

Amatol was used as an explosive scuff used to make plating, which is obtained from a mixture of trinitrotoluene ($C_7H_5N_3O_6$), also called TNT and ammonium nitrate (NH_4NO_3).

The presence of oxygen around ammonium nitrate has the effect of increasing the explosive power of TNT during detonation.

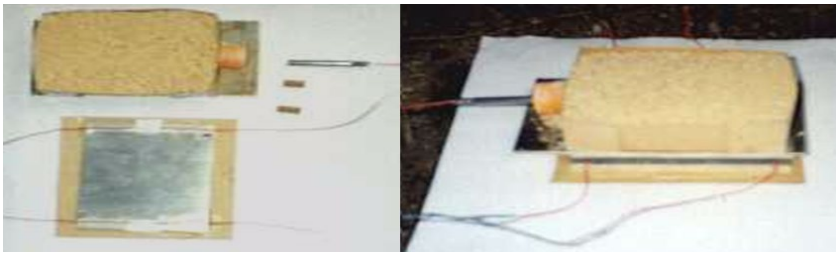


Fig. 6 Main components of the technological system used in cladding experiments

In order to achieve multilayer metal structures with special properties, it was tried to obtain with the explosion cladding process a layered metal material having as base aluminum alloy plates, aluminum alloy plates, with a thickness of 3 mm.

Thus, in the stereomicroscopic image of **fig.7**, the way in which the welding of plates was carried out, but also the presence of stainless steel fabric between the welded plates, is distinguished. It can be seen how the welding of the plates was carried out around the stainless steel fabric between the plates [10].

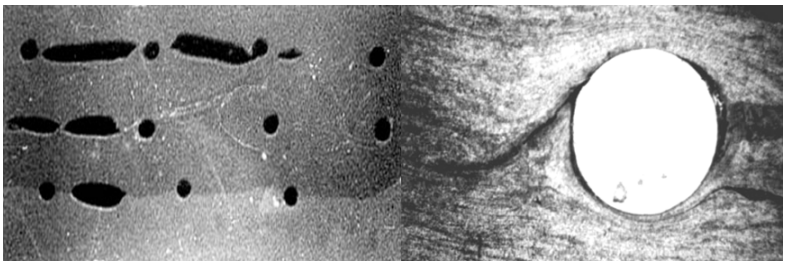


Fig. 7 Stereomicroscopic image of a plated structure

DISCUSSION

It is well known that the application of classical welding methods, besides the advantages it presents compared to other mechanical joining methods, also has a number of disadvantages with negative environmental implications.

Thus, if large quantities of residues, smoke and ultraviolet rays are removed during classical welding, which are dangerous for both humans and the environment by using the explosion plating process, these shortcomings with a negative impact on the environment are removed.

CONCLUSION

Knowing the scientific and practical importance of unconventional methods of obtaining layered materials with special properties and destinations presented during this work, it is considered appropriate to emphasise fundamental and applied scientific research in this field.

The management of the concerns towards this unconventional process of obtaining multilayer structures is due to the fact that from an economic and commercial point of view it is advantageous compared to the classical technological processes.

From the presented, the unconventional character of the method is detached, which has as its defining element the hydrodynamic behavior of the plates to be welded.

At the same time, it was emphasized the importance of using explosive materials to obtain start-up structures with special properties. Thus, it is deduced both the complexity of the phenomenon from the point of view of the specific parameters to be taken into account, but also the simplicity of the process considered as a whole.

The use of the Finite Element Method also allowed the interpretation of the phenomenon according to the variation of some parameters during the realization of the cladding process such as the variation of the collision angle β at different time intervals.

From what is presented in this paper, the importance of mathematical modeling of the mentioned process is clear, which allows an in-depth study on specific parameters, because studying them is much more difficult sometimes impossible, if only the experimental part is considered.

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THE IMPACT OF GEOTHERMAL HEATING PLANTS ON GREENHOUSE GAS EMISSION REDUCTION AND AIR QUALITY IMPROVEMENT

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ABSTRACT

In the context of the urgent need to combat climate change, renewable energy sources, such as geothermal energy, play a crucial role in reducing greenhouse gas emissions. This study examines the ecological impact in the form of avoided emissions for five geothermal heating plants located in Poland. The analysis included emissions of CO_2, SO_2, NO_x, CO, benzo(a)pyrene, and particulate matter (PM_{10} and $PM_{2.5}$), considering three reference scenarios based on conventional fuels: hard coal, high-methane natural gas, and heating oil. The calculations were based on emission factors for fossil fuels and annual geothermal heat production values. The results demonstrated that geothermal heating plants significantly reduce carbon dioxide emissions, one of the key greenhouse gases. Additionally, a substantial reduction in other pollutants was observed, confirming the positive impact of geothermal technologies on both the environment and public health. The findings indicate that geothermal energy is an effective tool in combating climate change, while simultaneously contributing to air quality improvement and supporting sustainable development.

Keywords: geothermal energy, greenhouse gas emissions, air quality, emission reduction, sustainable heating

INTRODUCTION

The growing global focus on reducing greenhouse gas emissions and addressing climate change underscores the urgent need to transition to renewable energy sources. Among these, geothermal energy stands out as a promising alternative, offering substantial environmental benefits and significantly reducing reliance on fossil fuels. Fossil fuel-based energy sources contribute substantially to pollution, affecting public health and exacerbating global warming, environmental degradation, and air quality deterioration [1].

This study examines the environmental benefits derived from emission reductions achieved by replacing fossil fuels with geothermal energy. In renewable energy projects, such as geothermal systems, environmental benefits can be quantified through "ecological effect" indicators, representing the annual volume of avoided emissions, calculated based on the elimination of conventional fuels and their respective emission factors (EF) [2]. Given the magnitude of emissions and their detrimental impact on the environment and public health, particular emphasis is placed on emissions of CO_2, CO, SO_2, NO_x, particulate matter, and benzo(a)pyrene [3].

Given the need to implement more sustainable heating technologies, this study aimed to evaluate the environmental impact of five geothermal heating plants located in Poland. It is important to note that, seven geothermal heating plants are operational within the country, nevertheless only five provided data on their annual geothermal heat

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production, which formed the basis of this analysis. The assessment focused on comparing the hypothetical emissions that would have been generated by burning fossil fuels—such as hard coal, natural gas, and fuel oil—against the emissions avoided through the use of geothermal energy. By considering different scenarios for fossil fuel combustion, key pollutant emissions were estimated, allowing for a quantitative demonstration of the environmental benefits associated with geothermal energy. This study not only illustrates the impact of geothermal energy on improving air quality but also emphasizes its potential role in mitigating the negative effects of the energy sector on the environment.

MATERIALS AND METHODS

Emission quantities (E) depend on the type, amount, and parameters of the fuel used: calorific value (CV), sulfur content, and the efficiency of the dust removal device (if present in the technological system). CO_2 emissions were calculated based on the Formula 1 [4]:

$$E = EF \cdot P \tag{1}$$

where:

E – emission magnitude [kg],

EF – CO_2 emission factor for the given calorific value [kg/GJ],

P – Total annual geothermal energy production or energy required for water heating [GJ].

The emission quantities of SO_2, NO_x, and CO were calculated using Formula 2 [2]:

$$E = B \cdot EF \tag{2}$$

where:

E – emission magnitude [kg],

B – amount of fuel combusted for fuels: solid [t/year], gaseous and liquid [m^3/year],

EF – emission factor for fuels: solid [kg/t], gaseous [kg/m^3], liquid [kg/m^3].

The emission amounts of PM_{10}, $PM_{2.5}$, and benzo(a)pyrene were calculated based on Formula 3 [5]:

$$E = \frac{B \cdot CV \cdot EF}{1\,000\,000} \tag{3}$$

where:

E – emission magnitude [kg],

B – amount of fuel combusted [t/year] or [thousand m^3/year],

CV – calorific value [kJ/kg] or [kJ/m^3],

EF – emission factor [g/GJ].

It was assumed that the coal-fired installation is equipped with a mechanical grate boiler with a thermal capacity of 3–12 MW, the gas installation uses a boiler with a thermal capacity of 2.5–30 MW, and the oil-fired installation employs a boiler with a thermal capacity of 5.5–30 MW.

Table 1. Emission Factor (EF) values for the analysed fuels [2], [4]

Pollution	EF	Indicator Unit
Hard coal (CV=22,28 MJ/kg)		
CO_2	94,81	kg/GJ
SO_2	16 · s	kg/t
NO_x	4	kg/t
CO	10	kg/t
Benzo(a)pyrene	$8,5 \cdot 10^{-4}$	g/GJ
PM_{10}	76	g/GJ
$PM_{2,5}$	72	g/GJ
Natural gas (CV=36,65 MJ/m³)		
CO_2	55,48	kg/GJ
SO_2	2 · s	$kg/10^6m^3$
NO_x	3700	$kg/10^6m^3$
CO	270	$kg/10^6m^3$
Benzo(a)pyrene	$8 \cdot 10^{-7}$	g/GJ
PM_{10}	0,5	g/GJ
$PM_{2,5}$	0,5	g/GJ
Fuel oil (CV=40,4 MJ/kg)		
CO_2	77,75	kg/GJ
SO_2	19 · s	kg/m^3
NO_x	5	kg/m^3
CO	0,5	kg/m^3
Benzo(a)pyrene	$1 \cdot 10^{-4}$	g/GJ
PM_{10}	2	g/GJ
$PM_{2,5}$	2	g/GJ

where:
s - total sulphur content in the combusted fuel [%]

The calculations assumed the maximum sulphur content as specified by current Polish legal standards. According to these regulations, the sulphur content for hard coal is limited to 1.7% [6], for natural gas it should not exceed 40.0 mg/m³ of fuel, approximately equivalent to 0.0027% [7], and for light fuel oil, it should not exceed 0.1% [8].

To evaluate the ecological impact, it is essential to determine the amount of fuel combusted. In the absence of direct fuel consumption measurements, the estimation was based on annual geothermal heat production data provided by heating companies (Table 2). These calculations enabled the determination of the quantity of conventional fuels — such as hard coal, natural gas, or fuel oil—that would be required to generate an equivalent amount of thermal energy if geothermal energy were replaced by conventional fuels. The amount of fuel combusted for each type of fuel was calculated as the ratio of annual geothermal heat production to the calorific value of the given fuel. Additionally, for fuel oil, a density of 0.85 g/cm³ was considered in the calculations.

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Table 2. Total annual geothermal heat production [GJ] for the analyzed geothermal heating plants

Geothermal company name	Total annual geothermal heat production [GJ]
Geotermia Mazowiecka	43086,00
Geotermia Poddębice	63405,00
Geotermia Pyrzyce	102691,00
Geotermia Stargard	319737,00
Geotermia Podhalańska	675873,00

RESULTS

Table 3 presents the calculated amounts of conventional fuels required to generate an equivalent amount of thermal energy as that produced by the geothermal heating plants.

Table 3. Calculated amount of conventional fuel required for heat production

Geothermal company name	Fuel amount per year		
	Hard coal [t]	Natural gas [m^3]	Fuel oil [l]
Geotermia Mazowiecka	1933,84	18441282,40	19681799,65
Geotermia Poddębice	2845,83	1730013,64	1254688,41
Geotermia Pyrzyce	4609,11	8724065,48	1846389,05
Geotermia Stargard	14350,85	1175607,09	2990419,34
Geotermia Podhalańska	30335,41	2801937,24	9310920,21

In 2023, replacing fossil fuels with geothermal energy in the analyzed heating plants resulted in significant environmental benefits. If these plants had relied solely on hard coal, their fuel demand would have reached 60 399,9 tons; for natural gas, 36 717,8 thousand cubic meters; and for fuel oil, 39 187,8 thousand liters. These results clearly indicate that the use of geothermal energy significantly reduces fossil fuel consumption, leading to a reduction in pollutant emissions (Table 4.) and positively impacting the environment.

Table 4. Calculated amounts of avoided pollutant emissions in relation to the analyzed fossil fuel variants

Geothermal company name	CO_2 [t]	SO_2 [kg]	NOx [kg]	CO [kg]	PM_{10} [kg]	$PM_{2,5}$ [kg]	benzo-(a)pyrene [kg]
Hard coal							
Geotermia	4084,98	52600,50	7735,37	19338,42	32745,36	31021,92	0,037
Geotermia Poddębice	6011,43	77406,46	11383,30	28458,26	48187,80	45651,60	0,054
Geotermia Pyrzyce	9736,13	125367,83	18436,45	46091,11	78045,16	73937,52	0,087
Geotermia Stargard	30314,26	390343,20	57403,41	143508,53	243000,12	230210,64	0,272
Geotermia Podhalańska	64079,52	825123,23	121341,65	303354,13	513663,48	486628,56	0,574
Natural gas							
Geotermia Mazowiecka	2390,41	0,01	4349,75	317,41	215,43	215,43	0,001
Geotermia Poddębice	3517,71	0,01	6401,05	467,10	317,03	317,03	0,000
Geotermia Pyrzyce	5697,30	0,02	10367,17	756,52	513,46	513,46	0,000
Geotermia Stargard	17739,01	0,05	32279,04	2355,50	1598,69	1598,69	0,000
Geotermia Podhalańska	37497,43	0,10	68232,74	4979,15	3379,37	3379,37	0,000
Fuel oil							
Geotermia Mazowiecka	3349,94	2383,91	6273,44	627,34	861,72	861,72	0,004
Geotermia Poddębice	4929,74	3508,14	9231,95	923,19	1268,10	1268,10	0,006
Geotermia Pyrzyce	7984,23	5681,80	14952,10	1495,21	2053,82	2053,82	0,010
Geotermia Stargard	24859,55	17690,75	46554,60	4655,46	6394,74	6394,74	0,032
Geotermia Podhalańska	52549,13	37395,42	98409,00	9840,90	13517,46	13517,46	0,068

For the analyzed data for 2023, emissions resulting from the hypothetical use of conventional fuels would amount to, in the case of hard coal: 127 586,7 tons of CO_2, 1 642 876,3 kg of SO_2, 241 599,5 kg of NO_x, 1 022 730,0 kg of PM_{10}, 968 910,5 kg of $PM_{2.5}$, and 1,144 kg of benzo(a)pyrene.

For the natural gas variant, the projected emissions would reach 74 659,9 tons of CO_2, 0,21 kg of SO_2, 135 856,0 kg of NO_x, 9 913,8 kg of CO, 6 728,6 kg of PM_{10}, 6 728,6 kg of $PM_{2.5}$, and a minimal amount of 0,001 kg of benzo(a)pyrene.

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In the case of fuel oil, the estimated emissions would be 104,628.9 tons of CO_2, 74 456,8 kg of SO_2, 195 939,0 kg of NO_x, 19 593,9 kg of CO, 26 914,2 kg of PM_{10}, 26 914,2 kg of $PM_{2.5}$, and 0,134 kg of benzo(a)pyrene.

The results indicate that the use of geothermal energy, compared to conventional fuel-based options, leads to a substantial reduction in emissions of CO_2 and other pollutants, such as SO_2, NO_x, particulate matter (PM_{10} and $PM_{2.5}$), and benzo(a)pyrene. This highlights the environmental benefits of replacing fossil fuels with a renewable energy source.

DISCUSSION

The conducted analysis clearly demonstrates that the highest amount of avoided emissions originates from coal-fired boilers, while the lowest is associated with natural gas systems. This is primarily due to the differing chemical compositions of fuels and the varying combustion efficiencies of each, which directly impacts their emission reduction potential when utilizing geothermal energy.

Hard coal, due to its high carbon content, requires a significantly greater supply of air during combustion compared to natural gas or fuel oil. As a result, burning coal produces substantial quantities of CO_2 and other pollutants, such as SO_2, NO_x, CO, and particulate matter [9]. Sulphur dioxide (SO_2) is a particularly harmful pollutant, when combined with water vapor in the atmosphere, it forms sulfuric acid, a primary contributor to acid rain. Additionally, coal contains numerous organic compounds, including polycyclic aromatic hydrocarbons (PAHs), which can partially transform into benzo(a)pyrene during incomplete combustion. The combustion process for coal is generally less efficient than for other fuels, which facilitates the emission of this compound. Benzo(a)pyrene, commonly associated with low-level emissions, is a highly carcinogenic and mutagenic compound that poses a serious health risk [10].

Combustion of natural gas requires less air than coal due to its lower carbon and higher hydrogen content. Consequently, natural gas emits significantly fewer pollutants compared to coal and fuel oil [11]. One of the primary advantages of natural gas is its approximately 40% lower CO_2 emissions (Table 4), a key greenhouse gas responsible for global warming. Although the combustion of natural gas does produce notable quantities of nitrogen oxides (NO_x), emissions of SO_2 and particulate matter remain relatively low. However, it is important to note that insufficient air supply can lead to the formation of volatile hydrocarbons, which adversely affect health and contribute to smog formation.

Petroleum-based fuels, such as fuel oil, consist primarily of heavy hydrocarbons, characterized by a higher hydrogen and lower carbon content relative to solid fuels. Combustion of fuel oil requires less air, resulting in lower CO_2 and CO emissions with similar levels of NO_x and SO_2 [9]. Fuel oil is considered cleaner than coal, as it contains lower amounts of sulphur compounds, nitrogen, and heavy metals, which contribute to larger particle and fine particulate emissions. Consequently, fuel oil combustion produces smaller amounts of PM_{10} and $PM_{2.5}$ particulates. Nonetheless, in terms of combustion cleanliness, fuel oil is outperformed by natural gas, which has the lowest pollutant emission levels among the analyzed fuels, making it one of the more environmentally sustainable options among fossil fuels.

In light of the obtained results, it can be concluded that the use of geothermal energy as a substitute for fossil fuels demonstrates particularly significant environmental benefits. The reduction of CO_2 emissions, one of the principal greenhouse gases driving global warming, is a critical achievement in combating climate change. Through the adoption of geothermal energy, the analysed heating plants have avoided emitting tens of thousands of tons of CO_2 (Table 4), which would otherwise have been produced through the combustion of fossil fuels. This reduction directly contributes to lowering the carbon footprint and supports both national and international climate protection commitments. In regions with high emission levels from conventional heat sources, replacing fossil fuels with geothermal energy could lead to a substantial decrease in overall CO_2 emissions, potentially slowing the rate of global temperature increase in the long term.

The conducted analysis also demonstrated that utilizing geothermal energy in heating systems enables effective reduction of SO_2 and NO_x emissions, directly contributing to decreased acid rain risk and improved air quality, with positive impacts on local ecosystems and the agricultural sector. This reduction in emissions mitigates the environmental impact of energy activities, promoting biodiversity conservation and the stability of soil ecosystems.

Furthermore, the analysis indicated a substantial decrease in PM_{10} and $PM_{2,5}$ particulate emissions, which pose significant public health risks. Reducing these particulate emissions potentially enhances residents' quality of life by lowering the risk of respiratory and cardiovascular diseases [12]. This underscores the health benefits associated with the development of geothermal energy in the heating sector.

Although the share of benzo(a)pyrene in total emissions is relatively low, the analysis demonstrated that geothermal energy use significantly reduces this harmful compound. Due to its carcinogenic and mutagenic properties, benzo(a)pyrene poses a serious health risk, especially in areas with high air pollution concentrations [13]. Reducing its emissions may help lower the risk of cancer and chronic respiratory diseases.

The continued expansion of the geothermal heating sector will yield long-term environmental and health benefits. Data analysis from 2023 suggests that increasing geothermal energy’s share in heating systems is a crucial step toward reducing pollutant emissions and improving air quality, particularly in regions with high emissions from conventional fossil fuels.

CONCLUSION

The applied emission factors and calculations enabled a quantitative assessment of the emissions avoided for various fossil fuels, thereby clearly illustrating the differences between the analyzed geothermal heating plants and hypothetical systems based on hard coal, natural gas, and fuel oil. The results unequivocally confirmed the hypothesis that geothermal energy offers substantial environmental benefits.

The calculations demonstrated that the use of geothermal energy in heating significantly reduces atmospheric pollutants, including CO_2, SO_2, NO_x, CO, particulate matter (PM_{10} and $PM_{2.5}$), and benzo(a)pyrene, supporting climate targets and enhancing air quality. These effects align with legal regulations imposing emission reduction obligations on the energy sector. The particularly high avoided emission levels for fuels with high emission potential, such as hard coal, underscore the importance of further development

and implementation of geothermal heating, positioning it as a viable alternative to fossil fuels, with reduced environmental and public health impacts from the energy sector.

Nevertheless, in future research it would be worth focusing on assessing the long-term impact of reduced emissions on residents' health and quality of life in areas neighboring geothermal heating plants. This analysis would provide detailed insights into the health-related benefits of decreased harmful emissions, with particular emphasis on improvements in air quality and the reduction of chronic population exposure to pollutants associated with traditional fossil fuels.

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SECTION

ECOLOGY, BIODIVERSITY, AND ENVIRONMENTAL PROTECTION

AUTOMATIC URBANISATION MONITORING FOR RISK ASSESSMENT BY REMOTE SENSING AND COPERNICUS DATA – A PRELIMINARY RESEARCH

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ABSTRACT

Rapid urbanization increases the vulnerability of cities to natural hazards, especially earthquakes, as unplanned growth can aggravate structural risks and strain infrastructure. This research is based on a project "Automatic urbanization monitoring for risk assessment by remote sensing and Copernicus data" which aims to improve the detection of urban growth patterns and identify areas with increased seismic vulnerability. This project's main goal is to develop and test a prototype for automatic urbanization monitoring for risk assessment aided by remote sensing and Copernicus data for fast and accurate data acquisition and to provide improved risk assessment for the study sites in Croatia. The development of an automatic system for urbanization monitoring for risk assessment will enable the acquisition of accurate and current spatial and attribute data of buildings, such as building construction year. Using advanced image processing and machine learning techniques, the system analyses Earth observation satellite data to map urban extent, assess changes in land use, and identify critical areas where rapid growth may affect structural stability. This preliminary research demonstrates an algorithm for building construction year detection from Earth observation (EO) data. This research utilized Sentinel-2 imagery to extract building construction years for Trešnjevka sjever in Zagreb, Croatia. The preliminary results are promising, demonstrating that Earth Observation (EO) data, specifically Sentinel-2, can effectively assess building construction year. This approach is adaptable to other locations worldwide and, as EO data, other satellite missions can be used like Landsat, PlanetScope, etc. The automated method offers valuable insights for urban planners and policymakers, supporting proactive disaster preparedness and enhancing urban resilience.

Keywords: remote sensing, risk assessment, Earth observation, urbanization

INTRODUCTION

The rapid pace of urbanization is increasingly exposing cities to natural hazards, with earthquakes posing a significant threat [1-2]. Unplanned growth in urban areas can exacerbate structural vulnerabilities and place considerable strain on infrastructure, heightening seismic risks [3-4]. This research stems from the project "Automatic urbanization monitoring for risk assessment by remote sensing and Copernicus data",

which aims to enhance urban growth detection and pinpoint areas with elevated seismic vulnerability. Implementing seismic risk mitigation strategies and emergency response and disaster planning are of the utmost importance, as earthquakes cannot be prevented and may occur with particular probability at any time. Despite the substantial scientific and technological progress in the field of earthquake engineering, destruction of the built environment, often with many fatalities and enormous economic losses, still occurs as a consequence of high-intensity earthquakes (e.g., Kobe 1995, Athens 1999, Turkey 1999, Tohoku 2011, Gorkha 2015). Observing the Southeast European region, Croatia belongs to the Mediterranean-trans Asian high-seismic activity zone and is one of the most vulnerable countries (Figure 1) [5]. The coastal area and northwest are the most exposed regions to earthquakes [6].

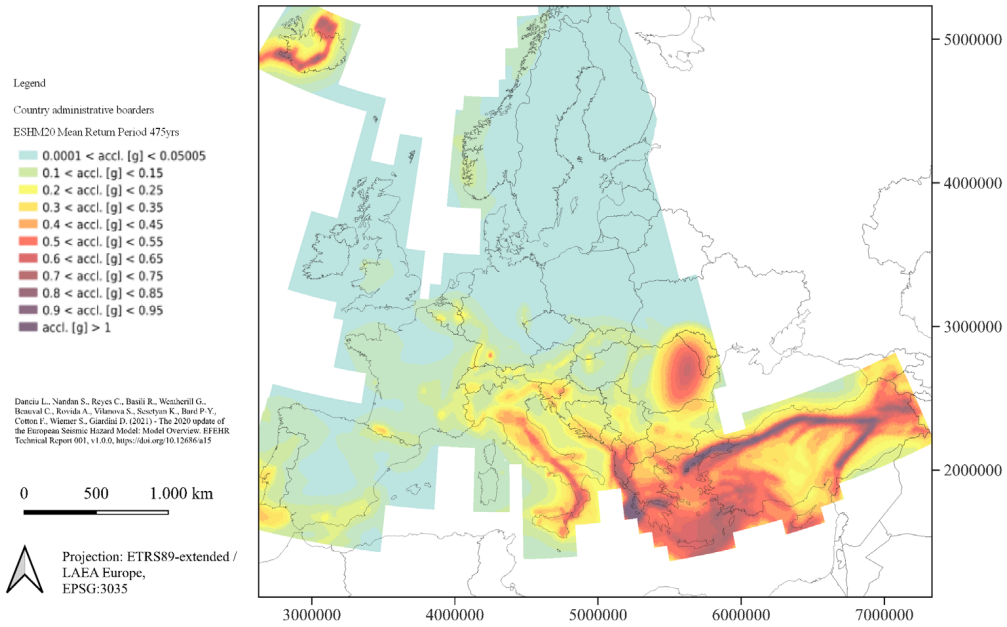


Figure 1. European Seismic Hazard Model [5].

The regions of highest seismic activity in Croatia are also the areas with the largest population and notable economic and social importance (e.g., regions of Zagreb, Split, Dubrovnik, and Rijeka): more than 30% of the area, or about 60% of the population, is exposed to stronger earthquakes with the expected catastrophic consequences [7]. It is important to point out that middle-income countries, such as Croatia, are usually the most affected by natural disasters concerning their direct losses in the percentage of GDP [8].

The main goal of this research is to develop an algorithm for automatically extracting buildings' construction year from remote sensing data for better earthquake risk assessment.

MATERIALS AND METHODS

The two most important variables for risk assessment are construction year and building height. Both variables can be assessed by Earth observation (EO) data. Below is a detailed explanation of the integration of these two variables into the overall seismic risk assessment model.

The seismic risk assessment consists of 3 main parts. These are seismic hazards, exposure and vulnerability of the building stock. To determine the vulnerability of buildings, it is necessary to have a certain set of data or attributes. Different methodologies approach vulnerability assessment with different accuracy, and this depends on the available data in the observed area. However, one of the indispensable and most important data are the year of construction and the height of the building.

- The year of construction is directly related to the regulations according to which the building was designed and built and says a lot about the quality of construction and deficiencies in the structure of the building. The building stock is classified into periods in which certain regulations and construction techniques were valid. These periods are different for each country. Thus, the year of construction of the building will modify its vulnerability curve and directly affect its seismic risk.
- Building height is also an essential attribute that has multiple applications. The application is reflected in the choice of the building's fragility curve and indirectly also in the building's vulnerability curve. There are ready-made curves for certain types of buildings in the literature and databases on building vulnerability curves. The height of the building also plays a crucial role in the dynamic parameters of the building, such as the natural period of the building's vibration. Based on it, it is possible to approximately evaluate the total seismic force on the structure for a specific seismic hazard at the location.

This preliminary research will present a building construction year detection algorithm. The study area for this preliminary study was defined as one part of the City of Zagreb (Figure 2). The study area (AOI) has ~500 ha and is internally called Trešnjevka sjever. The algorithm was based on building vector data acquired from the State Geodetic Administration from the Digital Cadastral Plan and Basic Topographic Database, as well as historical aerial imagery and Digital orthophoto maps. Furthermore, OSM buildings were used as well. All building vector data were integrated into one building layer.

For accuracy assessment data Google building year (GBY) and field measurements were used. Google building year (GBY) is a technology featured in Google Maps and Google Earth that provides interactive panoramas from positions along many streets in the world. Streets with Street View imagery available are shown as clickable blue lines on Google Maps [9]. Google building year (GBY) data were acquired for the purpose of verification and validation algorithm for building construction year determination prototyping. GBY data were acquired for the entire study area using random sampling. For each GBY, a location in the WGS84 reference coordinate system and PNG screenshots of pre and after-building construction were saved (Figure 3). From Google historical imagery, the exact building construction year was determined.

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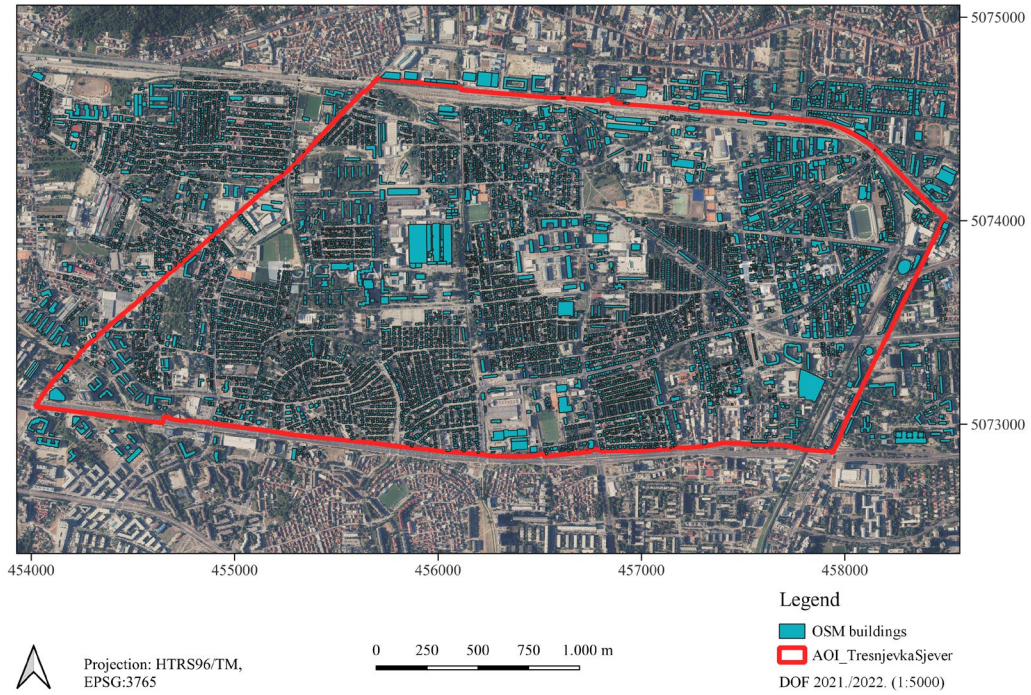


Figure 2. Study area Trešnjevka sjever located in the City of Zagreb, OpenStreetMap (OSM) buildings data and Digital orthophoto map 2021/2022 from State Geodetic Administration.



Figure 3. Google building year measurements examples for location Rabarova ul. 1b.

Algorithms were developed using spatio-temporal analysis of the Sentinel satellite imagery. Satellite images are multiband rasters, where every band has a certain wavelength of electromagnetic spectrum. Combining multiple wavelengths gives data for making decisions and conclusions using spectral indices to magnify different objects and phenomena. For this study, vegetation indices such EVI2 (Two-band enhanced vegetation index) [10], SAVI (Soil-adjusted vegetation index) [11], NDVI (Normalized difference vegetation index) [12] were used, and building indices NDBI (Normalized difference built-up index) [13] and BUI (Built-up Index) [14] (Figure 4). The algorithm was developed using previous research on land spatio-temporal analysis and land cover change detection [4,15].

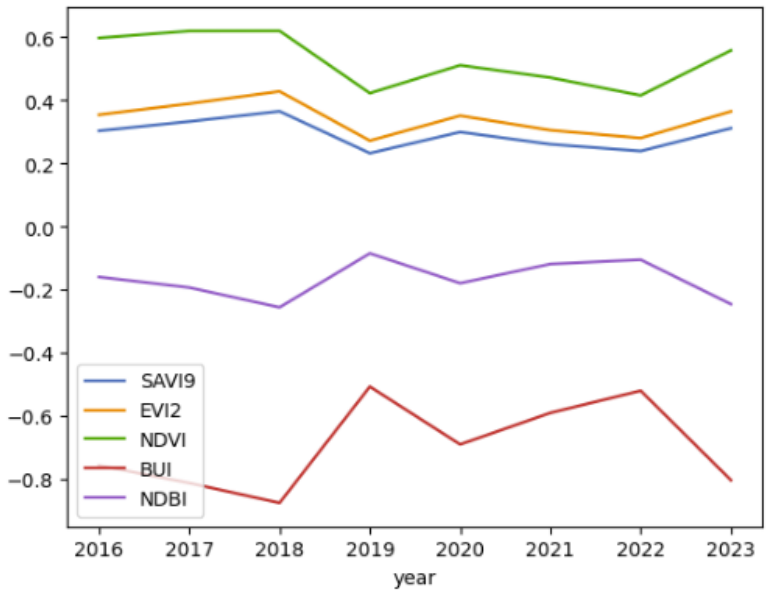


Figure 4. Vegetation (EVI2, SAVI, NDVI) and building spectral indices (NDBI, BUI) used for building construction year assessment.

As seen in Figure 4, there is an indication of the year where a spatial change happened. For final algorithm development, the EVI2 vegetation index and BUI building index were chosen, while they have less oscillation and anomalies, eliminating systematic errors. Across all accuracy assessment datasets, chosen indices showcase changes without spike errors in data.

RESULTS AND DISCUSSION

Preliminary research of the final algorithm was developed using EVI2 and BUI spectral indices, for example, building (Figure 5).

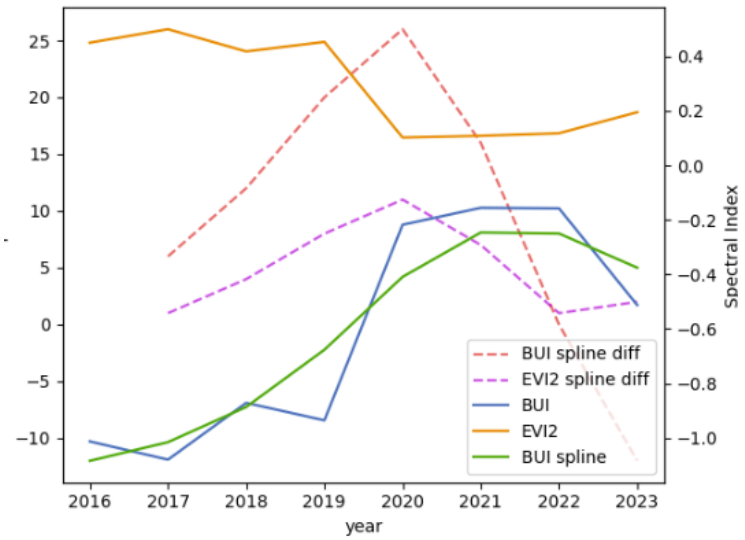


Figure 5. Building construction year detection using EVI2 and BUI spectral indices for example building. The detected year was 2020.

The developed algorithm was preliminary tested on the entire study site using Sentinel 2 imagery, and the results are shown in Figure 6.

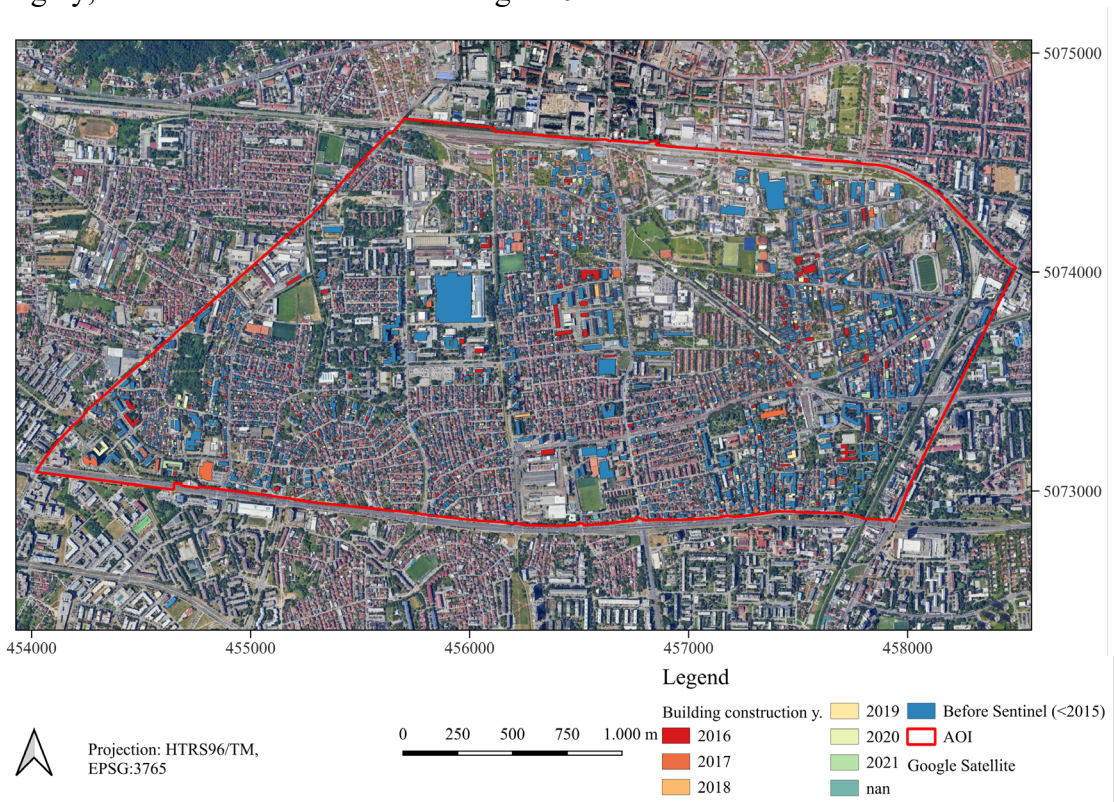


Figure 6. Preliminary results of building construction year detection using Sentinel 2 imagery.

The results of this preliminary research are promising and show very acceptable results using EO data, in this case, Sentinel 2, for the purposes of assessing the building construction year.

CONCLUSION

This research demonstrates the potential of automated urbanization monitoring for assessing seismic vulnerability in rapidly growing urban areas. By leveraging remote sensing and Copernicus satellite data, the project has developed a prototype system that provides timely, accurate spatial and structural data crucial for effective risk assessment. Results show an algorithm for building construction year detection from EO data. In this preliminary research, Sentinel 2 imagery was used for extraction building construction year for the study site Trešnjevka sjever in Zagreb, the capital of Croatia. Building construction year is an important variable for better earthquake risk assessment. The results of this preliminary research show promising and very acceptable results using EO data, in this case, Sentinel 2, for the purposes of assessing the building construction year. Preliminary research can be used for building year detection on other locations around the globe, and as EO data, other satellite missions can be used, e.g., Landsat, PlanetScope, etc. This automated, scalable approach offers valuable insights for urban planners and policymakers, enabling proactive disaster preparedness and contributing to the resilience of urban environments.

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ECOTOURISM AND ECO-FRIENDLY ACCOMMODATION AS ADAPTATION PRACTICES FOR CLIMATE CHANGE MITIGATION

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ABSTRACT

Nowadays, tourism represents a kind of environmental consumption, and tourists account for a significant proportion of consumption. Tourists therefore play an important role in developing or negatively affecting sustainable tourism. Eco-friendly accommodation, designed to reduce the negative environmental impacts of tourism become increasingly popular worldwide. Although the popularity of eco-friendly hotels has increased, the actual stays in such hotels are relatively short. The impacts of the tourism system on nature, tourist facilities, attractions and tourist habits require systematic research, with the main focus on the causes and consequences of and solutions to environmental problems. Ecotourism is also one of the research areas of environmental sociology, and eco-friendly accommodation represents part of ecotourism. Research into the behaviour of tourists towards, for instance, eco-friendly accommodation, can provide policymakers with relevant information to design new adaptation strategies to mitigate the economic impacts of climate change. The present research aims to analyse tourist practices for mitigating climate change impacts through eco-friendly accommodation based on case studies examined in Latvia.
Keywords: ecotourism, environmentally friendly accommodation, sustainability, tourist habits

INTRODUCTION

Previous research studies have found that international tourism due to an increase in tourist arrivals, increases energy consumption, carbon dioxide (CO2) emissions and air pollution, leading to climate change. For example, South Asian countries, particularly Sri Lanka and Pakistan, are on the verge of environmental pollution because of tourism growth, compared with other countries. The number of international tourists rose from 25 million in 1950 to 166 million in 1970 and reached 1.442 billion in 2018. By 2030, the number of international tourists is projected to reach 1.8 billion. Despite the positive effects in terms of employment and economic growth at destinations, such a significant increase in the number of tourists is likely to lead to even more environmental pollution [1]. Tourism growth or environmental sustainability must therefore be perceived as interdependent constructs. Tourism is a dynamic force that stimulates travel to explore nature, discover cultures, meet people and experience new traditions and events. The world is under threat in the environmental sector, and people are responsible for global environmental problems and they also have the capacity, opportunity and responsibility to eliminate the damage to nature.

Focusing on the environmental impacts of tourists, British sociologist E.Giddens created a theory of social change, arguing that for any given action, the individual is "guilty" in the sense that s/he could act differently at any moment during that action [2]. Because of the environmental impacts of tourism, more attention is being paid to conservation measures, one of which is the promotion of ecotourism. Ecotourism is one of the kinds of tourism that involves environmentally friendly accommodation. Ecotourism is a phenomenon that contributes to environmental sustainability through well-planned and careful destination management that can balance conflicting business practices and environmental sustainability interests. Ecotourism aims to minimise the environmental impacts of the areas visited by tourists. The mission of ecotourism is not only to promote respect for the natural environment and educate tourists but also generate socio-economic benefits for the communities of the areas where ecotourism products are supplied. However, it should be noted that tourists represent the central element of the tourism system, and all its elements – transport, hotel catering and entertainment – are directed towards meeting their needs and changes in demand. This also applies to ecotourism and environmentally friendly accommodation. It is therefore important to focus on the role of environmental conservation also from a sociological perspective and analyse the interaction of society with the environment and identify tourists' perceptions of this role today. The authors believe that the largest obstacle to an environmentally friendly lifestyle nowadays is a lack of knowledge about the environment, the value system regarding the environment, and therefore the present research puts forward a hypothesis: for most of the Latvian tourists, the choice of environmentally friendly accommodation is irrelevant and the criteria are unclear. To achieve the research aim, the authors focused on examining the paradigm of eco-friendly accommodation and Latvian tourists' habits and perceptions in the context of eco-friendly travel.

MATERIALS AND METHODS

To mitigate climate change impacts by means of eco-friendly accommodation, document analysis was employed to analyse tourist practices. The analysis of documents, research papers available in the public domain gave an insight into the conceptual framework of the research problem. The research analysed information on requirements for and certification of eco-friendly accommodation in the world and in Latvia. The following keywords were selected for a search: eco-friendly accommodation, eco-travel website, sustainable travel and criteria for eco-friendly accommodation.

A quantitative research approach was applied to identify the opinions of tourists, conducting an indirect questionnaire survey. The survey was conducted electronically, and its structure was based on the findings of the content analysis on eco-friendly accommodation practices. The respondents were selected based on non-probability sampling and convenience sampling, depending on their availability. More than half of the tourists surveyed represented employees (54%), 27% were self-employed, 9% were students, 6% were unemployed and 4% were retired. More than half (52%) of the respondents had a university degree, 38% had secondary or special secondary education and 10% had incomplete higher education.

This sample distribution was close to that found by the annual tourism survey conducted in Latvia, as women (55.5%), individuals aged 25-34 (21.6%), those with higher education (49.3%) and the employed (73.1%) were more likely to go on local tourism multi-day trips [3].

RESULTS AND DISCUSSION

An analysis of documents on eco-friendly accommodation and sustainable travel revealed that such accommodation needs to meet a variety of criteria. Eco-friendly accommodation is an accommodation facility whose structure has undergone significant environmental improvements to reduce the impact on the natural environment. Accommodation owners are committed to reducing the carbon footprint through a range of sustainable practices, e.g. installing solar panels, reducing waste, favouring non-toxic and biodegradable cleaning products and reducing energy and water consumption. Besides, as regards tourist catering, the accommodation facility must reduce the environmental impact by buying local products to avoid excessive carbon emissions as much as possible as well as modernising its facilities and using alternative sources of energy. There are many ways to qualify for an environmentally friendly accommodation facility, but the economic benefits for the community are never ignored. An eco-friendly accommodation facility typically meets six criteria that shape a conceptual framework or paradigm reflecting the key characteristics of the facility (see Figure 1).

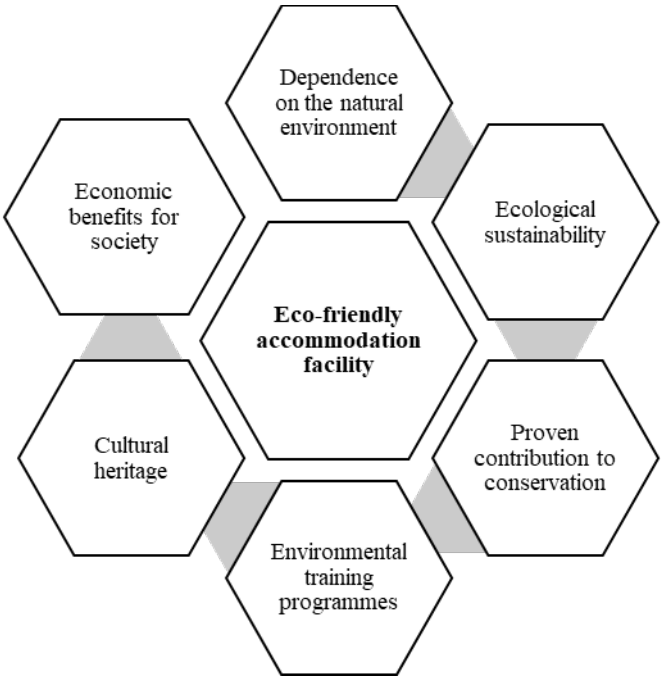


Fig. 1. **Eco-friendly accommodation paradigm**

There are various eco-travel websites around the world that make it easier to find this kind of accommodation. For example, Bookdifferent, a Dutch company founded in 2012, allows tourists to quickly browse one million affordable and responsible accommodation facilities worldwide. The website shows green indicators, including eco-labels, a carbon footprint calculator and a "staygreencheck" score to identify whether the accommodation facility is sustainable and eco-certified. This score is calculated based on four sustainability pillars: governance: effective sustainable management and compliance with the law, fairness and equal treatment of personnel and destinations; culture-friendly: respect for local traditions and care for nature and the environment [4]. It could be concluded that ecotourism and eco-friendly accommodation have their own quality management system with specific ways for controlling the quality of the product and

service, which involves the control of the technological stages of the final service and the control of meeting the quality standards both by the facility and its supplier companies.

A tourism company must identify the "stakeholders" who influence its activities. An important stakeholder in this context is tourists who are the consumers of eco-friendly accommodation services. The document analysis revealed that the websites offering eco-tourism conducted regular surveys. For example, Booking.com publishes a new report every year; in the 2023 Sustainable Travel Report, 80% of the tourists surveyed confirmed that "travelling in a more sustainable way was important to them", while 76% wanted to "travel more sustainably in the next 12 months". Regarding eco-friendly accommodation, 59% chose "those undergone sustainable certification" and 64% "would feel more comfortable in an accommodation facility if they knew it had a sustainability certificate or label". However, 39% of those surveyed said they did not trust sustainable travel labels. However, the 2022 survey results showed that 31% of the respondents did not know that sustainable accommodation even existed [5]. Therefore, the number of uninformed people was already 36% lower than that in the previous year. While this indicates the growing awareness and demand for sustainable destinations, it also reveals a large knowledge gap that still needs to be filled.

Green Key is one of the largest eco-labels in the hospitality industry worldwide and is currently awarded to more than 3200 hotels and other accommodation facilities in 65 countries. The eco-labelling programme [6] is based on five pillars, which are not substantially different from the eco-friendly accommodation paradigm discussed above:

1. Educating personnel, customers and owners to increase sustainability and environmental awareness at leisure facilities;
2. Preserving the environment by reducing the environmental impact of each facility globally;
3. Managing the facility economically by reducing consumption, which leads to lower costs;
4. The marketing strategy involves promoting the Green Key label and the institutions through the Green Key icon;
5. Contributing to the tourism and leisure industry by taking more responsibility.

Green Key has been awarded in Latvia under the supervision of the Environmental Education Foundation since 2008, and since April 2017 the Green Key eco-certification programme has been available to every environmentally conscious hospitality company and institution in Latvia. Green Key is one of the tools to reduce environmental impacts. To get Green Key, a tourist accommodation facility must meet more than 120 criteria in twelve categories: water, waste, energy, personnel involvement, use of chemicals, food and catering etc. The requirements to be met are divided into two categories: mandatory criteria and company management guidelines. The mandatory criteria are the basic ones that need to be met by a hotel to be certified and call itself environmentally friendly. The mandatory criteria mainly relate to infrastructure, resource savings, e.g. energy efficiency, energy consumption, water savings, waste sorting, food etc. The guideline criteria, as opposed to the mandatory ones, must be met at the time the accommodation facility qualifies for eco-certification.

The compliance of a hotel with the Green Key criteria in Latvia is assessed by three institutions: the Ministry of Environmental Protection and Regional Development, the Hotel and Restaurant Association and the Foundation for Environmental Education. The

following accommodation facilities in Latvia were awarded the Green Key eco-certificate at the beginning of 2024: Ventspils Seaside Campsite, Skrunda Manor House, Jaunmoku Palace Hotel, Dikli Palace Hotel, Baltic Beach Hotel, Avalon Hotel, Gallery Park Hotel & SPA, Radisson Blu (Daugava Hotel, Elizabete Hotel, Hotel Latvija, Ridzene Hotel). This leads to a conclusion that eco-friendly accommodation facilities are not only characteristic of ecotourism in rural areas. They could also be located in cities, which is even more positive, as it can slightly reduce urban pollution caused by tourism. For example, Radisson Hotel Group is one of the few hotel groups in the world with more than 450 hotels to have been awarded the Green Key certificate [7]. Radisson Hotel Group launched a Responsible Business Programme with three pillars: Think Planet, Think People and Think Together.

In Latvia, there is no certification system for high-quality ecotourism, but many related certificates are awarded to promote higher standards in the tourism business, such as the following logos: *Flower, Blue Flag, Latvian Eco-product, Latvian Rural Tourism Quality System, Green Certificate*.

Latvia has recently been focusing on nature conservation and if using its natural and cultural resources and traditions, the country can become an environmentally friendly tourist destination. Latvia has one of the highest proportions of forest in Europe (56.9%). In the rural areas of Latvia, food producers, as far as possible, develop local food systems, thereby supporting local farmers and suppliers of raw materials, as well as invest in environmental improvement and expand their output in an environmentally friendly way. This indicates that territorial communities become important players in fostering sustainable food systems, which involve also environmentally friendly accommodation. These processes are nowadays also influenced by discussions in the context of the European Green Deal and bioregions. As tourists, the residents of Latvia come from a country rich in natural resources, and one would expect that an environmentally friendly destination might not be a priority for them, as is also evident from information on websites giving advice for tourists. Where to seek cheap airline tickets? How to book a hotel? Should I choose booking.com or Airbnb? Should I buy travel insurance or not? The results of a survey conducted by the authors showed that most tourists of all age groups chose a day trip to travel around Latvia. Older tourists were more likely to travel for more than three days. Outside Latvia, 60% of 18-34-year olds, 63% of 35-54-year olds and 76% of 55+ year olds usually travelled for more than three days or took a longer holiday. Most of the respondents were more likely to travel within Europe because it was closer, more convenient and also cheaper. The most popular destinations were Bulgaria, Spain, Italy, Greece and France. Countries outside the European Union, such as Thailand, the United Arab Emirates etc., were less frequently mentioned. Almost all (93%) of the respondents travelled with their families, 5% travelled with friends and 2% travelled alone. Only 7% emphasised environmentally friendly travel, with nature tourism – animal and plant observation and ecotourism – being the main motivation. Of the total respondents, 43% preferred leisure tourism, i.e. spending free time in a relaxing way, 20% active and sports tourism, 17% cultural tourism, 7% entertainment tourism or enjoying nightlife, visiting amusement parks and shopping and 6% – business tourism and making professional contacts. A more detailed analysis of the survey data revealed that a relatively low proportion of the respondents spent eco-friendly holidays when travelling in Latvia, 3% of 18-34-year olds, 8% of 35-54-year olds and 13% of 55+ year olds always

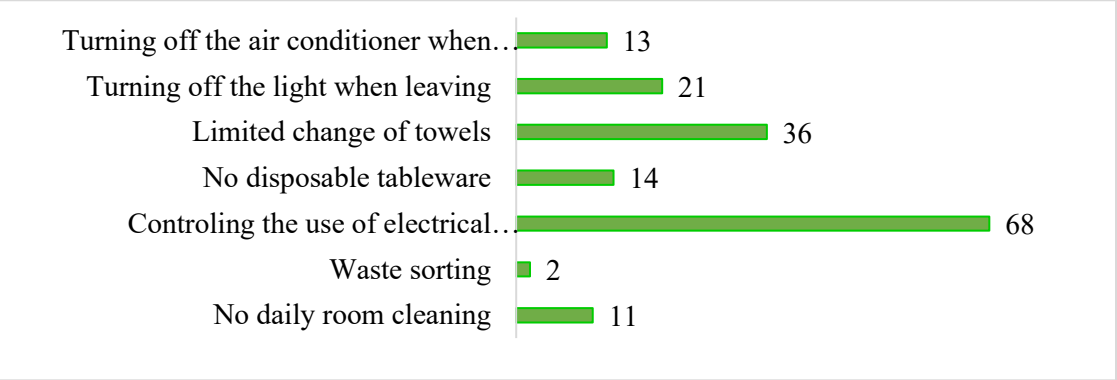
did so. Figure 2 shows both the respondents' practices and perceptions of environmentally friendly accommodation.



Source: authors' construction based on the survey

Fig. 2. **Opinions on the criteria for environmentally friendly accommodation (%)**

All the criteria for environmentally friendly accommodation, which were identified by the document analysis, were included in the survey answer options. However, the survey revealed that the respondents chose one or two criteria for environmentally friendly accommodation rather than all of them. An insufficient understanding of environmentally friendly activities while traveling was also confirmed by Figure 3.



Source: authors' construction based on the survey

Fig. 3. **Environmentally friendly practices at accommodation facilities (%)**

Overall, the survey on eco-friendly travel and accommodation did not show any significant differences in the opinions and experiences of travellers by age group or by occupation. Environmental problems cannot be separated from individual and collective responsibility, scale and potential future action; in this context, however, most of the Latvian tourists surveyed (77%) believed that environmentally friendly travel would be very important or important in the future, and only 2% considered that it would not be important. The tourism industry constantly seeks new ways and new products to attract customers, it is constantly evolving. The development of new tourism products also depends on the demand for them and the ability to sell them. The development of tourism products is impossible without research into the motivations and needs of tourists. By consuming tourism services, people satisfy their needs for leisure, entertainment,

education, health etc. Wilhelm Dilthey, in contrast, believed that the actions or behaviour of individuals cannot be fully examined and the uniform principles of behaviour cannot be established because it is impossible to capture all the unique historical circumstances that have influenced the development of individuals and societies. Both Kant and Dilthey believed that it was impossible to fully investigate the elements that influence individual behaviours [8]. Sociology, as a comprehensive discipline, can research various dimensions of tourism. Sociologically, in today's world, tourism seems to be a kind of environmental consumption. A significant part of this is consumed by tourists. Consequently, tourists play an important role in the development of sustainable tourism, as well as in the destruction of nature. The focus is on the relationship between society and the environment as a whole, with environmental sociologists generally placing particular emphasis on the study of the social factors that cause environmental problems, the impacts of the problems on society and efforts to solve the problems. Predicting tourist activities can also prevent environmental problems from occurring. By examining the behaviour of tourists towards the environment (e.g. local parks), policymakers are provided with relevant information to protect the parks [9]. The reasons for individual actions when travelling can vary, but can also be influenced by education and the promotion of environmentally friendly travel. German sociologist Max Weber's conclusions on human social behaviour emphasised an individual's subjective actions, which are influenced by the behaviour of others [8]. Ecotourism can focus on educating tourists about the natural environment, with an emphasis on ecological conservation. Some define ecotourism as an effort to create economic opportunities that make the conservation of natural resources financially feasible. However, one of the most overlooked aspects of ecotourism is the educational component. Social processes such as globalization and phenomena such as information technology also play an important role today. Social media can also influence an individual's behaviour and, in this context, there are various reservation systems around the world promoting eco-friendly accommodation.

The survey conducted by the authors emphasizes only one aspect of environmentally friendly travel, but it is essential because the accommodation is the tourist's home during the trip and the practices practiced there in relation to environmental preservation are also a small contribution to the reduction of environmental pollution caused by the tourism industry in the world.

CONCLUSION

The eco-friendly accommodation paradigm is based on a significant reduction of negative environmental impacts through green best practices in services, logistics, products and delivery. The key criteria relate to waste reduction, energy savings and water consumption reduction, while economic benefits for the host community are also important.

Eco-friendly accommodation as a sustainability practice becomes increasingly popular and sought after all over the world, and there is a trend towards healthier living with a view to preserving the environment. However, the assumption made at the beginning of the research was confirmed: the choice of eco-friendly accommodation is not so important for tourists and the criteria are also unclear; however, with increasing awareness and education about eco-friendly travel, a change in overall social behaviour could be expected.

In -making, The concept of sustainability is often referred to in environmental policy guidelines to describe the relationship between social aspects and the environment, but in science it should be increasingly used in an interdisciplinary way in the future. Coherent research in the sociology of tourism and the sociology of the environment can influence the needs of tourists and guide their choices towards ecotourism and environmentally friendly destinations.

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ENVIRONMENTAL IMPACTS OF THE COLLAPSE OF WASTEWATER BASINS IN THE VILLAGE OF UMM AL NASR IN THE NORTHERN GAZA STRIP THE RELATIONSHIP OF THIS DESTINATION TO THE 2030 GLOBAL DEVELOPMENT AGENDA

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ABSTRACT

This study addresses the severe environmental disaster in the village of Umm al-Nasr in the northern Gaza Strip, which faces one of the most severe environmental disasters. The equivalent of 130 thousand cubic meters of sewage flowed into the village of Umm al-Nasr from the sewage collection basin. The losses include the deaths of five citizens and the injuries of 35 others, in addition to environmental damage and material losses in the village as a result of this environmental disaster, including pollution levels, ecosystem disruption, and health risks.

The research aims to explore the complex impacts of this crisis on society and sustainable development goals (SDGs). On the impacts of such disasters on infrastructure, especially water supply, sanitation, and electricity, taking into account the exacerbating issue of overgrowth. An important finding of this study emphasizes the inadequacy of current infrastructure programs to meet the needs of the growing population. Deficiencies are evident in water supply, sanitation, and electricity. In addition to the high rates of population growth in the Gaza Strip, especially land has harmful effects on the quality and availability of groundwater. The community lacks the financial and technical resources necessary to properly maintain and develop basic infrastructure. Climate changes and increasing amounts of rainfall in the North: gaps in infrastructure planning and a lack of early warning. Durable and sustainable political solutions between the Palestinian Authority and Israel. Addressing political divisions within the Palestinian territories is essential to achieving stability in the region.

They pose challenges to achieving and have multifaceted impacts on sustainable development goals (SDGs), affecting health, poverty, and economic growth. They pose challenges to achieving SDGs related to health (SDG 3), poverty alleviation (SDG 1), and resilient cities (SDG 11). Integrated for Risk Management The global forces related to the United Nations' 2030 Agenda for Sustainable Development are Goals Goal 6 (clean water and sanitation), 11 (sustainable cities and communities), 13 (climate action), and 17 (partnerships for the goals)

Keywords: Sewage Overflow, Environmental Crisis, Sustainable Development Goals (SDGs), Risk Management, Linz Austria

https://doi.org/10.5593/sgem2024v/4.2/s19.37

BACKGROUND

Umm al-Nasr village a Palestinian population center in the northern Gaza Strip governorate, with an area of 800 dunums, was established in 1997 in an area close to Israeli settlements. It is bordered to the west by the site of the Digit settlement (formerly), to the east by the site of the Nissanit settlement (formerly), and to the north by a settlement site. Eli Sinai, while it is surrounded from the south by a series of sewage ponds, or what is known as a collection of sewage ponds.



The map "fig 1" for umm-Alnasr ARIJ November 15th 2005. The Applied Research Institute – Jerusalem [1]

INTRODUCTION

On 3/27/2007, the equivalent of 130,000 cubic meters of sewage poured into the village of Umm Al-Nasr from the sewage collection basin, and the wastewater flowed from it toward the village, sweeping away huge amounts of sand on its way, estimated at about 90,000 cubic meters, and burying a residential area. The area of the village is estimated at about 60 thousand square meters [2]

Study Objectives

1-the impact of disasters on achieving the Sustainable Development Goals (SDGs) and provide strategies to achieve those goals.
Environmental Impact Analysis: Assessing the environmental damage caused by sewage flow in Umm Al-Nasr village
2-Infrastructure assessment: assess the impact on water, sanitation, and electricity infrastructure.
Population Impact Study: Analyze the impact of population growth on water quality and availability.
3-Evaluating the political and a war response: examining the need for sustainable

political solutions between the Palestinian Authority and Israel.
4-Integrated risk management: developing strategies for early planning of infrastructure capacity
Resilience to climate change

Environmental and Humanitarian Impacts

The losses—the death of 5 citizens, the injury of 35 others, and the material losses in the village as a result of this environmental disaster—amounted to about 10 million US dollars. In addition to environmental damage, including pollution levels, ecosystem disruption, and health risks,. [3] In Beit Lahyia the North Gaza "sewage lake", whose emergency lagoon embankment failed in 2007 causing a deadly sewage flood. One of the two temporary lagoons built after the 2007 accident also collapsed in March 2009.

Water-related health impacts on the Gaza population, The environment is choked with untreated sewage, threatening Palestinian health and life, as well as water resources and the environment .With such poor water supply and sanitation conditions, health impacts are predictably severe. According to reports, that "26% of disease in Gaza is water related" - World Health Organization reports that from the samples they collect from wells, "the proportion of contaminants is growing fast". A WHO study found a high concentration of nitrates in the water supply from wells in different localities within the Gaza Strip, and this nitrate contamination was found to be the cause of the incidence of "blue-baby syndrome" among infants in the Gaza Strip[4] .

Challenges in the Pond Sector of Umm Al-Nasr Construction and infrastructure sector

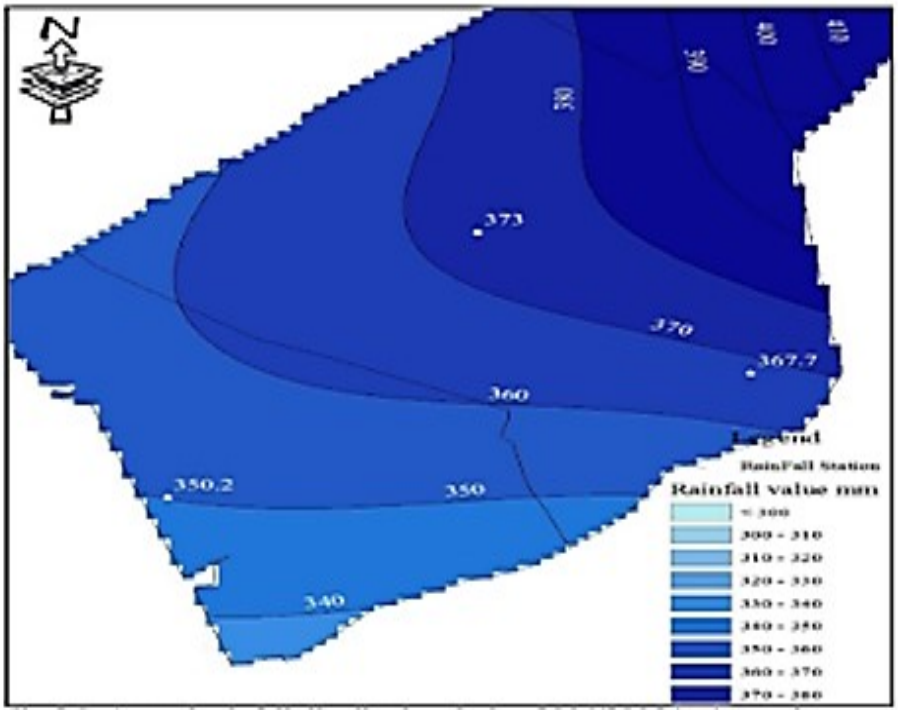
has completely stopped due to the comprehensive import ban placed on raw materials, All construction projects, were suspended. UNDP terminated all its contracts for infrastructure projects , including rehabilitation of roads and rehabilitation of water and sewage networks [5]The wastewater treatment ponds in Umm Al-Nasr have deteriorated over time, leading to structural failures and environmental hazards.[6] The final station was established at that time to serve 50,000 residents of the northern Gaza Strip; However, the current reality of the station is miserable, as the population of the North Governorate currently and still stands at 280,000 people [7]

Population Growth

The population of Gaza Strip continues to grow rapidly, thus increasing the amounts of poorly treated or untreated sewage being discharged into the coastal water.The population growth rate in the Gaza Strip is one of the highest in the world Contamination of Seawater: , the most important sources of seawater pollution are the anthropogenic activities which become more complicated and devastated in case of the rapid population growth and density. The increase in the human population and the improper management of their wastes has increased the amounts of wastes which enter the [8]sea in unacceptable amounts .The community lacks the financial and technical resources to properly maintain and upgrade the essential infrastructure

https://doi.org/10.5593/sgem2024v/4.2/s19.37

Climate changes and increased amounts of rain in the north



Rainfall Map " fig 2" for Season (2006/2007) The total quantity of rainfall in this season 2006/2007 in the study area is 41.5Mm3[9] . Climate change will have widespread impacts on regions. In fact[10] Rainfall: the winter is the rainy season, which stretches from October up to March. The rate of rainfall is varying in the Gaza Strip and ranges between 160mm/year in the south to about 400mm/year in the north [11]

Gaps in Infrastructure Planning Water Systems

Most of the wastewater treatment plants(WWTPs) in Gaza Strip are overloaded and are working beyond their designed capacities The situation with regard to treatment of wastewater or sewage is no less problematic, without huge investment in treatment facilities and associated infrastructure desperately needed to cope with the existing demand, of raw or partly treated sewage has to be released daily into the nearby Mediterranean Sea and environs, creating pollution, public health hazards and problems for the fishing industry Efficient operation of the existing wastewater systems are hindered due to continued electricity fluctuations [12].

Political Solutions

Following the January 2006 Palestinian legislative elections in which Hamas won a majority of the seats in the Legislative established. However, tensions between Group Fatah and Hamas quickly escalated, as Group Hamas refused to recognize the Middle East Quartet's (European union, Russian Federation, UN and USA) demands to accept all previous agreements, recognize Israel's right to exist, and renounce violence. This meant that international assistance to the new Government was heavily curtailed. Following several months of negotiations, a National Unity Government was established in March 2007, but President Abbas disbanded it three months later. Increased confrontations between Fatah and Hamas sub squinty escalated, ending with

the latter's violent take-over and expulsion of the Palestinian Authority from the Gaza Strip in June 2007 [13]

Table "1" United Nations' 2030 Agenda for sustainable development. Goal [14]

Goal 1	End poverty in all its forms everywhere
Goal 2	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
Goal 3	Ensure healthy lives and promote well-being for all at all ages
Goal 4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all Goal
Goal 5	Achieve gender equality and empower all women and girls Goal
Goal 6	Ensure availability and sustainable management of water and sanitation for all Goal
Goal 7	Ensure access to affordable, reliable, sustainable, and modern energy for all Goal
Goal 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all Goal
Goal 9	Industry, innovation, and infrastructure Reduced build resilient infrastructure, promote inclusive, and sustainable industrialization and foster innovation
Goal 10	Reduce inequality within and among countries
Goal 11	Make cities and human settlements inclusive, safe, resilient, and sustainable
Goal 12	Ensure sustainable consumption and production patterns Goal
Goal 13	Take urgent action to combat climate change and its impacts
Goal 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15	Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation, and halt biodiversity loss
Goal 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels
Goal 17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

https://doi.org/10.5593/sgem2024v/4.2/s19.37

METHODOLOGY

The researchers followed the descriptive and analytical approach to achieve the objectives of the study by analyzing the contents of a collection of sources such as reports and researches issued by the local and international institutions operating in the Gaza Strip, suitable for evaluating the quality of the sustainability reports with respect to the scope of each UN_SDG analyzed in the United Nations' 2030 Agenda for sustainable development

RESULTS

The relationship of this destination to the 2030 Global Development Agenda aims to achieve several global goals to:

- Goal 6: Ensure the availability of water and sanitation for all.
- Goal 11: Humanitarian Cities Association to ensure absolute freedom.
- Goal 13: Take immediate action to reverse its changes.
- Goal 17: Strengthen social development partnerships

Floods have multifaceted impacts on sustainable development goals (SDGs), affecting health, poverty, and economic growth. They pose challenges to achieving SDGs related to health (SDG 3), poverty alleviation (SDG 1), and resilient cities (SDG 11). Integrated Flood Risk Management (IFRM) strategies [15]



fig 3 Gaps Challenges in the basins wastewater Sector of Umm Al-Nasr

1. Lack of infrastructure: Umm Al-Nasr village suffers from a severe lack of infrastructure, including water supply, sanitation, and electricity, which hinders sustainable development efforts and negatively affects the lives of residents " fig 3"

2. Environmental pressure and population growth: Village residents face increasing challenges as a result of high population growth rates and pressure on limited natural resources, which puts groundwater quality and environmental sustainability at risk.

3. Climate changes and environmental disasters: Climate changes cause an increase in rainfall amounts and the occurrence of environmental disasters such as the flow of wastewater into residential areas, leading to enormous human and material losses.

4. Political and economic challenges: Political and economic tensions hinder permanent efforts to achieve sustainable development in the village, as delays in infrastructure development cause the provision of basic services to the population.

DISCUSSION

Among the global forces related to global United Nations' 2030 Agenda for sustainable development are The gap between the environmental, social, and economic partnerships between societies, by Goal 6 which aims to ensure the availability of water and sanitation for all, Goal 11 which implements Cities Sports, in particular Humanitarian Responsibility, as well as Goal 13 which calls for immediate action and then change, and Goal 17 Which encourages social development partnerships.

CONCLUSION

By addressing the mentioned shortcomings and achieving global goals related to sustainable development, the situation in Umm Al-Nasr village can be improved, the quality of life of its residents can be enhanced, and the surrounding environment can be preserved. These efforts require continued cooperation between local and international actors and the local community to achieve sustainable and positive change in the village and other areas facing similar challenges.

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EVOLUTION OF THE PROTECTION OF ENVIRONMENTAL HUMAN RIGHTS AT THE EUROPEAN COURT OF HUMAN RIGHTS

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ABSTRACT

The purpose of this article is to provide a legal analysis of the practice of the European Court of Human Rights (ECtHR) in the field of protection of environmental human rights from the point of view of the following key aspects: severity threshold, degree of discretion, positive obligations of states. Special attention was paid to the latest case of Klimaseniorinnen Schweiz and others v. Switzerland. On April 9, 2024, the ECtHR for the first time upheld a complaint in a climate change case. This is the first time when an international court has ruled on issues related to climate change, although there have been precedents at the national level. The ECtHR's decision can be seen as a vivid example when an individual can legally enforce an international convention (in this case, primarily the Paris Agreement on climate change). The article focuses on the main key aspects of this decision, such as the admissibility of the complaint, the content of the state's obligations in the climate sphere, in accordance with Article 8 of the European Convention on Human Rights, the degree of discretion, the assessment of the measures taken by Switzerland in the field of climate change prevention. The positive sides of the court decision were identified, which are the direct application of the norms of international climate law, overcoming the doctrine of action popularis by recognizing the right of NGOs to file lawsuits in climate cases and an attempt to define the positive obligations of states in the context of preventing climate change. The disadvantage of the decision, in our opinion, is that these positive obligations of states are not defined in sufficient detail. It is concluded that the decision of the ECtHR in the Klimaseniorinnen Schweiz case may lead to an increase in the number of complaints submitted by the member states of the Council of Europe to this court in connection with the unsatisfactory fulfillment by the states of their international obligations in the field of combating climate change, and may force states to accelerate reductions in fossil fuel consumption and improve their national environmental legislation. Despite the absence of any rule of binding precedent in international law, the decision of the ECtHR in the Klimaseniorinnen Schweiz case may have an impact on the decisions of other international judicial and quasi-judicial bodies in climate change cases. During the writing of the article, general theoretical methods of scientific research were used: system-functional method, analysis and synthesis, theoretical generalization.

Keywords: climate change; ECtHR; climate change litigation, human rights, international environmental law

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INTRODUCTION

Within the framework of the Council of Europe, individuals can protect their environmental human rights at the European Court of Human Rights. The Convention on the Protection of Human Rights and Fundamental Freedoms does not contain a provision prescribing the right to a favorable environment. However, the number of cases related to violation of environmental human rights by the actions or inaction of states which are dealt with by the European Court of Human Rights, is constantly increasing. On April 9, 2024, the ECtHR for the first time satisfied a complaint in a climate case. It is the first time when an international court has ruled on issues related to climate change, although there were already precedents at the national level. The case concerned a complaint made by four women and the Swiss association "Senior Women for Climate Protection"[1], whose members are older women who fear the consequences of global warming on their living conditions and health. They believe that Switzerland is not fulfilling its positive obligations under the European Convention on Human Rights (ECHR) because the state is not taking sufficient measures to mitigate the effects of climate change and to prevent a global temperature increase of more than 1.5°C, and thereby also not effectively protecting the applicants. The forecasting method made it possible to draw a conclusion that

MATERIALS AND METHODS

During the writing of this paper, both general scientific and special scientific research methods were used. The method of analysis and synthesis was used when clarifying the features of ECtHR's key decisions in the sphere of environmental protection and identify the main aspects of the application of the Convention on the Protection of Human Rights and Fundamental Freedoms from the point of view of the protection of environmental human rights. Sysrem-functional method allowed to identify the following key aspects which should be paid attention to before filing a lawsuit in order to evaluate success in the case: severity threshold, degree of discretion, positive obligations of states. The application of the system-structural method made it possible to investigate the components of the mechanism of protection of environmental human rights which is required from states and to reveal their content. With the help of the dialectical method, the regularities of the development of the system of protection of environmental human rights by the ECtHR were revealed, and the dynamics of the development of its practice in this area were also considered. Forecasting methods made it possible to draw a conclusion that the Klimaseniorinnen Schweiz case may have an impact on the decisions of other international judicial and quasi-judicial bodies in climate change cases. Method of generalization allowed to identify the positive sides of the ECtHR's decision in this case, which are the direct application of the norms of international climate law, overcoming the doctrine of action popularis by recognizing the right of NGOs to file lawsuits in climate cases and an attempt to define the positive obligations of states in the context of preventing climate change.

RESULTS

Most often the ECtHR examines violation of environmental human rights according to Article 8 of the Convention on the Protection of Human Rights and Fundamental Freedoms, according to which everyone has the right to respect for his private and family life, home, and correspondence. The ECtHR determined that there is a close

connection between environmental rights and the rights established in Article 8, because violations of human rights guaranteed by environmental legislation very often affect the private sphere of life. For a better understanding of how an individual can invoke the protection of his environmental rights at the ECtHR, we will analyze the court's key decisions in this area.

1. Admissibility of complaint

In environmental cases, the ECtHR did not consider it sufficient for the applicant to complain of general damage to the environment (for example, the Decision in the case of Di Sarno and Others v. Italy) [13]. According to the existing jurisprudence of the ECtHR, in this context, in order to claim victim status, the complainant must prove that he/she is affected by the environmental damage or risk he/she is complaining about (Decision in the case of Kirtatos v. Greck; Decision in the case of Lopez Ostra v. Spain) [11,12]. The criteria relied on by the ECtHR in determining the status of the victim in environmental cases mainly include issues such as the minimum level of seriousness of the harm in question (for example, Decision in the case of Dubetska and others v. Ukraine) [2], its duration and the existence of a sufficient connection with the complainant or complainants, in some cases including the geographical proximity between the complainant and the claimed damage to environment (for example, Decision in the case of Hatton and others v. the United Kingdom).[3]. The most pressing problem in environmental litigation is proof of a causal connection between cause and effect [4,5,6,14, 15].

However, in the Klimaseniorinnen Schweiz case the ECtHR recognized the need for a special approach to the status of victims in climate cases, due to the need to ensure effective mitigation of the adverse effects of climate change. The jurisprudence of the ECtHR on the status of victims is based on the existence of a direct impact of the challenged act or omission on the complainant or the existence of a real risk. However, in relation to climate change, everyone may be directly affected to some extent by the adverse effects of climate change, or may be at real risk of being directly affected. The fact remains that a potentially large number of persons could claim the status of aggrieved person on this basis, which is also not good, in the opinion of the ECtHR. Therefore, the court recognized the necessity of defining the following criteria that must be met by individual applicants: a) the applicant must be exposed to a high intensity of threat from the adverse effects of climate change, that is, the level and severity (risk) of the adverse consequences of a government measure or inaction affecting the applicant must be significant and b) there must be an urgent need to ensure individual protection of the applicant due to the absence or inadequacy of any adequate measures to reduce harm. After applying these criteria, the ECtHR found that the four individual applicants did not meet the necessary conditions for the status of an injured person under Article 34 of the ECHR and declared their complaints inadmissible. The ECtHR has established that in order to claim victim status in the context of climate change complaints, individual complainants must demonstrate that they are personally and directly affected by governmental action or inaction. As we can see, the criteria of a victim determined by the ECtHR are very strict and it is difficult for an individual to satisfy them. Because of this, in fact, the complaint filed by four elderly women was declared inadmissible. The ECtHR decided to solve this problem by enabling NGO to file lawsuits in climate cases and defined the criteria that ECtHR must meet to do so [1].

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According to the ECtHR, the Association "Senior Women for Climate Protection" had, on the contrary, the right (locus standi) to file a complaint regarding threats arising from climate change in the defendant state on behalf of those individuals who could claim to be exposed to specific threats or adverse effects of climate change on their lives, health, well-being and quality of life that are protected by the ECHR. According to the ECtHR, specific considerations related to climate change are in favor of recognizing the possibility that associations may, under certain conditions, have the right to represent individuals whose rights are or will allegedly be affected despite the fact that it cannot itself claim to be the victim of a violation of the ECHR. The ECtHR therefore considered it appropriate in this specific context to recognize the importance of taking into account the possibility of filing a complaint by an association in order to seek the protection of the human rights of affected persons as well as persons who are at risk of being affected by the adverse effects of climate change, instead of relying exclusively on proceedings that will each individual to lead on his own behalf. In doing so, the ECtHR also established the conditions that an association must meet in order to file a complaint: a) the association must be legally established or authorized to act in the relevant jurisdiction, b) it must be able to demonstrate that its purpose is to protect the human rights of its members or other affected individuals within the relevant jurisdiction and whose activities are limited to or include activities aimed at protection of these rights from threats arising from climate change and c) must be able to demonstrate that it can be considered genuinely qualified and representative to act on behalf of its members or other affected individuals within jurisdictions that are exposed to specific threats or adverse effects of climate change on the lives, health or well-being that are protected under the ECHR.[1]

2. Severity threshold

Before applying to the ECtHR, it is necessary to make sure that a certain level of damage to the environment has been achieved. In the case of Grimkovskaya v. Ukraine the ECtHR stated that if the case concerns environmental pollution, a violation of Article 8 of the Convention can only arise if the damage caused to the individual who made an application is sufficiently serious (Grimkovskaya v. Ukraine, 2011). This statement was also confirmed by the ECtHR in the case of Dubetska v. Ukraine, in which the ECtHR noted that environmental human rights will not be violated if the claimed damage is negligible compared to the environmental risks inherent in any modern city. [2].

All the circumstances of the case are taken into account when assessing the size of the damage, for example the intensity and duration of the harassment and its physical or mental effects on the applicant. The ECtHR also considers the findings of national courts and other authorities when determining the facts of the case, as well as relevant reports and medical certificates.

3. Content of climate-related obligations under Article 8 of the ECHR

Art. 2 and 8 of the ECHR also establishes the obligation of state to take certain positive measures to ensure rights guaranteed by the article including actions aimed at environmental protection (positive obligations of states).

In the Klimaseniorinnen Schweiz case the ECtHR found that Article 8 of the ECHR includes the right to effective protection by state authorities against the serious adverse

effects of climate change on lives, health, well-being and quality of life. It is therefore the state's duty under Article 8 to contribute to ensuring such protection. In this context, the primary duty of the state is to adopt and in practice effectively apply regulations and measures capable of mitigating the existing and potentially irreversible future effects of climate change. This obligation arises from the causal relationship between climate change and the exercise of rights under the ECHR and from the fact that the object and purpose of the ECHR as an instrument for the protection of human rights requires that its provisions be interpreted and applied in such a way as to guarantee rights that are practical and effective, not theoretical and illusory. From the above considerations, it follows that effective respect for the rights protected by Article 8 of the ECHR requires each state to take measures to substantially and gradually reduce their respective levels of greenhouse gas emissions in order to achieve neutrality over the next three decades. In this context, in order for the measures to be effective, it is the duty of public authorities to act in a timely, appropriate and consistent manner .[1]

No state can be labeled as solely responsible for climate change. But we must agree with the scientists, that state that what may appear marginal from a global point of view may be significant in the local context [4,7,8,9,10].Therefore, without a doubt, the extension of the application of Article 8 of the ECHR to the climate change cases is a valid and necessary decision.

4. Degree of discretion

According to the existing jurisprudence of the ECtHR, when ensuring the implementation of Art. 8 of the ECHR, the state has a wide margin of discretion. For example, in the case concerned noise nuisance near London's Heathrow Airport the ECtHR noted that a wide discretion must be given to the state, and it is not the task of the ECtHR to assess what the best policy might be in a particular area. [3].

In cases related to climate change, the ECtHR pointed out the necessity of distinguishing the determination of the desired goals and objectives in this direction, as well as the selection of means intended to achieve these goals. The ECtHR has determined that the nature and severity of the threat of climate change and the general consensus in relation to this issue require a reduction in the degree of discretion for states in setting targets to combat climate change. With regard to the second aspect, the choice of means, including operational decisions and policies adopted to meet international obligations, states should be accorded a wide margin of discretion. In assessing whether the state remained within its margin of discretion, the ECtHR examined whether the relevant national authorities, whether at legislative, executive or judicial level: have duly scheduled its targets for achieving carbon neutrality; set interim targets and methods for reducing greenhouse gas emissions; provided evidence of whether they have properly met or are in the process of meeting the relevant targets for reducing greenhouse gas emissions; update relevant greenhouse gas emission reduction targets with due diligence; acted in a timely, appropriate and consistent manner.[1] The recognition of the right of NGO to file a lawsuit in climate cases for the benefit of the general public shows the overcoming by the ECtHR of the doctrine of actio popularis.

The ECtHR stated that Switzerland's 2011 legislation (in force since 2013) required greenhouse gas emissions to be reduced by 20% overall by 2020 compared to 1990 levels. However, as the applicants pointed out, the Swiss Federal Council in an assessment from August 2009 found that there was scientific evidence to limit global

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warming, according to which industrialized countries (such as Switzerland) needed to reduce their emissions by 25-40% by 2020 compared to 1990 levels. The study in question also found, that in order to meet the commitments of the UN Framework Convention on Climate Change (which were higher than the 1.5°C limit), greenhouse gas emissions would have to fall continuously so as not to exceed 1 to 1.5 tonnes of CO2 equivalent per year per resident at the end of the century. However, progress that targeted a 20% reduction by 2020 was considered insufficient to achieve this goal in the long term, requiring additional efforts for the period beyond 2020. Moreover, as the government acknowledged, relevant domestic assessments found that even the goal of reducing greenhouse gas emissions for 2020 was not met. The revision of the legislation from 2011 left the period after 2024 unregulated, and therefore incompatible with the requirement of the existence of general measures specifying the mitigating measures of the defendant state in accordance with the timetable for achieving climate neutrality.[1]

The ECtHR therefore found that the Swiss Confederation did not fulfill its positive commitments in the field of combating climate change and meeting emission targets: there were some critical gaps in the process of implementing the relevant domestic regulatory framework by the Swiss authorities, including their failure to quantify national greenhouse gas emission limits, in addition, the ECtHR noted that the state had previously failed to meet its past targets for reducing greenhouse gas emissions. By failing to act in a timely, adequate and consistent manner with regard to the design, development and implementation of the relevant legislative and administrative framework, Switzerland exceeded its discretion and failed to fulfill its positive obligations in this context, resulting in a violation of Article 8 of the ECHR. In addition, the ECtHR found a violation of Article 6 para. 1 of the ECHR because the Swiss courts did not provide convincing reasons why they considered it unnecessary to examine the merits of the complaints of the Swiss association “Senior Women for the Protection of the Climate”, disregarding the convincing scientific evidence regarding climate change.

It is interesting and unusual for the ECtHR to consider scientific research as evidence when deciding a case. The plaintiffs relied on it to prove that the Swiss authorities had not done enough to prevent climate change.

CONCLUSION

Climate change litigation is becoming an important tool in the fight against climate change. At the same time, there is a trend of a significant increase in this type of cases at the national level. However, the decisions of international courts in this area can gain special weight in the fight against climate change. Such a decision is the decision of the European Court of Human Rights in Klimaseniorinnen Schweiz and others v. Switzerland. This is not just another decision of the ECtHR, but is a breakthrough decision, with which the international court for the first time satisfied a complaint in a climate case. The court's decision can be seen as a vivid example when an individual can legally enforce an international multilateral environmental agreement (in this case, primarily the Paris Agreement on climate change). The positive sides of the decision of the ECtHR are: the direct application of the norms of international climate law, overcoming the doctrine of action popularis by recognizing the right of NGOs to file lawsuits in climate cases and an attempt to define the positive obligations of states in the context of preventing climate change. The disadvantage of the decision is that these positive obligations of states are not defined in sufficient detail.

The decision may thus lead to an increase in the number of climate complaints submitted to the ECtHR and may force states to accelerate the reduction of fossil fuel consumption and improve their national environmental legislation. What changes should be made to the national legislation of individual states is a prospect for further research.

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EXPLORING THE HEALTH AND NUTRITION INTERCONNECTION IN HUMAN-DOG RELATIONSHIP FROM A MEDICAL AND SOCIAL PERSPECTIVE

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ABSTRACT

This study explores the interconnection between health, nutrition, and the emotional bond in the human-dog relationship. Using a multiple-choice questionnaire, the research examines health issues, dietary choices, food rewards, and emotional ties among dog owners, with a focus on individuals aged 31-45 from diverse backgrounds. The main objective is to understand how health, nutrition, and emotional bonds are linked between dogs and their owners. The survey covers topics such as health observations, veterinary care, food rewards, and owners' nutritional knowledge. Results reveal frequent health issues in dogs, particularly obesity, highlighting the importance of addressing these conditions. In contrast, owners reported fewer health problems related to diet. Regular veterinary visits were common, indicating responsible pet care. The use of commercial dog treats as rewards was widespread, with many owners believing it strengthens their bond with their pets. While owners showed moderate nutritional awareness, there is potential for targeted education to improve practices. Many respondents were willing to adjust their dogs' diets for health reasons, showing a proactive attitude towards canine well-being and an openness to expert dietary advice. The study underscores the need for holistic approaches that integrate health, nutrition, and emotional connections, with opportunities for interventions to enhance both human and canine health. Further research is recommended to validate these findings

Keywords: human-dog relationship, health, nutrition, humanization, society

INTRODUCTION

The human-dog relationship is characterized by mutual emotional companionship and shared experiences dating back thousands of years [1]. Alongside the emotional bond between dogs and humans comes a responsibility for their care including providing adequate nutrition which is essential for their health and well-being [2].

Researches has shown that dog ownership can confer various health benefits to owners including increased physical activity, social interaction and emotional well-being [2]. Dogs have been associated with improved cardiovascular health with reduced stress levels and an overall improved quality of life for their owners [3-5].

Understanding the dynamics between dietary practices, feeding habits and nutritional knowledge of dog owners is crucial for promoting optimal health outcomes for both humans and their canine counterparts and for advancing understanding of human-animal interactions.

The purpose of this study was to investigate nutritional behaviours between dogs and their owner within medical and social perspective. By using a comprehensive epidemiological survey tool and analysing data from a sample of dog owners living in the western part of Romania we aimed to elucidate the factors that influence nutritional behaviours in this population and identify opportunities for targeted interventions in order to improving the health and well-being of both humans and their canine companions.

MATERIALS AND METHODS

This study used a cross-sectional survey design to investigate nutritional behavioural correlates between dogs and their owners by applying a structured multiple-choice question designed to elicit information about various aspects of dog and their owner's nutrition

The study group included 100 dog owners residing in the western part of Romania. Participants were recruited from local communities, veterinary clinics and practices, and online dog owner groups. Inclusion criteria required participants to be at least 16 years of age and to currently own at least one dog.

Data collection took place between September 2023 and June 2024. The questionnaire consisted of structured multiple-choice questions organized into several sections covering demographic information, dietary choices, feeding practices, health observations, veterinary involvement, food rewards, emotional bonds, and nutritional knowledge. The participants were informed about the purpose of the study, voluntary participation, confidentiality of responses and their right to withdraw at any time without consequences.

Descriptive statistics were used to analyse survey responses including frequencies and percentages for categorical variables. Subgroup analyses were performed to explore potential variations in feeding behaviours based on demographic factors such as age, sex, and dog breed.

RESULTS

The results of this scientific study provide valuable insights into the complex dynamics of nutritional behaviours between dogs and their owners by highlighting the interaction between owner traits, feeding practices and canine health outcomes.

In terms of section 1 of the survey - participants information - the age distribution suggests a diverse representation, with a notable focus on the 31-45 age group, a stage where individuals often have stable lifestyles suitable for owning pets. This group tended to show a greater preference for commercial dog food and they are more likely to use food for training purposes. The balanced gender representation aligns with wider trends in pet ownership where both men and women are equally engaged in dog care. Female owners prioritized premium quality dog food and incorporated fresh ingredients into their dog's diet compared to male owners. Male owners, on the other hand, tended

to rely more on commercial dog food and were less likely to seek veterinary advice for dietary recommendations. In addition, female owners demonstrated a higher level of emotional attachment to their dogs. The distribution by different occupations reflects the diverse socio-economic backgrounds of dog owners. In addition, there was a correlation between breed size and the frequency of food rewards used, with owners of small breeds being more likely to use treats for training compared to owners of large breeds (Fig. 1).

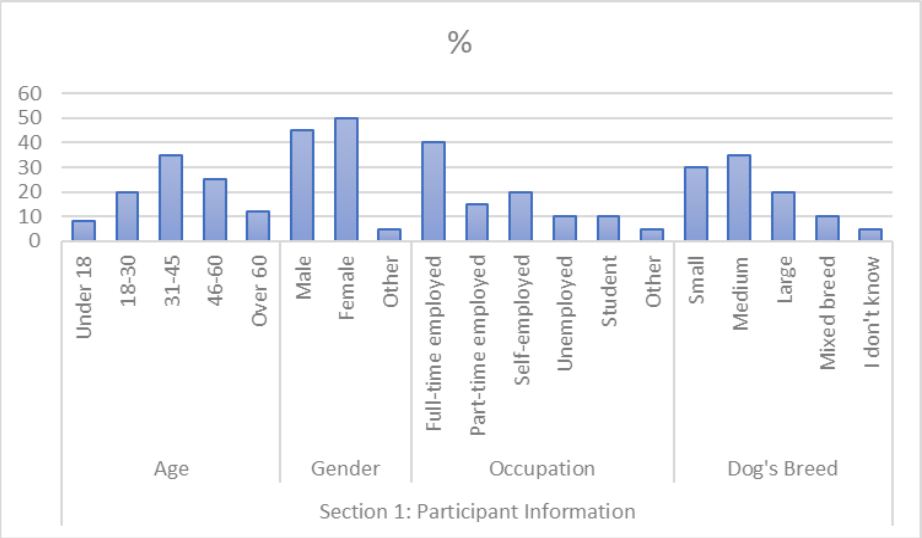


Fig. 1. Participants distribution according to owners age, gender, occupation and dog's breed

In section 2 - health and nutrition problems - a significant correlation was found between owner-reported self-awareness of their dogs' nutritional requirements and the occurrence of health problems in them. Health problems reported in dogs (25%) may indicate common challenges such as obesity or metabolic conditions, reflecting the need for increased awareness and preventative measures. Relatively low personal health issues related to diet or metabolism (15%) may suggest that owners' health is less directly affected by diet compared to their dogs. Regular vet visits and guidance (60%) emphasizes a responsible approach to pet care by seeking professional advice to maintain dogs' health through proper nutrition (fig. 2).

Veterinarian involvement plays a crucial role in shaping feeding behaviours among dog owners emphasizing the importance of collaborative relationships between owners and veterinarians in order to promote optimal dog nutrition.

In section 3 - food rewards and emotional bonds - a positive correlation was observed between the frequency of using food as rewards and the prevalence of obesity in dogs. The frequent use of food as a reward (50%) is consistent with positive reinforcement practices in dog training. Common types of rewards such as commercial dog rewards (70%) indicate trust in pre-set and easily accessible options (fig. 3).

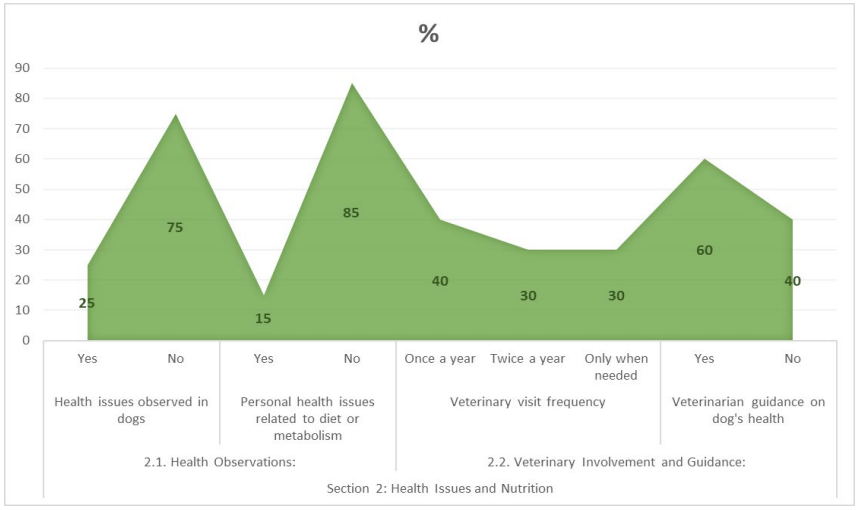


Fig. 2. Information about owner-dogs health issues and veterinary involvement

Excessive use of food to support positive behaviour may contribute to excessive caloric intake and subsequent weight gain in dogs, emphasizing the need for moderation and alternative reward strategies to prevent obesity-related health problems.

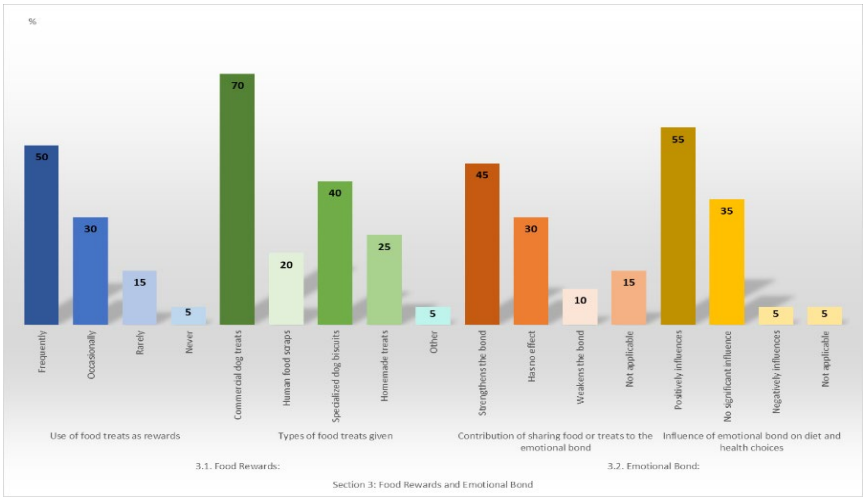


Fig. 3. Interconnectivity between food rewards and owner-dog emotional bond

Owners who reported a strong emotional bond with their dogs were more likely to modify their own eating habits based on their dog's nutritional needs. The emotional connection between owners and dogs influences dietary decision-making processes, with owners prioritizing their dog's health and well-being over personal preferences indicating a reciprocal relationship between human and canine eating behaviours.

Analysing the results in section 4 - nutritional knowledge and practices - it was shown that participants with higher levels of education and income reported greater awareness of their dogs' nutritional requirements. Willingness to make dietary changes for dogs (70%) shows a positive attitude towards prioritizing dog health. The reported likelihood of seeking professional dietary advice (45%) suggests an openness to expert guidance indicating a potential receptivity to educational interventions (fig. 4). Socio-economic factors such as education and income play an important role in shaping nutritional

knowledge and practices among dog owners, highlighting possible disparities in access to information and resources related to canine nutrition.

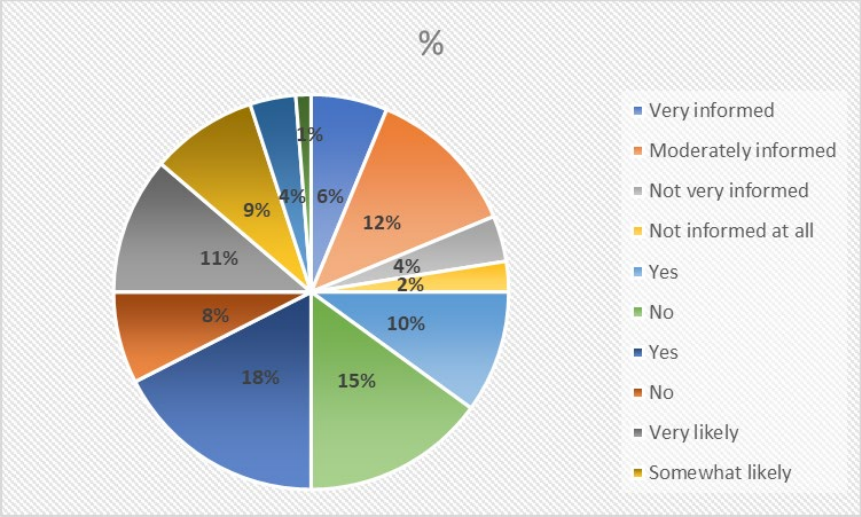


Fig. 4. The influence of awareness of nutritional requirements on the dietary modifications for health

Understanding these differences can help tailor interventions and educational programs to meet specific needs and preferences, ultimately promoting the health and well-being of both dogs and their owners.

In conclusion, the presented distribution provides information about the attitudes and practices of dog owners regarding the health, nutrition and emotional connection with their pets. These findings suggest opportunities for education and targeted interventions to increase awareness, improve nutritional practices, and promote health maintenance in both dogs and their owners. Further research and interventions aimed at improving owner education, fostering collaborative relationships with veterinarians, and promoting healthy dietary practices are warranted to improve the nutritional well-being of dogs and their owners.

DISCUSSION

By considering the results of this study, stakeholders in public health, veterinary medicine, and human-animal interactions can develop targeted interventions to address the nutritional needs of both humans and their canine companions, fostering a healthier and more harmonious interspecies relationship.

The positive correlation between owner-reported nutritional knowledge and their dogs' health status suggests that educated owners are better equipped to make informed dietary decisions for their pets [6]. This finding emphasizes the importance of educational interventions aimed at improving owner awareness of the nutritional needs of dogs and the benefits of a balanced diet. Moreover, studies have shown that owners who prioritize their own health are more likely to extend similar practices to their pets [7]. Thus, promoting nutrition education and healthy lifestyles among owners can have dual benefits for both humans and their four-legged companions [8].

Regular veterinary consultations play a crucial role in shaping dietary practices among dog owners [9]. Veterinary guidance can provide owners with evidence-based dietary

recommendations tailored to their dog's specific needs, thereby improving overall health outcomes and reducing the risk of dietary disease. In addition, veterinary involvement facilitates early detection and management of nutritional deficiencies or health problems, helping to improve the quality of life for both dogs and their owners [10]. Thus, fostering collaborative relationships between owners and veterinarians is essential to promoting optimal dog nutrition as well as overall well-being.

The significant correlation between the frequency of use of compensatory foods and the prevalence of obesity in dogs highlights the potential role of food rewards in the development of canine obesity [5, 11]. Owners should be educated about the risks of overreliance on high-calorie food rewards and encouraged to explore alternative reward strategies, such as praise or play, to reinforce positive behaviours without compromising their pet's health. Moreover, controlling obesity in dogs is beneficial not only for their physical health but also for their owners, as studies have shown that obese pets can negatively impact the owner's well-being and increase the burden on caregivers [5, 8]. Therefore, interventions aimed at promoting healthy weight management practices in dogs have the potential to improve overall health outcomes for both pets and their owners.

The strong correlation between the emotional bond between owners and dogs and the types of food choices made for the dog suggests that the quality of the human-animal relationship may influence food decision-making processes [9]. Owners who share a strong emotional connection with their dogs may be more inclined to prioritize the health and well-being of their pets, leading to healthier eating practices. Moreover, studies have shown that the emotional connection between owners and their pets can have positive effects on the owner's mental and physical health, including reducing stress levels and improving cardiovascular health [7, 12]. Therefore, promoting strong human-animal bonds can indirectly contribute to better health outcomes for both dogs and their owners.

The subgroup analyses performed in this study align with existing literature on the influence of demographic factors such as dog age, sex, and breed on nutritional behaviours among owners. Incorporating insights from previous research, these findings provide valuable context and enhance our understanding of the complex interplay between human demographics and dietary practices in the context of pet ownership.

The observed differences in nutritional behaviours between age groups are consistent with findings from previous research. Studies have shown that younger generations often prioritize convenience and affordability in pet care leading to a greater reliance on commercial pet foods [11], whereas older owners tend to have a greater awareness of holistic health practices and may prefer homemade or raw diets for their dogs [9, 10]. This suggests that age-related factors such as lifestyle preferences and nutritional knowledge significantly influence pet dietary choices.

Gender differences in feeding behaviours among dog owners align with broader trends in caring for and emotional attachment to animals. The research indicates that women are more likely to view pets as members of the family and demonstrate higher levels of emotional involvement in their caregiving activities [13]. As such, female owners may be inclined to prioritize premium quality foods and holistic approaches to nutrition for their pets. Instead, male owners may adopt more pragmatic and utilitarian attitudes to feeding, opting for convenience and practicality over premium quality [14].

Breed-specific variations in nutritional behaviours corroborate findings from specialty nutrition studies. Research has shown that different dog breeds have distinct physiological needs and dietary requirements [10]. For example, small breeds may require higher energy densities in their diets to support their fast metabolisms, while large breeds may benefit from diets with controlled levels of calcium and phosphorus to mitigate the risk of skeletal problems [15]. By considering breed-specific factors in making nutritional decisions, owners can better meet the unique needs of their pets and promote overall health and well-being.

These discussions highlight the very diverse nature of the relationship between owners and their dogs emphasizing the importance of considering both human and animal factors in promoting optimal nutrition and overall well-being.

Through this study we hope to contribute to the growing body of knowledge on human-animal interactions and their implications for public health and veterinary medicine. By understanding the dynamics of nutritional behaviours between dogs and their owners we can better support the health and well-being of both humans and their beloved canine companions.

CONCLUSION

The study highlights the link between an owner's nutritional knowledge and their dog's health, highlighting the role of education in promoting well-being. Veterinary guidance is crucial to evidence-based dietary recommendations, ensuring optimal health outcomes. Emotional bonds drive dietary choices, emphasizing the reciprocal nature of human-dog relationships. Moderation in reward consumption is essential to prevent obesity in dogs, with education on alternative reward strategies key to success. Socio-economic factors influence nutritional practices, highlighting the need to address disparities for the well-being of all dogs. The study identifies several areas where targeted interventions can improve nutritional behaviours among dog owners. Educational initiatives, veterinary outreach programs, and community resources can impress upon owners the importance of making informed food choices and promoting the health and well-being of their canine companions. In conclusion, this study underlines the importance of the complex interaction between owner behaviours, dog health outcomes and socio-economic factors in the context of canine nutrition. By addressing these factors through education, collaboration and targeted interventions we can improve the nutritional well-being of dogs and strengthen the human-dog bond for the future.

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GEOSPATIAL ANALYSIS OF DEGRADED AREAS IN LATVIA

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ABSTRACT

In order to limit climate change, it is necessary to look for areas in each country where facilities for the production of electricity with renewable energy resources can be placed. In Latvia, agricultural and forest land areas are used for the realization of these goals. The aim of the study was to look for alternative areas, thus looking for opportunities to reduce the pressure on areas whose main purpose would be agricultural production. In the study, 297 geospatial analysis of land units on which municipal waste collection and storage sites of administrative territories of Latvian regions were historically located, which are considered polluted or potentially polluted territories. The cadastral information of the territories was viewed and analyzed. Geospatial measurements were made from the geometric center of the land units to the nearest public road, inhabited place, nature protection areas, as well as electrical network objects. The goal was to find out which units of land would be suitable for further detailed study of the construction sites of solar and wind power stations according to their area and geospatial location. The possible electricity production potential of the studied areas was calculated. It was determined that the state and the municipality own 66.3% of the land units included in the study. Of the land units included in the study, 6.7% would have potential for electricity production with renewable energy resources.

Keywords: degraded area, renewable energy, geospatial analysis

INTRODUCTION

In order to mitigate climate change and strengthen the country's energy independence, it is necessary to increase the use of renewable energy resources in electricity production. In the sustainable development strategy Latvia 2030, it is defined as one of the state's strategic goals [10]. The rational use of the land must be the focus of attention when it is necessary to determine new territories for the placement of electricity production with renewable energy resources (sun, wind, etc.). Latvia, like the other Baltic States, is an energy deficit country on an annual basis. The amount of water in the cascade of hydroelectric power stations of the Daugava River is important for Latvia. Unless there is a rainy summer or a snowy winter, it should be calculated that from the total annual gross electricity consumption of ~ 7 TWh, around 70% of the required amount of electricity is produced on site. The rest must be procured from international markets. In 2023, 88% of the country's gross electricity consumption of 6,887 GWh was produced locally in Latvia, due to the increased water flow in the Daugava River [2]. Under the influence of the geopolitical situation, regulatory acts have been approved in Latvia, which also allow the use of agricultural and forest land for the placement of solar and wind power plants [7]. The aim of the study is to search and evaluate alternative places for the placement of renewable energy resources - solar and wind power plants, thus reducing the impact of the placement of power generation equipment on agricultural and

forest land. The Land Management Law stipulates that degraded areas should be primarily selected for construction. Land units were selected for the analysis, on which the territories of former rural collective farms and village communal waste dumps were historically located, which are considered polluted or potentially polluted territories according to the regulatory framework (Figure 1).

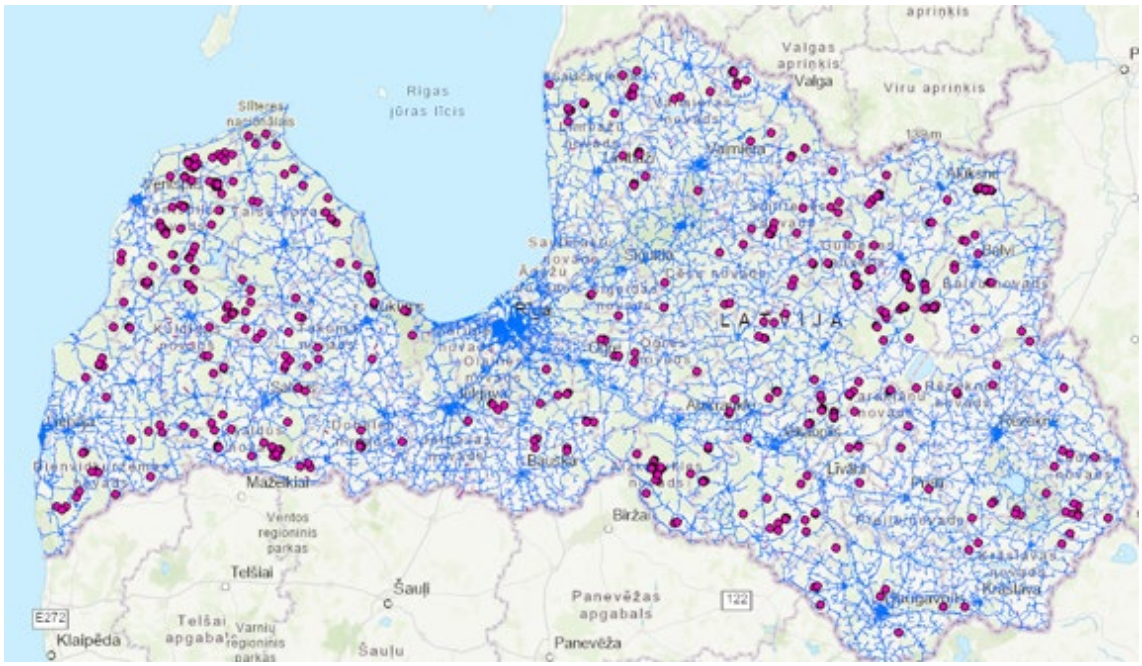


Figure 1.Location of degraded sites and electricity distribution networks (blue) in Latvia

In the article, we will designate them as degraded areas. These areas seem to have several important features. They are located at a certain distance from populated areas, access roads were built on them, and in some cases, connection to electrical networks was provided. The listed factors are important in determining the construction sites of solar and wind power plants, which is confirmed by previous studies [1], [8], [12], [13], [14]. In Latvia, the use of degraded areas has been little studied. The issues of degraded territories and guidelines for their research, planning and use are determined within the Interreg Latvia - Lithuania cross-border cooperation program 2014-2020 [5]. So far, in-depth studies have been carried out on the identification of potentially profitable locations for solar and wind energy installations both in EU countries and in the USA. The studies cover almost the entire country and the territory of individual municipalities. In all cases, geospatial information analysis was used for data extraction. The use of brownfield sites for the construction of solar and wind energy facilities has been studied relatively less. So far, studies on degraded areas have focused on areas of former construction and mineral extraction sites. In the USA, guidelines have been developed for the use of brownfield sites for the placement of solar and wind power plants directly in the areas of former waste dumps [15]. However, in the studies so far, there has been less analysis of the land units in which the degraded area is located, the composition of the land use types, the areas of the areas suitable for the construction of solar and wind power plants, the legal ownership, the purpose of real estate use. The researched data are important in the feasibility study of the choice of possible construction sites, which is an essential part of the construction process of solar and

wind power plants [9]. The study included 297 degraded (contaminated or potentially contaminated) sites throughout the territory of Latvia.

MATERIALS AND METHODS

The database of the Latvian Environment, Geology and Meteorology Service (lvgmc.lv) was used to identify the territories, which contained the registration numbers of polluted and potentially polluted places and the cadastral designations of the relevant land units [11]. The area of the contaminated or potentially contaminated territory (ha) was determined from the data of the cadastral register according to the type of land use - "other land" or calculated. Distances to objects of interest were measured in geospatial materials from the visually determined geometric centre of the land unit, for which geographical and Latvian LKS-92 TM coordinates were fixed. Using the availability of the Balticmaps.eu navigation function, the distances along the road network to the parish centre and the capital Riga were determined [3]. Distances to the nearest inhabited place (homestead) and power grid lines are determined by measuring the shortest distance along the air line from the geometric centre of the land unit to the nearest homestead or distribution power grid (0.4 to 20kV), hereinafter - ST or high-voltage grid (110 to 330 kV) , hereafter AST, for the line. Taking into account the addresses of AST 110/20 kV substations, the distance along the road network from the degraded area to the nearest AST substation was measured. Distances to nature protection objects were determined in two ways, using publicly available data of nature protection objects [6]. First, by recording whether or not there is a nature conservation object in the land unit. Second, the geospatial data measured the distance from the geometric centre of the land unit to the nearest nature protection object. In addition to the geospatial analysis of the land units of the degraded areas, the theoretical potential of electricity generation was calculated according to the following scheme. Land units owned by the municipality were selected with the purpose of use (NLM1005) – construction of waste management companies. Next, the areas of the land use type "Other land" of the specified land units were summed up. Taking into account that in this study we adopted approximate calculations, it was assumed that the sun is used for 1800 hours, the average solar radiation per unit of area is 1180 (kWh/m2) per year, the placement factor of solar panels is 0.5 (50% of the area can be placed), the efficiency factor is 0.12 (the panels use 12c% of the possible solar radiation) and the total amount of energy produced by the sun is calculated according to the following formula:

$$E1=P\cdot A\cdot K1\cdot K2, \quad \text{where} \tag{1}$$

E1 - the total amount of electricity produced by solar radiation (GWh) per year;
P - Average amount of solar radiation (kWh/m2) per year;
A - Usable land area (m2)
K1 – placement ratio of solar panels;
K2 – efficiency factor of solar panels.
The potential of electricity produced by wind energy was calculated assuming that the average number of operating hours of the wind generator per year is 2000 hours (h) and the average wind power per unit area is 165 W/m2. The wind power utilization factor was set at 0.4. The total amount of electricity produced by wind was calculated according to the formula:

$$E2=A\cdot K1\cdot K2\cdot K3, \quad \text{where} \tag{2}$$

E2 – total amount of electricity produced by wind power (GWh) per year;
A – in the area available for wind flow;
K1- wind power per 1m2;
K2 – time of wind operation in hours per year;
K3 – efficiency coefficient of wind use.

RESULTS

Analyzing the cadastral information of land units, it was calculated that out of the total 297 pcs. of the total area of land units 2806.2 ha, degraded areas made up 22,8% or 640,3 ha. Considering that the state and municipality own 66.2% of the total number of land units and 48.7% of their total area, it can be predicted that the rest of the degraded land unit's territory, which is not degraded, could also be used for solar and wind energy facilities for deployment. The results on the legal ownership of land units are summarized in Table 1.

Ownership of land units with degraded areas Table 1

Land ownership	Quantity, pcs.	Including, %	Area, ha	Including, %
Country	11	3,7	391,1	13,9
Municipality	186	62,6	975,2	34,8
Individual	69	23,2	1023,0	36,4
Legal person	31	10,5	417,3	14,9
In total	297	100,0	2806,6	100,0

Additional analysis confirmed this, as 38.4 % (114 units) of land unit use purposes were code 1005 (Waste management). On the other hand, 35.4% (105 units) and 12.4% (37 units) of land units had the purpose code of 0101 (agricultural land) and 0201 (forestry land), which indicated that more than half of 47.8% of degraded land units have been cultivated and returned to the economy. By carrying out geospatial measurements, it was confirmed that the land units with degraded areas are provided with an access road, as 45.7% (136 units) of the land units are accessed by a public road. At a distance of up to 0.50 km, the access road was available for 26.2 % (38 units) of land units. The distance to the public road, which is greater than 0.5 km, was only 8.2% (24 units) of land units. Looking at the distances to the nearest inhabited places (detached houses), it can be seen that the weighted average distance of 0.50 km is greater than the minimum distance of 0.8 km, which is defined in the regulatory acts as the minimum distance in relation to the wind power plant. However, these were separate areas of rural homesteads and not a village. The measurement results of average and average weighted (the number of land units is taken as weight) geospatial distances are summarized in Table 2.

Measurement results up to the road and settlements Table 2

Indicators,	Distance, km				
	Public road	Inhabited Place	Parish center	County center	Capital city Riga
Kurzemes objects	0,14	0,45	5,94	24,51	123,93
Zemgale objects	0,15	0,60	5,99	22,82	78,54
Vidzeme objects	0,11	0,48	4,65	26,37	136,87
Latgale objects	0,26	0,48	3,96	22,43	190,68
Average distance	0,16	0,50	5,14	24,03	132,5
Weighted average distance	0,14	0,50	5,96	23,96	117,71

By carrying out geospatial measurements, it was confirmed that the land units with degraded areas are provided with an access road, as 60.4% (84 units) of the land units are accessed by a public road. At a distance of up to 0.5 km, the access road was available for 71.9 % (214 units) of land units. Taking into account that the distance from the geometric center of the land unit to its border could also be added here, the access road provision was 71.9% of the total number of land units. Looking at the distances to the nearest inhabited places (detached houses), it can be seen that the weighted average distance of 0.5 km is greater than the minimum distance of 0.8 km, which is defined in the regulatory acts as the minimum distance in relation to the wind power plant. However, these were separate areas of rural homesteads and not a village. The measurement results of average and average weighted (the number of land units is taken as weight) geospatial distances are summarized in Table 2. The distances to the nearest ST (0.4 – 20kV) and AST (110 – 330 kV) objects were measured in geospatial materials in the location of solar and wind power plants against the electric networks. Current regulations stipulate that power plants with a capacity of up to 14.99 MW are connected to distribution networks, but starting with a capacity of 15.0 MW, plants are connected to a high-voltage (110-330kV) network. The results of the measurements showed that the location of the ground units in relation to the distribution networks is in a better position compared to the high-voltage networks. The average weighted distance from the border of the land unit to the nearest object of distribution networks is 0.46 km, which can be assessed as satisfactory. Wind and solar power plants with a capacity greater than 14.99 MW are built near high-voltage (110-330kV) networks [2]. The average weighted distance to the high-voltage line (10.31 km) and the 110/20 kV substation (14.9 km) obtained in the study would not be satisfactory for the potential investor. However, this does not mean that you should not look for and find individual land units, where the distance to the electric network line is not greater than 0.5 km. However, in these cases, the area of the land unit should be taken into account. Swedish experience indicates that the minimum area that would be economically justified for the construction of a solar power plant is 2 ha [12]. The results of measurements up to the electric grids in the cross-section of regions are summarized in Table 3.

Measurement results to electrical networks Table 3

Objects of electrical networks	Distance, km		
	0.4 - 20kV line	110 -330 kV line	110/20kV substation
Zemgale objects	0.64	15,56	9,72
Vidzeme objects	0,45	8,04	18,89
Latgale objects	0,39	10,3	17,51
Average distance, km	0,42	9,12	18,23
Weighted average distance, km	0,46	9,56	16,67

When conducting a geospatial analysis of the location of land units in relation to nature protection territories, it was found that 28% (31 obj.) of land units had protection zones of nature protection objects, which impose restrictions on economic activity. The average distance from the boundary of the land unit to the nature protection object outside was 2.97 km. The average results of the study initially show a sufficiently large margin of distance to nature protection objects. However, this does not allow us to draw the conclusion that there could not be obstacles in the construction of power plants, because the study included only the open data of nature protection objects, and also did not look at bird migration routes. According to the methodology determined in the study, 20 land units suitable for electricity production were found. Land units with a total area of 151.17 ha and a degraded area of 109.18 ha, for which electricity generation potential calculations were made. The calculated results of 77.30 GWh of solar and 144.11 GWh of wind energy potential for electricity production are considered sufficient to continue research. Estimates of electricity produced by wind should be further analyzed, as they look very optimistic in a relatively small area. The results were compared with the annual electricity consumption of Smiltene, a separate Latvian county town of 80.1 GWh [4]. From the obtained results, it can be concluded that up to 6.7 % of degraded areas have potential for electricity production. Considering that the average values of solar and wind power (W/m2) in the country were taken into account in the calculations, further studies should take into account the values characterizing the geography of a specific land unit. For each land unit found, more detailed analysis and calculations may be made in the future.

DISCUSSION

It is important to note that the study is a feasibility study of specific land units with degraded areas. The study differs from the works of other authors, with the analysis of specific, legally formed land units in rural areas. The minimum area of land units of 2 ha determined in the studies of other authors, where it is profitable to build solar power plants, was taken into account. The study took into account the most important points found in previous studies, to which distances must be measured in order to assess the suitability of a unit of land for the production of electricity with the sun and wind. It was determined that the average area of land units in rural areas of Latvia, where degraded areas are located, is 9.44 ha. The study revealed that at least 40 to 50% of analysed degraded areas will belong to the state and local governments. The research made it possible to find 6.7% of land units with an adequate area for the placement of electrical

equipment, which belong to municipalities with the purpose of waste management (code 1005). For them, the theoretically possible potential of produced electricity was calculated, which is close to the average electricity consumption of Latvian regional cities of 50 to 80 GWh per year [4]. The measured distances in the geospatial environment made it possible to cautiously evaluate the potential of degraded areas, which could be used for the placement of power generation equipment. The study revealed that degraded areas will be more suitable for the construction of solar and wind power plants that would be connected to distribution electric networks with a capacity of up to 14.99 MW. The field of further research would be to examine each land unit found in more detail and make more accurate calculations of solar and wind potential

CONCLUSION

1. A feasibility analysis of cadastral data and geospatial data of 297 land units in the Latvian countryside, where Soviet-era rural collective farm waste dumps were located, covering an area of 2806.6 ha was carried out. It is estimated that 5 to 10% of these (6.7% in our analysis) could be used to generate electricity.

2. As a positive factor, the state and municipalities own 48.7% of the total number of land units, which may facilitate the coordination of possible construction processes.

3. The results indicate that the analysed land units would be more suitable for the siting of power plants with a capacity of up to 14.99 MW, as the distances to the distribution grids are on average 0.48 km. The distances from the land parcels to the high voltage grids indicate that the construction of higher capacity power plants in the analysis area would be unjustified.

4. The data collected are feasibility data. Further field surveys of each of the 6.7% of land parcels found in the analysis would be necessary to obtain additional data and assess their suitability for electricity generation.

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GREEN SUPERCOMPUTING – CALCULATING TSUNAMI WAVE PROPAGATION

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ABSTRACT

Nowadays, the use of supercomputing for solving almost any task ranging from industrial to the ecological ones has been increasing. It should be noted that this requires lots of energy, which negatively affects the environment and is costly. However, in a number of cases it is possible to achieve high performance calculations without the use of supercomputers but instead by relying on special processors, focused on a particular class of tasks. While optimizing the computational pipeline for a particular mathematical model, the modern Field Programmable Gates Array (FPGA) platform provides an opportunity to accelerate the numerical solution of a problem by orders of magnitude using a personal computer (PC). This point is here discussed for the case of tsunami modeling. Underwater earthquakes can cause destructive tsunami waves resulting in significant casualties and economic losses. Therefore, after each seismic event, the hypocenter of which is underwater, many supercomputer centers start the modeling process in order to determine the coastal areas where the tsunami wave may cause a loss human life or infrastructure destruction. This certainly requires a lot of energy. The paper shows the possibility of numerical modeling of transoceanic tsunami wave propagation on a grid with a step of 1 geographic minute using a PC platform, which demonstrates significant performance compared to supercomputer calculations. The modeling process (numerical solution of the system of differential equations of shallow water, well describing the process of tsunami wave propagation) takes only a few minutes using a PC with hardware accelerator. Such performance, comparable to the capabilities of a modern computing cluster, is achieved thanks to hardware acceleration - a specialized FPGA-based calculator used as a co-processor. The correctness of the solution is confirmed by comparison with known exact solutions of the system of shallow water equations. The limitation of the proposed method is the size of the random access memory of the device, since high performance is achieved provided that there is no necessity to use the hard disc memory of the computer. The application of the proposed computation technology will allow use “green supercomputing” in many cases.

Keywords: green, supercomputing, tsunami, wave, propagation

INTRODUCTION

High Performance Computing (HPC) is often regarded as the way to resolve any technical or even ethical problems (Artificial Intelligence, ChatGPT, etc.). However, energy consumption of such systems has been dramatically increasing over the last years. In addition to the lists of Top 500 (see http://top500.org) of the most powerful supercomputers, the lists of Green-500 (cf. http://green500.org) of the most energy-efficient computer systems are being published regularly. A supercomputer (say, HPC system) is a computer with performance greater by orders of magnitude compared to the performance of a general-purpose, or personal, computer.

Modern Field Programmable Gates Array (FPGA) platform provides the possibility (with the help of software tools) to design computing pipelines optimized for the implementation of a particular algorithm. In other words, it is an opportunity to create a "supercomputer on the table" using software tools. Printed board with a microchip FPGA, working as part of a personal computer as a coprocessor or independently, is able to solve a particular computational problem with very high performance. With the appropriate software library, the same hardware configuration can be a high-performance computing system to solve a whole set of problems.

In this paper, the capabilities of this technology are demonstrated by solving the problem of tsunami wave propagation. The destructive tsunami wave that followed The Great Tohoku Earthquake of March 11, 2011, offshore Japan has shown the insecurity of coastal territories from man-made and natural disasters of seismic character. Studies on the possibility of timely warning of tsunami hazards have been widely developed. However, to this day, the problem remains not fully solved.

Different software tools provide high accuracy simulation of the tsunami wave generation, propagation, and inundation of a dry land. MOST (Method of Splitting Tsunamis, NOAA Pacific Marine Environmental Laboratory, Seattle, WA USA) [1,2], widely used as a reference code in "tsunami research" community could be considered as the reference code. It is official instrument of the tsunami warning services of the USA. Among alternative software solutions, it is also necessary to mention TUNAMI code (Tohoku University's Numerical Analysis Model for Investigation of Near field tsunamis, Tohoku University, Japan) [3,4]. The improved version named NAMI-DANCE [5] was written in C++ using, in particular, the MPI (Message Passing Interface) and OpenMP (Open Multi-Processing) parallel programming methods. This parallel implementation makes it possible to achieve a very good performance at the modern cluster supercomputer systems.

However, each of these tools requires extended computational resources and typically consumes valuable time. Moreover, one can hardly expect results of the required analysis in a few minutes even when relying on the supercomputer processing. It should be also noted that disaster events, such as the Great Tohoku Earthquakes, may lead to power shutdowns.

MATERIALS AND METHODS

It is common among research community to use the nonlinear system of shallow water differential equations to simulate tsunami wave dynamics. The following system [6] was used for numerical treatment:

$$\begin{aligned} H_t + (uH)_x + (vH)_y &= 0 \\ u_t + uu_x + vu_y + gH_x &= gD_x \\ v_t + uv_x + vv_y + gH_y &= gD_y \end{aligned} \quad (1)$$

Here $H(x,y,t)=\eta(x,y,t)+D(x,y)$ is the sum of the known depth profile $D(x,y)$ and the wave height $\eta(x,y,t)$ (to be determined), the entire height of water column, being the sea surface disturbance (wave height), $D(x,y)$ – depth (which is supposed to be known at all grid points), $(u(x,y,t),v(x,y,t))$ is velocity vector, g - acceleration of gravity.

A parallel version of McCormack finite-difference scheme [7] was developed for the numerical solution of system (1). The scheme has the second order of approximation and a convenient for parallel computing stensil. This has allowed the design of a Calculator optimized for the FPGA architecture [8,9]. Depending on the specific FPGA microchip, the Calculator can operate either as part of a PC as a coprocessor (Xilinx Virtex-7 VC709) or independently (ZCU106 as System-On-Chip) [10]. PC with hardware acceleration board is suitable for use in data centers, while System-On-Chip (SoC) has possible application in ocean sensors (edge computing).

Using Calculator (based Xilinx Virtex-7 VC709) with a regular modern PC allows achieving the following performance: on a grid of 9601x6781 nodes 36000 time steps with 3 sec intervals (i.e. 30 hours of wave propagation) the calculation requires 1352 sec (i.e. 22.5 minutes).

In reality, to solve the system of shallow water equations, researchers get a supercomputer at their workplaces.

Comparison of the obtained numerical solution both with known exact solutions of the shallow water system (cases of sloping bottom and depth increase according to the parabolic law) and with the results of calculations using the MOST software package [1] on real bathymetry showed a good match [8].

For numerical modeling of transoceanic tsunami propagation, a region covering the most part of the Pacific Ocean (except for its westernmost part) was selected. The choice of the region was driven, first of all, by the interest in the impact of the Chilean tsunamis on the coast of Japan, the Kuril-Kamchatka zone, and the Aleutian Islands with Alaska. In addition, there was a limitation on the number of grid nodes by the size of the operative memory (RAM) of the FPGA-based calculator in use. When using McCormack's difference scheme to solve the system of differential equations (1) and the FPGA microchip Xilinx Virtex-7, the limitation on the size of the arrays is approximately 6.4×10^7 numbers. Because of these constraints, the computational grid 9601x6781 nodes was used. It covers the region from 130° E on the left boundary to 70° W on the right boundary and from 53° S on the lower boundary to 60° N on the upper boundary. Depth profile for the selected region was taken from the GEBCO 1 arc min global digital bathymetry [11]. Figure 1 visualizes the bottom and land topography of the selected region.

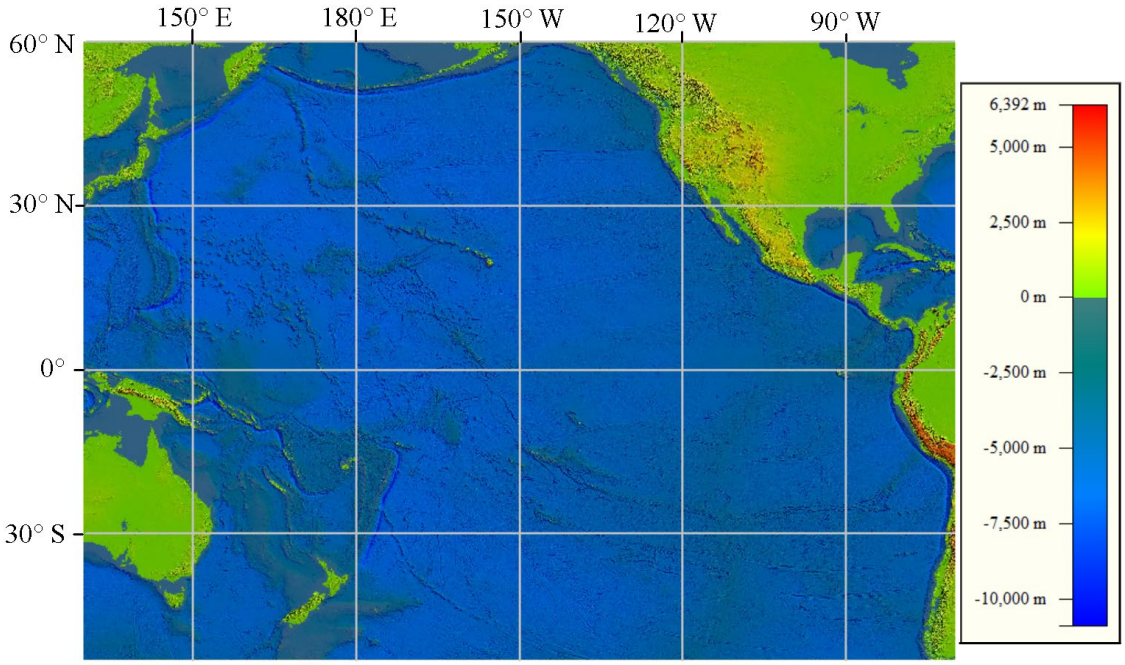


Figure 1. Visualization of the 9601 x 6781 computational grid topography of the Pacific Ocean used in the simulation at a detail of 1 geographic minute (on the order of 2 km along the meridian).

In the computational experiments, tsunami propagation from model sources was simulated. These sources have the form of ellipses with long axes oriented at angles from 70 to 90 degrees relatively to the east-west direction, being approximately parallel to the coastline. Inside these ellipsoidal sources, the initial vertical displacement of the water surface was given by the formula (2):

$$\eta(x,y)=\frac{\eta_0}{2}\left(1+\cos\left(\pi\left(\frac{x^2}{r_1^2}+\frac{y^2}{r_2^2}\right)\right)\right), \tag{2}$$

where r_1 and r_2 are the semi-axis lengths of the source ellipses, while x and y are the distances to its centers along the parallels and meridians, respectively. The sizes of model sources were the same in all calculations and corresponded to the sea bed displacement area caused by an earthquake with magnitude 9.0 in this subduction zone. The length of the short axis of each ellipse was taken equal to 84 km, the long axis - 500 km, and the maximum surface displacement in the center was taken as η_0 = +5 m although the maximum initial bottom (water surface) displacement for a magnitude 9.0 earthquake is typically on the order of 10 meters.

Several positions of model tsunami sources near the coast of South America were considered, see Figure 2.

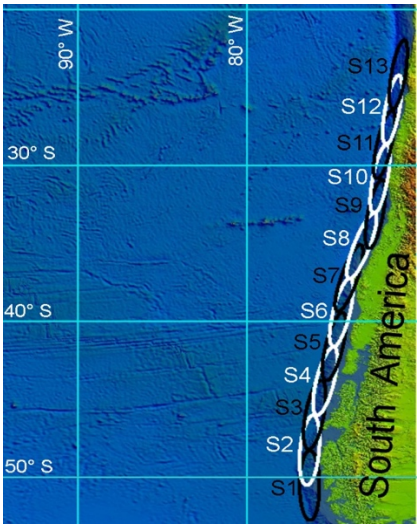


Figure 2. Positions of the model tsunami sources.

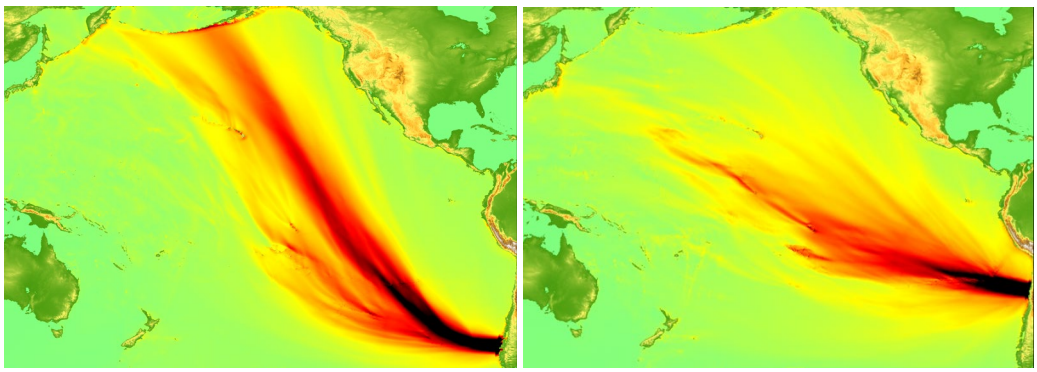


Figure 3. Results of numerical simulation of tsunami propagation from model sources S3 (left) and S11 (right), the locations of which are shown in Figure 2.

RESULTS

A series of computational experiments with model ellipse-shaped tsunami sources have demonstrated that such elongated sources have a strong directivity of the initial wave energy radiation. Further on, the direction of propagation of the maximum wave heights can change, either maintaining the main direction or gradually changing it. Thus, in the case of the model source S3, the propagation of waves with the largest amplitudes deviates to the north, Figure 3 (left part). In case of source S11, the maximum amplitudes continue to propagate in the direction orthogonal to the long axis of the elliptical model source, Fig. 3 (right part).

DISCUSSION

The results of computational experiments show that the distribution of maximum tsunami wave heights depend directly on the location of the source. As the tsunami source moves northward along the coast of Chile, the direction of wave radiation with maximum amplitude will shift to the northwestern Pacific Ocean. For example, the highest tsunami waves from the S3 source are observed at Aleutian Islands (Figure 3 left part). Here, the calculated maximum heights reached 100 cm, i.e. it can be dangerous. In the case of the S11 source, the maximum amplitude values from the same initial disturbance propagate practically without change of direction and, in addition,

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any significant wave amplitudes in the open ocean are not observed further than approximately the middle of the Pacific Ocean. But off the coast of Japan the tsunami height increases up to 1 m in some places.

CONCLUSION

In the case of megatsunamis off the coast of Latin America, the localization region of maximum wave amplitudes strongly depends on the position of the initial disturbance at the tsunami source. In general, the further south along the coast of Chile the source is located, the more northeasterly is the region of maximum amplitude values in the northwestern Pacific Ocean. Depending on the position of the source, significant amplitudes can be observed, for example, off the coast of the Aleutian Islands, Kamchatka Peninsula, the Kuril Islands, or the coast of Japan. In some cases, already in the middle Pacific, the maximum amplitudes may become small enough to be of no concern.

Using the proposed tools of hardware acceleration of calculations of the solution of the nonlinear shallow water system it became possible to estimate fast - within half an hour – the expected distribution of maximum wave heights in the opposite part of the Pacific Ocean.

ACKNOWLEDGEMENTS

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LONG-TERM VEGETATION DYNAMICS IN THE SPACVAN BASIN (1984-2023): REMOTE SENSING INSIGHTS INTO CLIMATIC IMPACTS AND EXTREME WEATHER EVENTS

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ABSTRACT

This research focuses on the long-term assessment of vegetation quality dynamics in the Spacvan Basin from 1984 to 2023. The objective is to evaluate how specific climatic factors influence vegetation health. The study employed remote sensing techniques, analyzing satellite images from the LANDSAT and Sentinel missions. The Spacvan Basin, covering 43,519 ha, served as the area of interest. Data collection, processing, and analysis were conducted using the Google Earth Engine platform. NDVI values were measured over the period from 1984 to 2023, revealing an overall increase in the index despite notable climate parameters. NDVI data for six years from 2018 to 2023 allowed the estimation of the start and end of the phenological cycle, which were then compared with results derived from an algorithm designed for this purpose. The phenological cycle was found to vary by an average of one month, with a two-month variation observed in 2023. The results indicate that rising temperatures and declining precipitation affect the phenological cycle, though these effects are generally short-lived.

Keywords: climate change, forest, remote sensing, spatio-temporal analysis, vegetation

INTRODUCTION

Climate change has become a focal point of scientific research and environmental policy over the past few decades [1]. Increasing temperatures, changes in precipitation patterns, and more frequent extreme weather events have spurred significant scientific attention to understanding global long-term ecological impacts on forested ecosystems [2]. Forests play a critical role in biodiversity preservation, carbon storage, and local economies, making them an essential subject of research in the face of climate-driven environmental change [3]. Among these vital ecosystems is the Spacvan Basin, located in eastern Croatia, a lowland forest region primarily composed of pedunculate oak (Quercus robur) and known for its ecological and economic importance [4]. The Spacvan Basin is one of the largest continuous oak forests in Europe, spanning approximately 40,000 hectares, and serves as a unique case study for understanding vegetation dynamics in response to climate change. Over recent decades, both regional and international studies have increasingly focused on this area to assess the health and quality of its forest stands under shifting climatic conditions. Former research [5] has documented the importance of pedunculate oak in Croatia, particularly emphasizing its ecological role and the historical phenomena of forest dieback. This research highlights how forestry expertise has maintained the basin's overall surface area over the last

hundred years, despite ongoing pressures from environmental change and human activity. Recent studies [6] have further deepened our understanding of the sensitivity of lowland oak ecosystems in Croatia to climate change, focusing specifically on forests in the Lonjsko Polje and Spacvan Basin. Using dendrochronological methods, this research demonstrated that trees in the Spacvan Basin exhibit greater sensitivity to climatic variability than those in other comparable lowland ecosystems. This heightened sensitivity underscores the importance of ongoing monitoring and the potential impacts of future climatic changes on the area's vegetation dynamics. The economic significance of the Spacvan Basin is another factor that brings urgency to its study. Lasić [7] examined the economic contributions of the basin's forests, emphasizing their role in the economy of Croatia's Vukovar-Srijem County and the national forest economy. However, forest dieback, droughts, and soil moisture depletion have raised concerns about the sustainability of these forests, as extreme weather events increasingly challenge their resilience.

The literature thus far provides a robust foundation for further research. However, a gap exists in understanding the long-term trends of vegetation dynamics in the Spacvan Basin as they pertain specifically to climatic drivers over multiple decades. This study aims to bridge this gap by leveraging remote sensing technologies to analyze vegetation changes in the Spacvan Basin from 1984 to 2023. Remote sensing offers unique advantages in assessing temporal changes across large areas, making it possible to detect subtle shifts in forest health, phenological events, and responses to extreme weather events over time.

MATERIALS AND METHODS

Study area

The study area for this research is the Spacvan Basin (Figure 1). The Spacvan Basin is part of the Pannonian Plain in the lowest part of the Posavina region. Located in the Vukovar-Srijem County, it lies between the Sava and Danube rivers, within the Bosut River watershed and its tributaries. The basin's central watercourse is the Spacvan River, from which it derives its name. Covering an area of 43,519 hectares, it represents the largest continuous lowland pedunculate oak (Quercus robur) forest in both Croatia and Europe. By comparison, France, the European country with the most extensive oak forests, has the Fontainebleau Forest, a pedunculate oak forest that spans just over 18,000 hectares, significantly smaller than the Spacvan Basin [8]. The Vukovar-Srijem County and the Spacvan Basin forest are situated in a moderately continental climate zone, characterized by hot, sunny summers and cold, snowy winters. The average annual temperature is around 11 °C, with an average maximum temperature of 29.9 °C in the warmest months and a minimum of 12.2 °C. Annual precipitation ranges within a relatively narrow span, from approximately 650 mm in the eastern part to around 800 mm toward the west, with the highest precipitation levels in spring and mid-summer. Relative humidity averages 79%. Despite this relatively even distribution of precipitation, the winter months are the driest [9]. The Spacvan Basin is also considered a national treasure due to its contributions to the past and future development of Vukovar-Srijem County and Croatia as a whole. The area contains roughly one-fifth of the total pedunculate oak forest in Croatia. The largest wood-processing enterprise, Spacvan Wood Industry, exports wood products to Italy, France, Spain, and Bosnia and Herzegovina. In 2014, the Vinkovci Forest Management Division generated a profit of

60 million HRK, accounting for 41% of the total profit of Croatian Forests in that year [7].

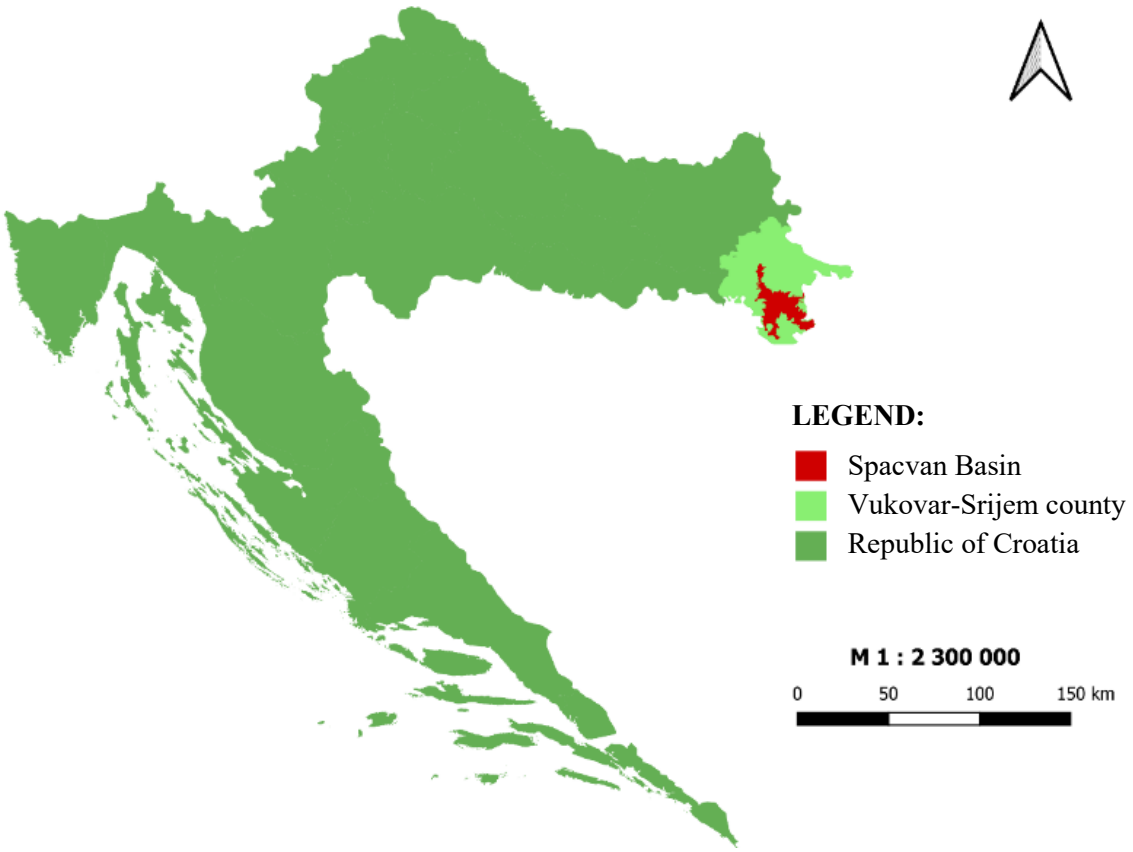


Figure 1. Location of the Spacvan Basin (red) in Vukovar-Srijem county (light green) in the Republic of Croatia (dark green) [4].

Data collection

Climate Change Knowledge Portal (CCKP) is an information hub provided by the World Bank Group, offering access to comprehensive climate and development data [10]. This study has utilized data on average annual air temperature and precipitation spanning from 1983 to 2023. Satellite data were obtained via the Google Earth Engine platform, a powerful tool for geospatial analysis and visualization. The Earth Engine platform allows access to over 600 spatial datasets, including satellite images dating back to the 1970s, and is built on JavaScript API [11]. For the 40-year satellite imagery analysis, we utilized data from the LANDSAT missions. LANDSAT 5 images were analyzed from 1984 to 2000, LANDSAT 7 from 2000 to 2013, LANDSAT 8 from 2013 to 2021, and LANDSAT 9 from 2021 to 2023. Several parameters were set prior to analysis. First, a spatial boundary was defined by importing a vector layer of the Spacvan Basin boundary, sourced from Bioportal (https://bioportal.hr/). The cloud cover parameter was also adjusted to filter images with less than 20% cloud cover, reducing processing time and ensuring clear results.

Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) calculation

Land Surface Temperature (LST) was derived from the LANDSAT satellite missions, as it is a crucial variable for studying the long-term effects of climatic impacts [12]. Using consistent satellite data across multiple decades, LST enables continuous, reliable data acquisition without relying on extensive physical sensor networks. The LST analysis for the Spacvan Basin was based on LANDSAT 5, 7, 8, and 9 missions from 1984 to 2023, utilizing an algorithm adapted from Ermida et al. [13].

The Normalized Difference Vegetation Index (NDVI) is a metric that indicates vegetation density and health, with values ranging from -1.0 to 1.0. Negative values indicate clouds or water, near-zero values indicate bare soil, and high positive values indicate dense vegetation. Sparse vegetation generally falls between 0.1 and 0.5, while forested areas and dense vegetation typically score above 0.6. NDVI is calculated using the near-infrared (NIR) and red channels with the following formula:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad (1)$$

For this study, the third and fourth channels were used for LANDSAT 5 and 7 missions, and the fourth and fifth channels for LANDSAT 8 and 9, respectively.

Detection of Phenological Cycle Shifts

Phenology, the study of seasonal biological events, is particularly relevant to understanding how climatic changes affect vegetation. Land Surface Phenology (LSP) examines these dynamics using multispectral satellite data [14]. Two key concepts in phenology are the start of season (SOS) and end of season (EOS). This study analyzed the SOS and EOS for the Spacvan Basin from 2018 to 2023 using Sentinel-2 satellite data and an algorithm adapted from Descals et al. [15], comparing it with estimated SOS and EOS values derived from NDVI calculations.

RESULTS AND DISCUSSION

The climate parameter analysis yielded the expected results. The average air temperature in Croatia (Figure 2 left) has risen sharply, especially since 2014, with an increase of nearly two degrees in the past decade. Given that the historical average temperature was 10°-12°C, the recent rise to 14°C is significant and concerning. This trend aligns with the World Meteorological Organization's data showing 2023 as the hottest year on record. Average precipitation in Croatia (Figure 2 right) has gradually declined, though less drastically than the temperature increase. Notably, the highest rainfall occurred during the 2014 Gunja flood, after which precipitation has consistently decreased. The combined data suggests that climate change in Croatia has accelerated significantly over the past ten years.

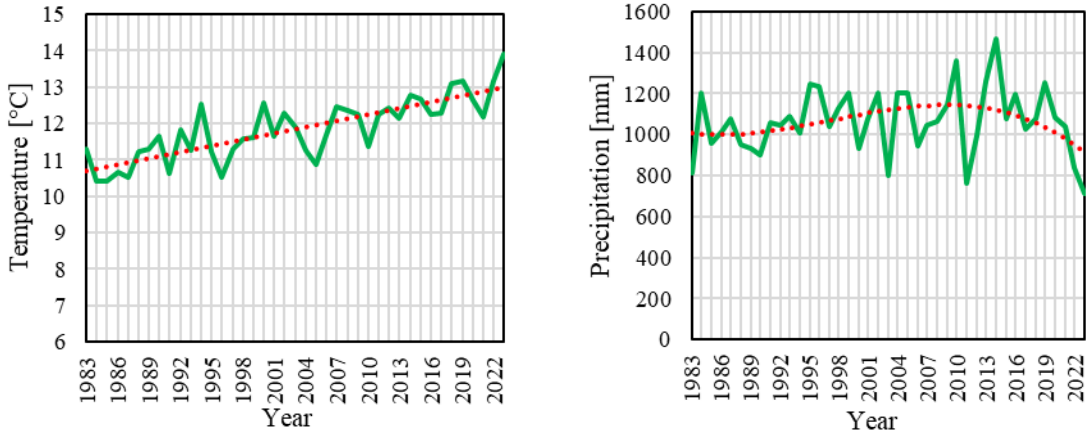


Figure 2. Graph of the average air temperature (left) and average precipitation value (right) and trends (red dotted) in Croatia from 1983 to 2023.

Land surface temperature (LST) in the Spacvan Basin (Figure 3 left) shows a slight upward trend but less fluctuation than air temperature due to soil's slower response to heat changes. However, in the past decade, the incidence of extreme low soil temperatures has decreased significantly. Despite increased temperatures and reduced rainfall, the NDVI analysis (Figure 3 right) indicates a mild increase in healthy vegetation. Specific years like 1989, 1996, 2003, and 2006 showed lower NDVI values, reflecting earlier warm periods. The year 2014, despite being the warmest until then, saw vegetation recover after a flood. NDVI values increased from 2015 onward but dipped again in 2019 and 2023, both marked as exceptionally hot years.

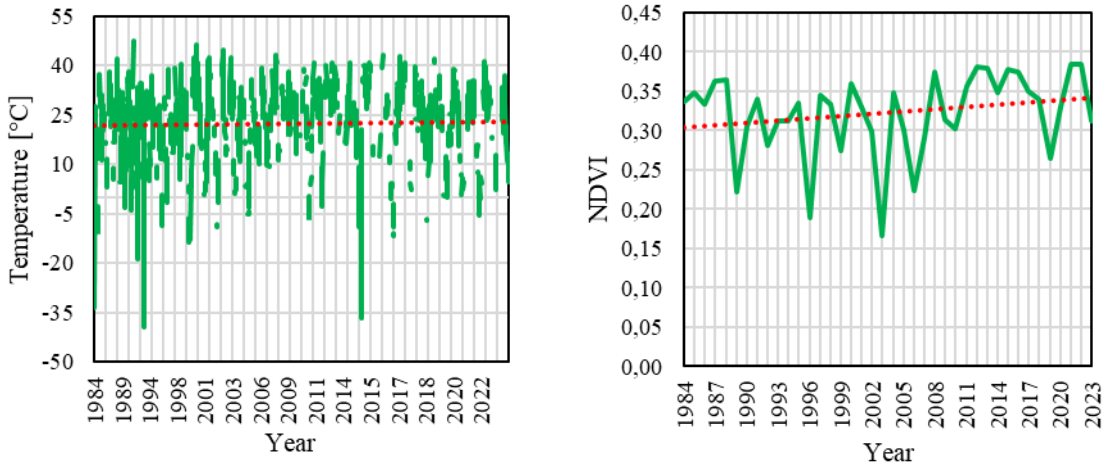


Figure 3. Graph of LST (left) and average NDVI (right) and trends (red dotted) in the Spacvan Basin from 1984 to 2023.

The main goal of this research was to estimate the months in which the growing season begins and ends, defining the time interval of the phenological cycle. The same time period was selected as in the phenological cycle analysis conducted using an algorithm on the Google Earth Engine platform. This allows a comparison between the estimated start (Start of season – SoS) and end (End of season – EoS) of the phenological cycle

based on NDVI values and those obtained through the algorithm. For this purpose, an algorithm was developed to calculate the beginning and end of the pedunculate oak growing season in the Spacvan Basin area, with results presented in Table 1.

Table 1. Calculation results for the start and end of the pedunculate oak growing season in the Spacvan Basin area [4].

Year	SoS	EoS
2018	April	August
2019	May	August
2020	April	September
2021	May	September
2022	April	August
2023	May	October

The normal phenological cycle of pedunculate oak starts in March or April and ends in September. Comparing calculated data (Table 1) with the normal cycle shows that the cycle has shifted by at least a month over the past five years, either at the start or end. In 2023, it was delayed by up to two months, starting and ending later. This caused the trees to bud again in some areas, as October's climate resembled spring conditions [4].

CONCLUSION

The effects of climate change are present and visible worldwide. Rapid climate changes are a major challenge for today’s humanity. Given that forests are the lungs of the world, it is particularly crucial to monitor the impact of climate change on them and vegetation overall. Additionally, humans play a key role in caring for forests and vegetation. It is necessary to address the causes of sudden climate changes to reduce the drastic growth rate and mitigate the consequences. A spatio-temporal analysis was conducted using remote sensing methods on the dynamics and quality of forest cover over a forty-year cycle. Additionally, a six-year cycle analysis was carried out to detect changes in the phenological cycle of pedunculate oak in the Spacvan Basin area. Despite the drastic increase in temperature and decreased precipitation, the forest shows a trend of improving vegetation quality. The key conclusion of this study is that long-term climate effects impact vegetation conditions, but recently, these effects have appeared more quickly than before. The shortened cycle of climate change is inversely proportional to problems and damage to vegetation. As the cycle shortens, the impact on vegetation could become more severe. All analyses shown in this research were conducted using algorithms on the Google Earth Engine platform and based on freely available satellite imagery. Accordingly to all the above, it can be concluded that remote sensing offers unique advantages in assessing temporal changes across large areas as

well as making it possible to detect subtle shifts in forest health, phenological events, and responses to extreme weather events over time.

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ON THE NORTHERN LIMITS OF *SCOLOPENDRA CINGULATA* WITH NEW DATA FROM ROMANIA

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ABSTRACT
In this moment the populations of *Scolopendra cingulata* from Austria, Hungary and the new discovered populations from Romania represents the northern limits of *S. cingulata* in Europe. These three northern small populations of *S. cingulata* are very important in understanding the evolutionary history of this iconic species for Europe.

Keywords: *Scolopendra cingulata*, distribution, northern Europe limits.

INTRODUCTION

Scolopendromorpha (Arthropoda: Myriapoda: Chilopoda) order include more than 700 centipedes with worldwide distribution, but with the biggest diversity in the tropical and subtropical regions. The trunk has usually 21 segments with 21 pairs of legs (sometimes 23 with 23). The length of the body can go from 9 mm to more than 30 cm. Almost all species from Scolopendridae family have four ocelli on both sides of the head. *Scolopendra* Linnaeus, contain more than 100 species, the majority in the tropics, but also in the warmer temperate regions, like the Mediterranean Region. *Scolopendra* genus include large and very large centipedes, the biggest centipedes in the world, some species with more than 30 cm length, like *Scolopendra gigantea* Linnaeus from South America. *Scolopendra* species are predators, hunters, carnivores, having a painful bite, using the anterior legs transformed in forcipules, for injecting the venom in the pray. The big *Scolopendra* species can eat big arthropods (even scorpions and tarantulas), but also small vertebrates, like small amphibians, reptiles, birds and mammals [1]. The bite of *Scolopendra* species can produce an intense and long-lasting burning pain, edema and redness, and in extremely rare cases can even kill humans, like small child [2, 3].

MATERIALS AND METHODS

In the last twenty years we investigate Romania for seeking *S. cingulata*. Maps (Figure 2, 5) were made with Google EarthPro® (7.3.6.9345 Release, Google, Santa Clara, CA, USA) and pictures taken with Canon digital cameras (Canon Inc., Tokyo, Japan). We use Adobe® Photoshop® CC (20.0.0 Release, Adobe, San Jose, CA, USA).

RESULTS

Scolopendra cingulata Latreille, 1829 (Mediterranean banded centipede, Megarian banded centipede) (Figure 1) is maybe the most likely to meet centipede species in the Mediterranean Region and the adjacent warmer areas. It can be considered as a charismatic, iconic species, easy to recognise even by the non-specialist people, being also kept as a pet in terrariums by some persons. It's the only one Scolopendridae species in Romania, and even has a popular name here, being named "cârcăiac", from the Turkish name "kirkayak" (kirk= forty, ayak=foot), since the period when the

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historic province Dobrudja, where *S. cingulata* are more common, where under the Ottoman Empire influence and administration. In the temperate areas, in late autumn, there are reported cases of *S. cingulata* entering in the houses, seeking refuge for the overwintering, and because of that some specialized companies in disinsection and deratization, also mentioned this species in the list of the offered services.



Figure 1. *Scolopendra cingulata* (David's Valley Hay Natural Reserve, Iaşi County)

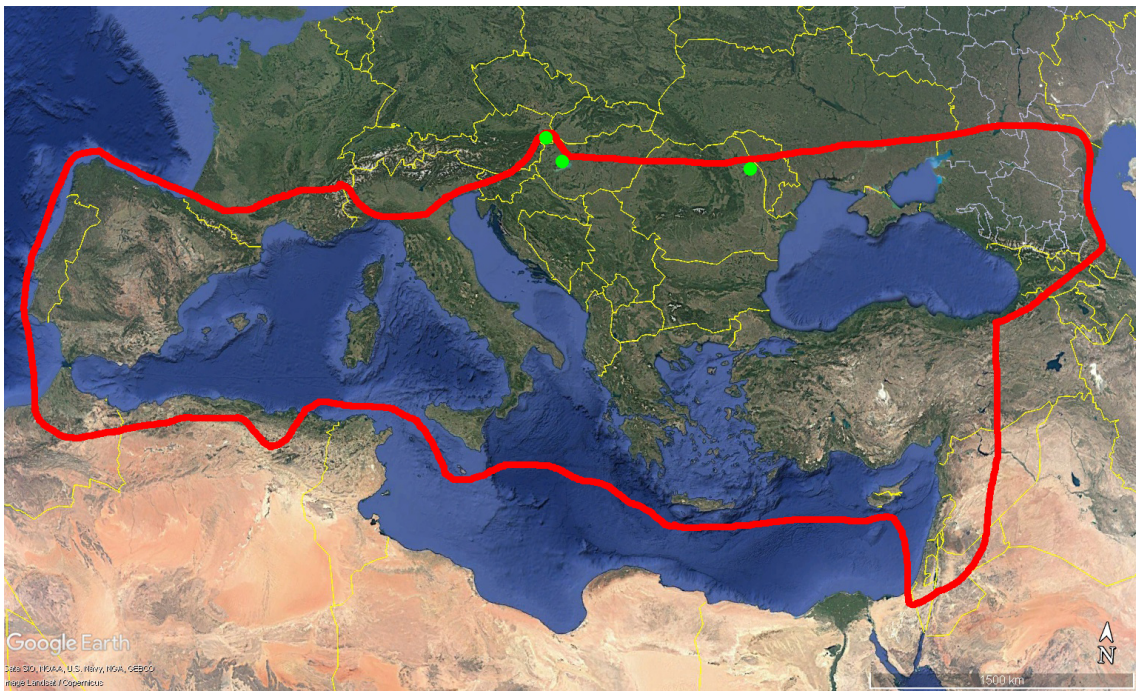


Figure 2. Distribution of *Scolopendra cingulata* (red line) in Europe and adjacent areas, including northern points (green dots) from Europe in Austria, Hungary and Romania.



Figure 3. David's Valley Hay Natural Reserve (Iaşi County)



Figure 4. The Forest and Meadows from Mârzeşti, Site of Community Interest (ROSCI0171) (Iaşi County)

The general colour of the body is brown to orange yellow, frequently with alternate brown and orange transversal stripes, with orange to yellow legs, darker on juveniles. In the spring, younger specimens can have a red round spot on the head. With the around 15 cm maximum length is one of the smallest species from *Scolopendridae*, but still a big apparition when is found, being Europe's largest centipede [1, 3]. The adults can reproduce just with the third year of life, and the females caring their eggs and larvae

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for more than 50 days in the brood chamber in the soil. The eggs and larvae younger than 35 days cannot survive without the mother's care [4].

The general distribution area in Europe and the adjacent areas is from Portugal to Turkey, including Egypt, Libya, Morocco, Tunisia, Cyprus, Ukraine, Russia [5, 6] (Figure 2). There are also mentions from Iran and Middle Asia. In Romania it was found until present research just in the southern half part of the country, more frequent in Dobrudja, but also in many sites from Oltenia and the southern part of Muntenia, few points from south-western part of Banat, one mention from Transylvania and few from the southern part of Moldavia [7] (Figure 5, green marks). We also investigate the mentions from the so called "citizen scientists" from platforms like iNaturalist and some Facebook groups but the spots where similar, close to, or merged with the literature data. We found *S. cingulata* more in the north of Romania (Figure 5, red marks), in the David's Valley Hay Natural Reserve (Iaşi County) (Figure 3) and in The Forest and Meadows from Mârzeşti (Iaşi County), Site of Community Interest (ROSCI0171) (Figure 4). It was not found in others investigated areas for seeking protected or rare invertebrates from the border area of Romania with the Republic of Moldova [8]. Both David's Valley and Mârzeşti protected areas preserve flora and fauna from regions with steppe conditions [9], these regions being the most in need to be protected in Europe, but also in the world, because of the destroying of these types of habitats by the humans.

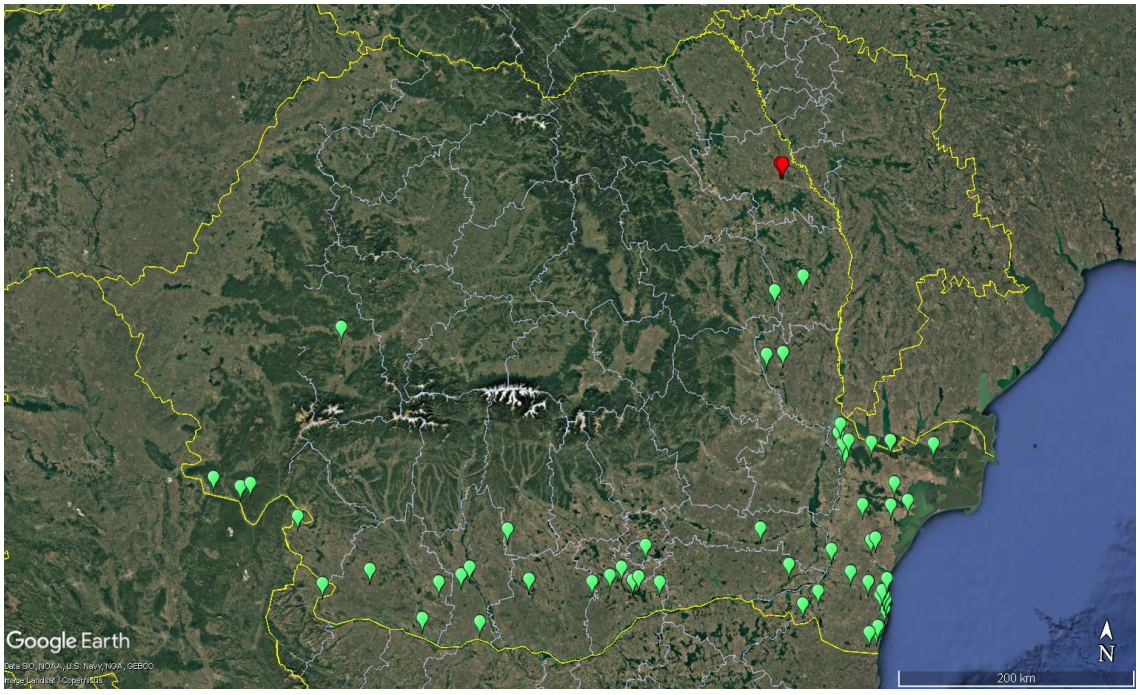


Figure 5. Distribution of *Scolopendra cingulata* in Romania (with green the old records, with red the new records from David's Valley Natural Reserve and Mârzeşti SCI)

S. cingulata it's an unscrupulous terrestrial voracious predator that eat any animal that can kill it, usually not longer that own body. Can be active in the daytime for seeking the pray, but prefer to stay borrowed in leaf litter, under stones, logs. Its venom can produce problems to humans but is not so toxic as that of other scolopendrids. It's a thermophilous species found in Mediterranean and Sub-Mediterranean ecosystems, with xerophytic character [3]. Prefer xerophilous biotopes, calcicolous, lapidicolous environment, short grassland habitats, even with sparse tree and shrub cover, limestone

slopes, rocky grassland patches, open places with many stones, karstic biotopes but just at the enter of the caves, never inside [1, 3, 6, 7, 10, 11]. It can be even an opportunistic species found in riparian habitats like the Văcărești Natural Park from the inside of Bucharest city, the first and the biggest urban natural park from Romania [12] (unpublished data until now).

DISCUSSION

S. cingulata it's a thermophilous species with Mediterranean and Sub-Mediterranean areal in Europe and the adjacent areas [1, 3, 5, 6, 10]. It's considered as a colonizer species in the Mediterranean area, coming into Mediterranean Basin from the western parts of Asia, from Anatolia, being also an intruder into the south European countries, from Spain to Italy and to the Balkans [6].

Even Romania is not a part of Mediterranean and Sub-Mediterranean regions, there are some southern species that spread in the southern and the south-eastern part of Romania, and from here to the north [13]. The spread of these species in the Lower Danube Basin it was facilitate by the favourable climatic and ecological conditions, and the proximity with the Pontic-Mediterranean glacial refuge, a centre of spreading the Mediterranean fauna [13]. *S. cingulata* can be considered as a part of the advancing species from the South-East-Mediterranean fauna.

Some authors even give some proofs for the presence of a Sub-Mediterranean biogeographic enclave spaces in Romania, the northern outpost being close to Iași [13]. In the Upper Holocene, with the cooling of the climate, the areal of some southern species it was shrinking in some isolated enclaves, the actual glacial relicts [13]. For the north of Italy, the presence of *S. cingulata* is considered as a relict one [10]. The recent rediscovered populations from the north of Austria, in Leitha Mountains, close to Lake of Neusiedl [3] and the relatively recent discovered five more extant populations in addition of the two anterior known localities in Hungary, at the Vértes Hills [11], can be also considered as a biogeographical relicts in possible microrefugia [3, 13]. All these three northern populations from the north of Europe, from Austria, Hungary and Romania can be considered as relict populations from the Tertiary period [3, 13].

The actual possible expansion of the areal of *S. cingulata* from the primary distribution area must be also corelate with the human activities, like the accidental anthropogenic introductions with luggage, and the imported food products [14]. It must be also investigated how the climatic changes can affect the areal of *S. cingulata*.

CONCLUSION

S. cingulata populations from the north of Europe, from Austria, Hungary and Romania, are very important in understanding the historical natural evolution of this species. It's also a representative species for understanding the generally geographical evolution of the Mediterranean, Sub-Mediterranean, South-East-Mediterranean, Pontic-Mediterranean, Lower Danube Basin fauna, being an illustrative studying case.

This charismatic species, *S. cingulata*, is under legal protection in Hungary [11], with recommendation to be protected also in Austria [3] and Italy [10]. For Germany is considered "extremely rare", with similar recommendation to be protected [15]. Unfortunately, this iconic species, have no legal protection in Romania and is not included in any red list or red books of protected species from this country. We strongly

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recommend the introduction of this captivating and rare species in the future red lists and red books of fauna from Romania, with the legal protection. It's also very important to protect the habitats where *S. cingulata* is found. Can be considered as an indicator species for habitats in need to be protected and used as an umbrella species for taking active measures in protecting these areas.

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RESILIENCE OF AGRICULTURAL FARMS IN THE FACE OF CLIMATE CHANGE: THE CASE OF THE TODGHA OASIS, MOROCCO

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ABSTRACT

This study investigates the adaptive strategies of farmers in the Todgha oasis, Morocco, as they respond to the pressing challenges of climate change. Through a mixed-methods approach, we assess the resilience mechanisms adopted to sustain agricultural production amidst increasing temperatures, unpredictable rainfall, and shifting ecological conditions. Key findings reveal that farmers rely heavily on traditional water management systems, including khettaras and modern pump-assisted irrigation, to mitigate water scarcity. Additionally, the oasis's date palm cultivation forms a microclimate that supports a variety of crops, underscoring the importance of agroecological diversification in local resilience. Despite these efforts, rising climate impacts have affected both crop yields and livestock productivity, prompting farmers to diversify their income through off-farm activities and, in some cases, migration. This research emphasizes the critical need for policies and investment in climate-resilient infrastructure that respect traditional practices while introducing technological advancements. Supporting these strategies is essential to ensuring the sustainability and economic vitality of the Todgha oasis in an era of climate change.

Keywords: Climate Change Adaptation; Agricultural Resilience; Todgha Oasis; Sustainable Livelihoods; Water Resource Management; Mitigation Strategies; climate impacts

INTRODUCTION

Moroccan oases cover a total area of 107,324 km², accounting for 15% of the national land area (710,850 km²). Of this, only 2% is cultivated, while the remaining 98% consists of desert zones [1] (Kabiri, 2014). These oases serve as crucial ecological buffers against desertification and provide essential habitats for biodiversity, hosting a wide array of plant resources, including roses, saffron, vegetables, and cereals, some of which are endemic [2]. However, this heritage faces constant threats from several adverse factors, such as drought, desertification, soil salinization, biodiversity loss, low agricultural productivity, and inefficient use of date palms [3] [4]. Recognizing these challenges, UNESCO incorporated the pre-Saharan Moroccan oases into its global network of biosphere reserves in 2010, aiming to mitigate biodiversity loss and improve local livelihoods.

Bioclimatically, the Moroccan oasis regions are characterized by an arid to Saharan climate with highly irregular rainfall and strong continental effects. Rainfall is often

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intense and occurs in short bursts as storms, leading to violent floods. The average annual rainfall is only 132 mm, with around twenty rainy days per year [5]. In some valleys, however, microclimates develop due to the presence of water and vegetation, with high reliefs offering some protection and mitigating aridity. Nonetheless, oases remain "vulnerable and fragile ecosystems," susceptible to degradation from external factors such as climate change, which drives both global warming and increased desertification [6] [7]. Climate change poses a significant challenge for oasis regions, with substantial long-term environmental, social, and economic implications [8] [9].

For example, in Tinghir, between 1961 and 2008, average temperatures rose by 0.3°C per decade, and severe water deficits of up to -84% were recorded in 2000 [10]. The early 2000s experienced frequent droughts, although some years had no deficits relative to the average. Projections for 2030–2050 indicate seasonal and annual warming of 1 to 2.2°C, along with reductions in cumulative winter rainfall across oasis areas [11]. In Todgha, this decline could reach 35% compared to 1971–2000 levels [12]. Such changes are expected to have profound impacts on local populations and the economy, where agriculture remains a primary pillar.

In response to recent climate variations, oasis farmers have developed various adaptation strategies. Here, "adaptation" refers to the adjustment of natural or human systems in response to climatic stimuli or their effects, aimed at minimizing adverse impacts or leveraging beneficial opportunities [13] [14].

This article aims to identify and analyze these adaptation strategies, as well as the perceptions of oasis farmers regarding observed local climate changes. It draws on an empirical study conducted in the Todgha oasis, located in the Tinghir province of southeastern Morocco. Through this case study, we illustrate how local adaptation strategies reflect broader responses to territorial development challenges. Indeed, there is a continuum between development activities (addressing current non-climatic issues) and adaptation activities (focused on mitigating future climate impacts) [15].

MATERIAL AND METHODS

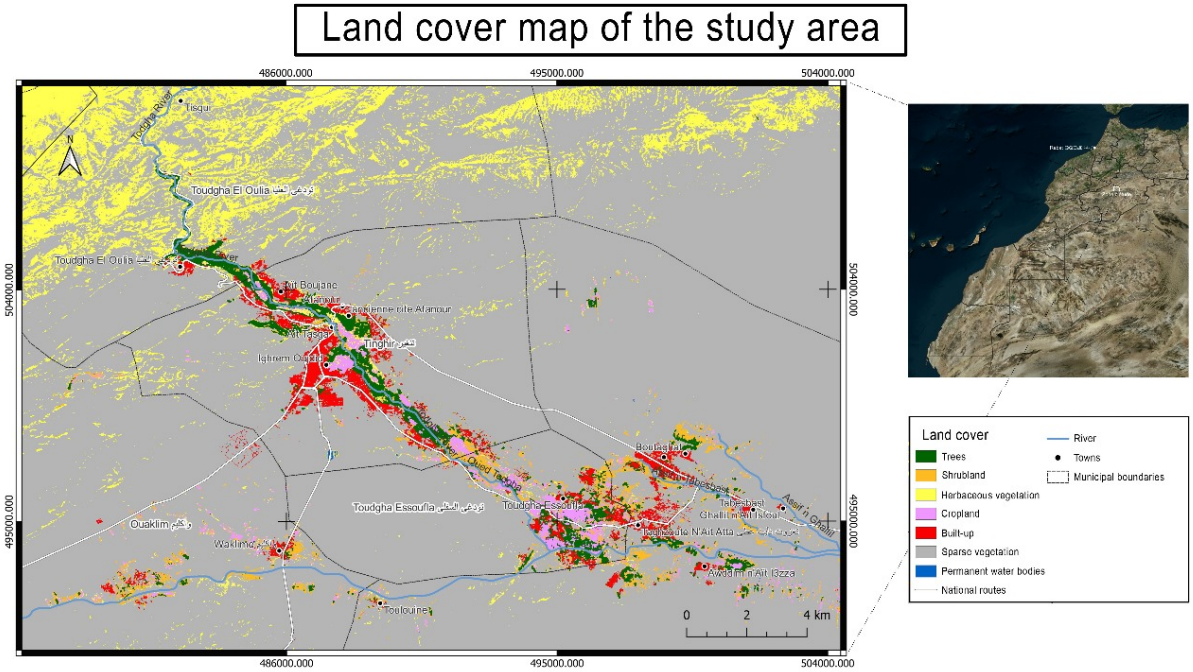
Study Area

Our research focuses on the Todgha Valley region (Figure 1), located in the Tinghir administrative province of southeastern Morocco. The valley now encompasses four municipalities: Tinghir, the urban center, and three rural communities—Todgha El Oulya, Todgha Soufla, and Taghzoute. Local authority is divided, with rural zones overseen by a high-ranking official and the urban center managed by the pasha. According to the 2014 census, approximately 80,000 residents live across the valley's 64 villages. The valley is home to three main ethnic groups: primarily the Ait Todgha group residing in the upper valley, the Ait El Hart who inhabit two villages, El Hart Morabtin and Niaamine, in the middle section, and the Ait Atta tribe in the lower valley.

Tinghir, the valley's main town, is located 169 km east of Ouarzazate and 162 km west of Errachidia, positioning the Todgha Valley between Morocco's major oasis areas, Draâ and Tafilalt. Stretching roughly 40 kilometers, the valley meanders along a typically dry riverbed, with an average width of about one kilometer.

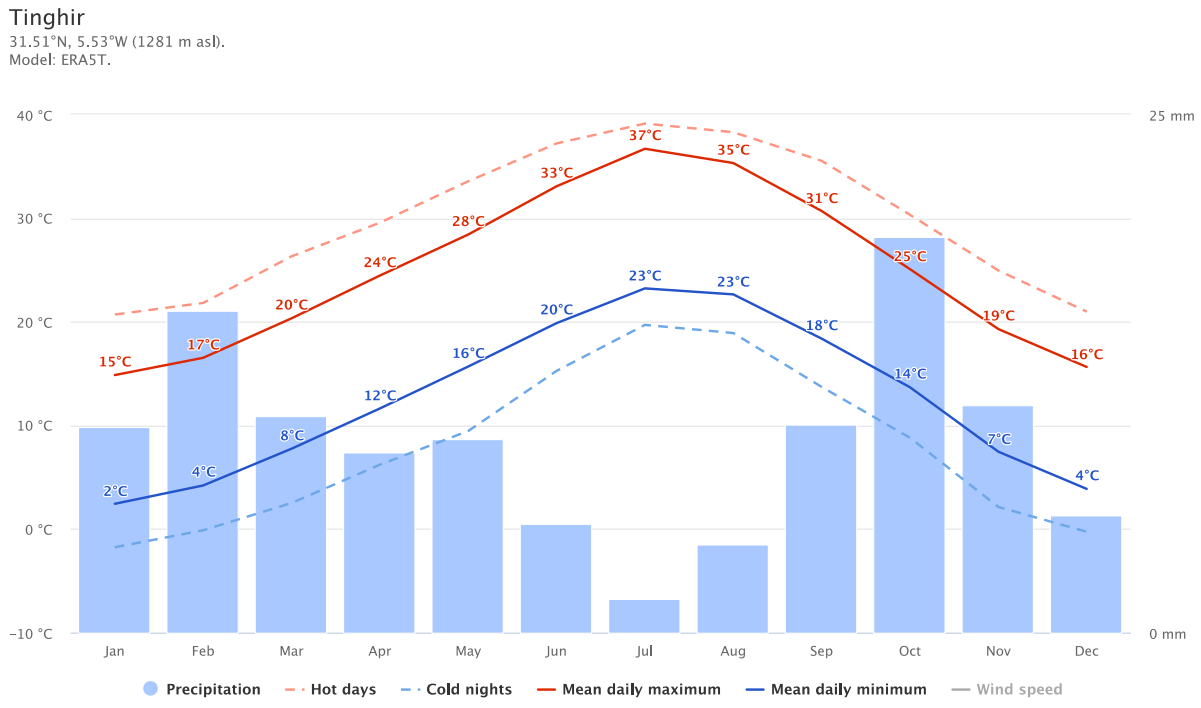
Over the year, the average temperature at the oasis is 20.1°C, and the average rainfall is 156.9 mm (Figure 2).

Figure 1: Land cover map of the study area



Note: Land cover map of the study area at 10 meters precision (Sentinel-2, 2022)

Figure 2: Average temperatures and precipitation



Source: (meteoblue, 2024)

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Investigation tools and analysis methods

The study population consists of two decision-making levels. The first includes staff responsible for the design and implementation of agricultural projects at the regional level, comprising five individuals: two managers from the Regional Office for Agricultural Enhancement of Ouarzazate (ROAEA) and three from the Tinghir Agricultural Advisory Center (AAC). The second level involves 35 farmers from the Tinghir oasis, including five women, selected randomly without aiming for statistical representativeness.

Data collection took place in March 2024, employing a questionnaire for the farmers and a semi-structured interview guide for institutional managers. The farmers' questionnaire gathered information on production systems, distribution of tasks, perceptions of climate changes, their impact on production systems and livelihoods, and adaptation strategies. The interview guide aimed to identify institutional actions addressing climate change and gather perceptions on climate shifts, agricultural impacts, and response strategies. A descriptive analysis method was used to analyze the collected data.

RESULTS AND DISCUSSION

Production System of the Surveyed Farms

To evaluate the impact of local climate change on farmers and their coping mechanisms, an understanding of their production systems was essential.

Plant Production System

At Todgha oasis, agriculture and livestock farming dominate economic activities, with 77% of respondents engaged in these sectors. Most farms use irrigated agriculture, with 17% of farmers holding plots between 0-1 ha, 72% holding between 1-3 ha, and 11% holding more than 3 ha. Farmers utilize different planting "strata" to maximize land use and income, as shown in Table 1.

Table 1: Main crops in Todgha oasis

Type of Crop	Species
Fruit Trees	Palm, olive, almond, apricot, fig, apple, quince, peach, plum, walnut, vine, pear, pomegranate
Vegetables	Tomato, onion, zucchini, turnip, carrot, melon, eggplant, potato
Cereals	Soft wheat, durum wheat, barley, maize
Legumes	Alfalfa, peas, broad beans

Date palms are central to the cropping system, with underlying layers of fruit trees and cereals/legumes. Water scarcity has led 39% of respondents to adopt this stratified system, though some (29%) have stopped cereal farming. The date palm also provides a protective microclimate. Olive trees, following date palms, are crucial, alongside almonds and apples for commercial purposes, with other fruits grown for self-consumption.

Livestock farming complements crop production, serving as labor and income sources. Intensified livestock farming, with D'man sheep and Deraa goats, addresses the region's specific climatic challenges, while cattle are kept primarily for self-consumed milk due to limited facilities. Livestock feeding relies on local alfalfa, straw, and purchased concentrates, especially during lean months [16] [17].

Climate Change Effects on Local Population and Economy

Local climate shifts, particularly rising temperatures and decreasing precipitation, were noted by 43% of respondents. These changes include a reduced rainy season, unpredictable rainfall patterns, and challenges for rosaceous fruit trees (e.g., apples) that need cold temperatures, leading to reduced cultivation. AAC officials and farmers observed early date palm spathe emergence and a general decline in fodder production, impacting milk yield and leading to livestock sales during dry spells.

Farmers' Climate Adaptation Strategies

Farmers have adapted to environmental changes with strategies affecting their cropping system and livelihoods.

Cropping System Adjustments

While cereals remain essential, farmers have adapted by increasing barley cultivation due to its resilience [18]. ROAEA has facilitated crop diversification, providing drip irrigation systems. However, a portion of farmers (20%) have shifted to more profitable crops, while others (28%) have reduced or abandoned intensive cropping due to water scarcity and labor shortages.

Irrigation Management

Given water limitations, 93% of farmers identified water scarcity as the primary agricultural constraint. Traditional khettaras, though effective in reducing evaporation, are threatened by reduced groundwater levels. Restoration of khettaras has been pursued as an adaptive measure, with ROAEA assisting groundwater recharge efforts [19] [20]. Some farmers now rely on deeper wells and electric pumping, though they face water table depletion [21].

Income Diversification

With agricultural income uncertain, 64% of farmers have diversified their income sources, often turning to small businesses or seasonal urban migration. Migration and agrotourism provide supplementary income, yet also reduces local agricultural labor availability [22].

CONCLUSION

This study highlights the complex and evolving relationship between agriculture in the Todgha oasis and the challenges posed by climate change. The surveyed farmers demonstrate resilience through a variety of adaptive strategies, from optimizing traditional cropping patterns and water management techniques to diversifying income sources beyond agriculture. Despite limited arable land and a dependency on traditional equipment, farmers in Todgha continue to rely on the date palm as a staple of both agricultural production and ecological stability, creating microclimates that support a diverse range of crops.

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However, rising temperatures and erratic rainfall have directly impacted both plant and animal production, affecting crop yields, livestock productivity, and local livelihoods. The necessity for innovative irrigation solutions, like the khettaras and modern pumping systems, underscores the importance of water as a critical resource. While these efforts reflect the community's ingenuity and resilience, challenges such as declining groundwater levels and the need for economic support through migration reveal systemic vulnerabilities.

Moving forward, support for sustainable agricultural practices and investment in climate-resilient infrastructure will be crucial for the long-term viability of the Todgha oasis. Policymakers, local authorities, and development organizations should prioritize interventions that strengthen traditional knowledge and support technological advancements to enhance agricultural productivity. By aligning with these adaptive strategies, the Todgha community can mitigate climate risks and sustain its agricultural legacy in the face of environmental change.

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SURGICAL KERATECTOMY WITH KERATOPLASTY OF A MELANOMA IN A PERSIAN CAT USING VETRIX EYEQ GRAFT

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ABSTRACT

An ocular melanoma is a type of cancer that originates from the uncontrolled growth of melanocytes. In cats, melanomas are rare, with diffuse iris melanomas being the most common eye tumors. This case report describes an 8-year-old female Persian cat referred to our clinic for evaluation due to a dark spot extending to the cornea, obscuring vision, and unresponsive to prior drug treatments. Diagnosis was confirmed through histopathological examination of a tissue sample. The present case report details a complex keratectomy surgery performed to remove the melanoma, utilizing an amniotic graft to reconstruct the cornea. Initially, the procedure began as a straightforward keratectomy, but the melanoma's deep and superficial extension into the corneal tissue required filling the surgical gap with several layers of An-vision Vetrix® EyeQ amniotic graft for corneal reconstruction. The surgery was completed by applying a protective An-Bandage lens and suturing the external eye angle to reduce the palpebral fissure for added protection. Postoperatively, Vetrix EyeQ amniotic eye drops, An-HyPro eye gel, and antibiotic drops were administered for one month. The cat was reexamined at 1 week, and again at 1-, 6-, and 12-months post-surgery, with no signs of melanoma recurrence observed during follow-up. Our study demonstrates the feasibility of successfully removing the melanoma without enucleation, provided that proper surgical and postoperative management is applied, leading to favorable visual outcomes.

Keywords: keratectomy, cat, melanoma, An-vision Vetrix eyeQ graft, an-Bandage lens

INTRODUCTION

Melanocytic tumors are common in dogs but rare in cats [12]. Melanoma, regardless of location, is infrequent in cats [10, 13]. However, melanocytic neoplasia is the most common type of ocular tumour in cats, with feline diffuse iris melanoma (FDIM) being the predominant form. Other forms, such as limbal melanomas and atypical melanomas (affecting the choroid or ciliary body), are less commonly observed [1, 2, 4, 7, 15]. According to the literature, ocular melanomas in cats are more prevalent than oral or dermal melanomas, with ocular and oral melanomas being more malignant and associated with higher rates of mortality and metastasis than dermal melanomas [10]. Ocular melanomas can be located intraocular, affecting the iris and/or ciliary body, palpebral, or involve the entire eye. Orbital melanomas, although rare in both cats and dogs, generally carries a poor prognosis due to its aggressive nature [14]. Histologically, Patnaik's study (1988) found that intraocular melanomas in cats can consist of mixed, epithelioid, or spindle cells. Metastasis was observed in 63% of cats with intraocular melanoma and in all cats with palpebral melanoma. The behavior of

feline diffuse iris melanoma (FDIM) is variable and difficult to predict. Some FDIM lesions progress benignly, either growing slowly or remaining static for years without significantly affecting the ocular or systemic health of the cat. However, other tumors behave aggressively, invading ocular structures and reducing life expectancy due to metastatic disease. This variability makes management and timely enucleation of FDIM cases particularly challenging in practice [7]. Enucleation is often indicated when iridial pigment changes progressively increase in size or number, or in cases of intractable uveitis or glaucoma [11].

The aim of our case presentation is to assess whether adequate surgical management of corneal melanoma can be achieved by removing all affected tissue with sufficient safety margins, while performing corneal graft transplantation. Additionally, we aim to determine if successful graft healing can lead to a favorable visual outcome post-surgery.

MATERIALS AND METHODS

Patient: An eight-year-old female Persian cat was presented with slowly progressive hyperpigmentation of the cornea in the left eye, which had been enlarging over a period of six months. The ventral medial cornea exhibited a dark, irregular, and diffusely pigmented mass. Both the pupillary light reflex and menace responses were positive in the left eye, and the physical examination revealed no abnormalities.

Clinical and Ophthalmological Evaluation: A detailed case history and comprehensive general examination were performed to identify any systemic conditions that could impact the surgery or anesthesia protocol. Following the clinical assessment, a complete preoperative ophthalmologic examination was conducted. Intraocular pressure (IOP) was measured in both eyes to rule out glaucoma, with results showing normal IOP levels. Tyndall negative.

Complementary Tests: Routine paraclinical tests were carried out, including a complete blood count and serum chemistry profile, both of which were unremarkable. The complete blood count showed that RBC and WBC levels were within normal limits, with no abnormalities detected. Thoracic, abdominal, and skull radiographs did not reveal any evidence of metastasis. Fine needle aspiration cytology was performed on the dark corneal tissue, in order to check it for corneal sequestrum or melanoma.

Recommendation and Action: Due to the extensive neoplastic invasion of the cornea and the high metastatic potential of diffuse iris melanoma in cats, as well as its long latency period, enucleation was recommended based on literature guidelines. However, as the owner did not consent, a keratectomy was performed to remove the melanoma. The excised corneal tissue was replaced with a multilayered amniotic graft.

Materials: The surgical materials and instruments included sterile drapes, an eye speculum, ophthalmic instruments (Figure 2), a single-use keratome, sterile swabs, single-use syringes and eye cannulas, a viscoelastic substance in a preloaded syringe (for potential corneal perforation), an An-vision Vetrix® EyeQ amniotic graft (Vetrix Company, Roswell, Georgia, United States of America), an an-Bandage lens (An-Vision GmbH, Hennigsdorf, Germany), and 8-0 polyglycolic acid absorbable sutures. For optimal visualization of the eye's anatomical structures during surgery, we used a surgical microscope with five-step magnification, 10x tilting binoculars, a wide field of

view, a 50W LED lighting system and an articulated mobile arm allowing for horizontal and vertical adjustments (UKloupes Limited Company, Bristol, United Kingdom).

Technique: This report will detail the **keratectomy procedure** performed on the left eye. Figure 1 shows the external appearance of the patient's left eye, highlighting the corneal melanoma.

Postoperative Diagnosis was confirmed by histopathology.



Figure 1. Aspect of the left eye of the cat



Fgure 2. Ophthalmological surgical instruments

RESULTS

A **cytological evaluation** by fine needle aspiration was performed for differential diagnostic from corneal sequestrum taking account of the breed and aspect of the tissue; cytology confirmed the cells of mass with increased mitosis, corneal pigmented cells, with malignant potential as melanomas with diffuse involvement of the corneal stroma. Initially, enucleation of the left eye was recommended but was declined by the owner Given the owner's decision, we reconsidered our surgical approach and opted for keratectomy with corneal reconstruction.

Preparation: The eye was stabilized using an eye speculum, providing easy access to the surgical area with minimal risk of injury (Figure 3). The eyeball was then draped. For pre-anesthetic induction, 0.03 mg/kg of atropine (Atropine sulfate, 0.5 mg/kg) was administered subcutaneously. Additionally, 0.5 mg/kg of medetomidine (Domitor injectable, 10 mg/2 mL), 0.1 mg/kg of butorphanol (Butorphanol, 1 mg/1 mL), and 6 mg/kg of propofol were administered intravenously. Anesthesia was maintained using isoflurane gas, with Ringer's lactate solution provided to ensure adequate perfusion throughout the procedure.

Surgical Procedure: The surgery began as a simple keratectomy. We made a small incision at the edge of the clear cornea and proceeded to remove the dark melanoma tissue (Figure 4, Figure 5). The resection extended as deep as the modified and pigmented corneal tissue, ensuring that all melanoma tissue was carefully removed, along with an additional 2-3 mm of healthy corneal tissue for safety margins. The deep corneal tissue was meticulously resected to avoid breaching the anterior chamber of the eye. Next, the corneal reconstruction began with the use of a corneal diamond burr to polish the margins (Figure 7).

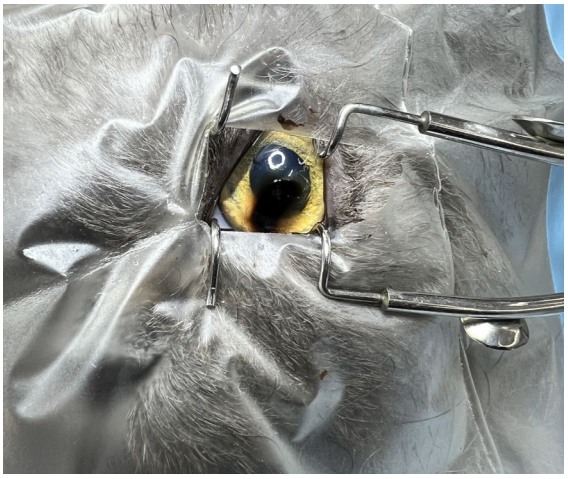


Figure 3. Preparing the eye for surgery



Figure 4. Starting resection of the modified corneal tissue

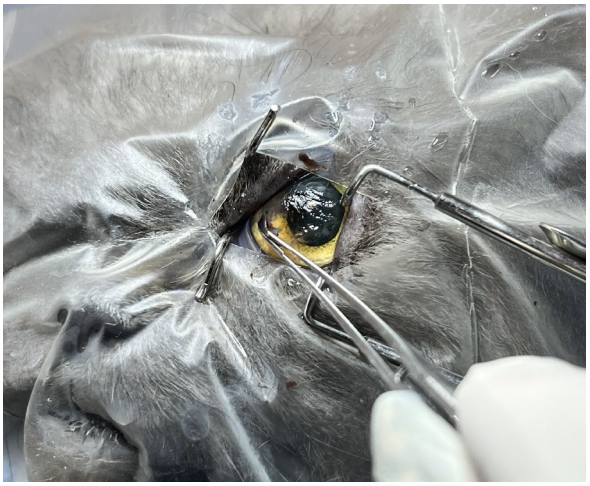


Figure 5. Keratectomy procedure

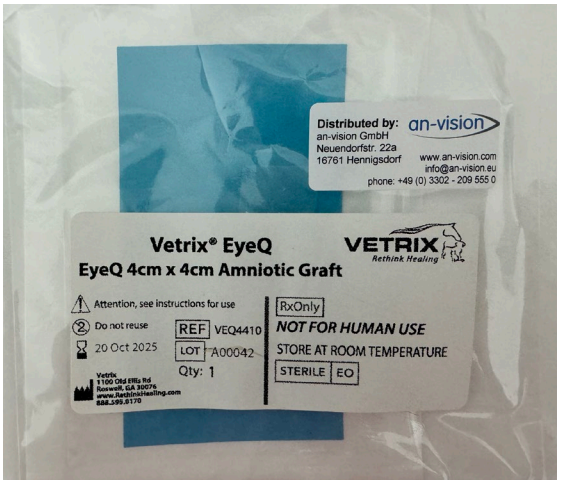


Figure 6. Aspect of the graft package

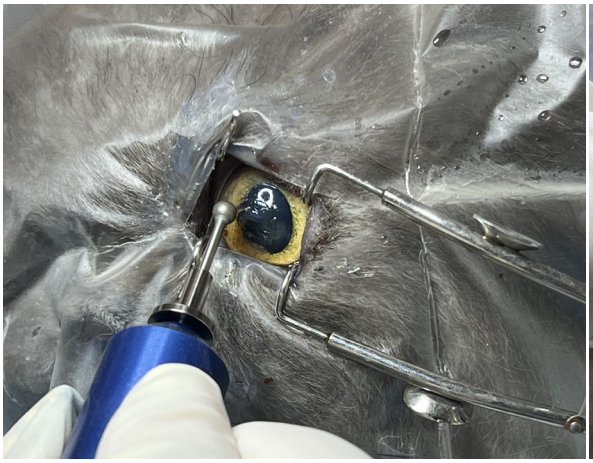


Figure 7. Corneal Diamond Burr Debridement

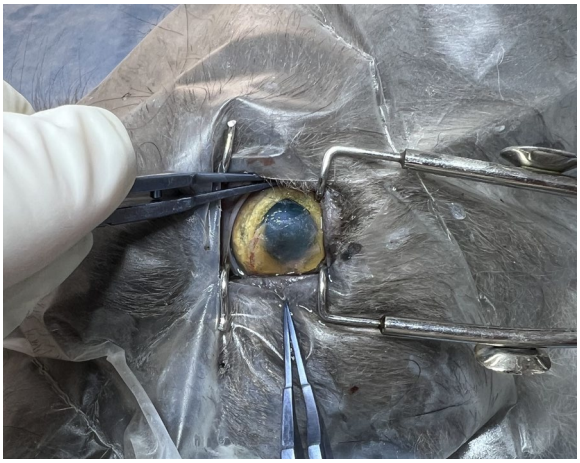


Figure 8. Modeling and fixing the graft layers

Three layers of Vetrix EyeQ amniotic graft (An-Vision, Germany) were pre-cut and placed into the corneal defect (Figure 6-8). A larger graft was applied over the entire eye to hold the layers in place and assist with the healing of the corneal margins. The large graft was secured using 8-0 polyglycolic acid sutures, attaching it to the dorsal and ventral sclera. To protect the graft, an an-Bandage lens was placed (Figure 9, 10). To



Figure 9. Preparing the bandage lens



Figure 10. Aspect of the eye at the end of surgery

stabilize the lens, two 2-0 polyglycolic acid sutures were used to partially close the palpebral opening at the external corner of the eye.

Postoperative and follow up procedures: At the end of the procedure, an intraconjunctival injection of gentamycin and dexamethasone was administered. Postoperative care included the application of topical eye drops containing gentamycin and dexamethasone, Vetrix EyeQ amniotic eye drops, and an-HyPro eye gel, all administered daily, 3 times per day. No postoperative uveitis was observed during follow-up examinations. One year after surgery, the cat remained clinically normal with no recurrence of melanoma in the left eye.

Proper management of complications is crucial for achieving a favorable visual outcome after surgery. In this case, the patient showed no signs of metastasis or recurrence one-year post-surgery, highlighting the importance of early diagnosis and treatment to avoid the need for enucleation.

The **definitive diagnosis** was confirmed by histopathology, which revealed pleomorphic spindle cells with varying pigmentation. Some cells were heavily pigmented "plump cells," while others were lightly pigmented, with increased mitotic figures. These findings were consistent with diffuse melanoma.

DISCUSSIONS

According to available literature, this is the first documented case of corneal melanoma in a cat in Romania. Corneal melanoma from this case report is an atypical melanoma, very rare and not documented in the literature (no reports with this primary localization was found). Melanocytic neoplasms in veterinary species can occur in various ophthalmic locations, including the eyelid, conjunctiva, cornea, sclera, anterior and

posterior uvea, and orbit [14]. In cats, melanocytic tumors are observed in three distinct patterns within the eye, listed in decreasing frequency: diffuse iris, limbal, and atypical melanomas. The malignancy of these tumors is often correlated with their location within the eye. Diffuse iris melanomas (FDIM) are indolent yet malignant, while limbal melanocytomas, more common in dogs, are generally benign and well-differentiated in both dogs and cats. Feline atypical melanomas, which usually arise in the ciliary body or choroid, can present as benign morphologically but have demonstrated malignant potential in post-enucleation follow-up cases [5].

Due to the less noticeable location of posterior uveal masses, atypical melanomas tend to grow larger and extend outside the sclera before being diagnosed, unlike FDIM [5]. As FDIM is the most common intraocular tumor in cats, its recognition and management hold significant importance for clinicians and pathologists. A previously described histopathological grading system for FDIM categorizes tumors as "early," "moderate," or "advanced," with prognosis depending on the disease's extent at the time of enucleation [6]. No breed or sex predisposition has been noted for these tumors, and most affected cats are older than nine years at diagnosis [3]. The cat in this case was eight years old. The diagnosis of diffuse iris melanoma can be challenging due to its slow growth and subtle onset [8]. In this case, the diagnosis was only made after referral to our clinic, following multiple unsuccessful treatments with antibiotic and anti-inflammatory eye drops. Fine needle aspiration biopsy provided an initial diagnosis through cytology, which was later confirmed by histopathological examination of the surgically removed tissue.

When diffuse iris melanoma is suspected, it is important to perform a physical examination, complete ophthalmic evaluation, a complete blood count (CBC), serum chemistry panel, and thoracic and abdominal radiographs [3]. In this case, the CBC and serum chemistry results were normal, and thoracic and abdominal radiographs revealed no evidence of metastasis. Keratectomy surgery was chosen as the preferred treatment, aimed at restoring vision and removing the malignant tissue. By this stage of melanoma development, the cat had already experienced partial vision loss in the affected eye, and its aesthetic appearance was also compromised. Considering the metastatic potential of diffuse iris melanoma in cats and the long latency period for metastatic disease, early enucleation has been recommended. Some ophthalmologists have attempted to treat small, focal hyperpigmented areas on the iris with a diode laser, preserving vision and maintaining the integrity of the eye [9]. However, the long-term success and potential side effects of this procedure remain uncertain [11]. According to Polton (2024), wide-margin surgical resection is the current standard for local melanoma control, regardless of the tumor's primary location. Enucleation, though recommended due to the metastatic risk of these tumors, was refused by the owner, prompting reconsideration of another surgical option.

Inadequate postoperative inflammation management may result in vision loss due to corneal opacifications from the corneal scars resulted from keratectomy or badly healing graft or from bacterial infections if they cannot be managed; therefore, antibiotic and amniotic eye drops were used to prevent such complications.
A limitation of the study is the period of monitoring. Further research is necessary to anticipate and prevent postoperative complications. Long-term studies of diffuse iris melanoma in cats are needed to better understand the tumor's behavior.

CONCLUSION

Corneal removed tissue was replaced by an artificial graft, amniotic multiple layers in this case. Good management of complications is an important point for obtaining a good visual outcome after surgery. The patient no evidenced metastasis and recurrence after one year, this case also highlights the importance of early diagnosis and treatment to avoid eye enucleation procedure.

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THE CITY SHEEP PROJECT – A SUSTAINABLE WAY TO MANAGE URBAN GREEN SPACES?

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Beak Consultants GmbH, **Germany**

ABSTRACT

In Germany, a considerable amount of arable land is used for the cultivation of animal feed, and significant resources are spent on the import and export of feed. These factors generally contribute to the large ecological footprint of meat and dairy production.

Particularly peripheral areas of cities such as housing or industrial estates often have considerable, contiguous green spaces. The way they are usually managed inherents potential for improvement in terms of sustainability. One option is to use these green spaces for grazing, to be carried out as rotational grazing due to the competition for use.

A research project conducted within the city of Freiberg, Saxony, Germany was implemented as an example to investigate whether the use of urban green spaces for grazing would be practical and feasible. The investigations were based on an urban grazing project that was carried out in summer 2020 under the name "city sheep project" ("Projekt Stadtschaf"). In the framework of the project, data was collected and evaluated with regard to sustainability. Nutrient balance, biodiversity, emission and immission control, economic efficiency and social acceptance were therefore considered. It was found that grazing urban green spaces has clear advantages over conventional management in terms of sustainability from an ecological perspective.

Keywords: Rotational grazing, Urban, Freiberg, Freiberg, Sustainability

INTRODUCTION

Two seemingly independent processes in everyday life deserve closer attention:

The first process concerns the way of livestock keeping. Ruminants primarily fulfill the demand for animal products such as meat and dairy. Their natural diet consists mainly of roughage, which is essential for their special digestive process. In response to increasing demand for animal products, farmers are compelled to enhance animal performance, which is typically achieved by feed supplements such as grains or soy. That feed is grown on arable farmland. In Germany, 56 % of the total grain harvest is used for animal feed (https://www.bmel-statistik.de/ernaehrung/versorgungsbilanzen/getreide).

The second process is observable in temperate regions around the world: the pasture growth from green spaces is regularly cut and taken to a composting farm. In compliance with the recognised sustainability strategies - especially the consistency

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strategy, which aims for a complete circular economy modelled on nature - the resulting green waste should be regarded as a valuable resource instead of waste.

Given this context, a question arises from the intersection of these two processes: Could urban green spaces be used as a form of urban pastureland? Under what circumstances might this be feasible, and what economic, ecological, legal, animal health, and agricultural factors must be considered in assessing the viability of such a strategy?

MATERIALS AND METHODS

Some aspects were investigated through desktop studies and interviews, however the main portion of data was achieved by field work. The central research was the City sheep project: two sheep were placed on a 1,500 m^2 green space that was situated in a residential area with commercial section, and managed in rotational grazing. This project served as basis for a range of investigations leading to key findings.

A sustainability analysis of both processes described in the introduction sets the investigative frame. It follows the three sustainability pillars model which takes into account ecological, social, and economic aspects. A second analysis is based on the concept of sustainability strategies – the efficiency, consistency, and sufficiency strategies. The scenario of forage-based use of urban green spaces was subjected to an examination of the criteria for sustainability pillars and sustainability strategies. The aim was to determine whether sustainability improves with grazing compared to the baseline situation.

The general suitability of urban green spaces for feeding purposes was analysed under the agricultural aspect. It relates to the characteristics of the feed and included recording of the plant stock of urban green spaces, derivation of their feed value, and determination of feed-related key data from hay analyses.

The consideration of the technical aspect included the collection of data on the management of urban green spaces by means of a questionnaire as well as the capturing of information on the composting process in interviews with the composting plant runners.

The environmental aspect was considered with soil sampling and consecutive nitrogen analytic campaigns. The plant stock recording yielded respective data, too. Further investigations focused on noise pollution from the sheep, fecal contamination and other possible impairments in order to determine the impact of grazing on human well-being.

The perception and acceptance of grazing animals in the city was examined under the social aspect. Three surveys were conducted through online questionnaires regarding the history of urban livestock farming, the land managers' motives for the type of green space management, and the acceptance of the city sheep project. Verbal feedback from visitors of the grazing space and from social media were included in the evaluation.

Questions regarding time expenditure were discussed under the economic aspect, including rough effort estimations for both management alternatives. The respective data was obtained from the survey with the land managers and from the City sheep project daily work.

RESULTS

History of urban livestock farming (strictly related to Freiberg, Saxony, Germany)

Data on place, period, kind and number of animals, and the way of fencing of urban husbandry were collected via a questionnaire and visualised as shown in **Figure 1**.

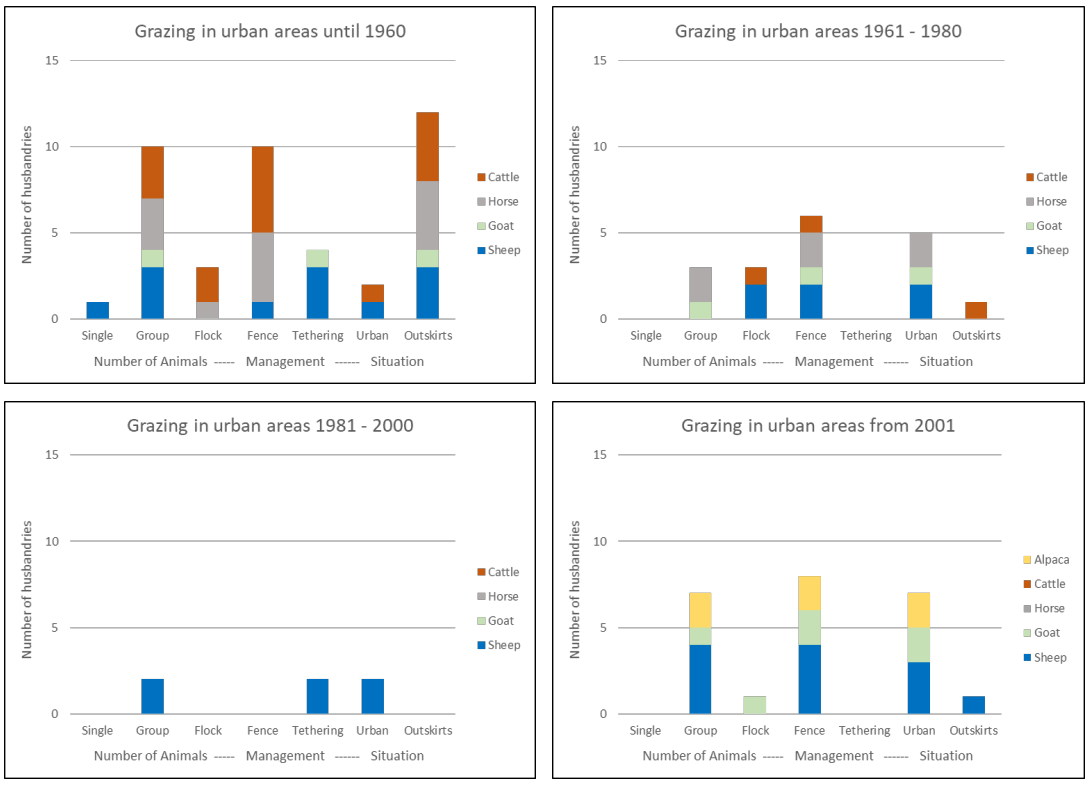


Figure 1. Historical distribution of urban livestock in Freiberg

Interviews with the composting plant runners

Large portions of fresh green waste that accumulate especially in spring result in a high temperatures during the rotting process. On the one hand, this circumstance requires increased attention to the prevention of smouldering fires, which require extra work. On the other hand, higher temperatures accelerate the composting process.

Survey of land managers regarding the kind of management

The most common form of management is mowing with disposal (composting plant) of the mown material. When asked what made the land managers refrain from grazing or haymaking, the most frequent answers were the unsuitability of the land due to dirt or noise, the impairment of the visual appearance of the area and the lack of a provider for such services. One manager pointed out that a commercial area could not be grazed.

Costs, on the other hand, are not a factor in the reluctance to graze.

Survey in the City sheep project context

An online questionnaire with regard to the City sheep project was provided to the local residents and visitors of the project. **Figure 2** shows responses to the questions if and what bothers them with the project and what they fear the animals could be disturbed from.

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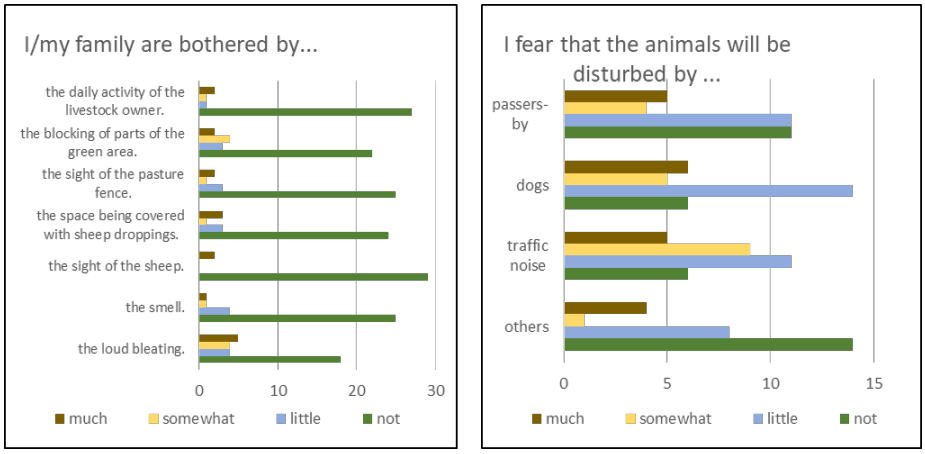


Figure 2: Selected responses from the City sheep project survey

The evaluations from the City sheep project were largely positive (90 % in the questionnaire). Negative evaluations were related to animal well-being concerns and considered a rural setting to be a much better place for animal husbandry. One person considered sheep being food, but not belonging on a green space.

Determining the efforts required for green space management

The time expenditure for mowing ranged from approximately 211 to 1,300 man hours per ha per year, strongly depending on the mowing frequency. In contrast, the time effort for rotational grazing management in the City sheep project amounted to 1 man hour per day (approximately 1,400 man hours per ha per year). Thus, the mowing time effort ranges from 14 % to 93 % of the pasture based management.

It should be noted that this rough assessment does not consider cost for equipment and machinery for both forms of management.

Plant stock recording

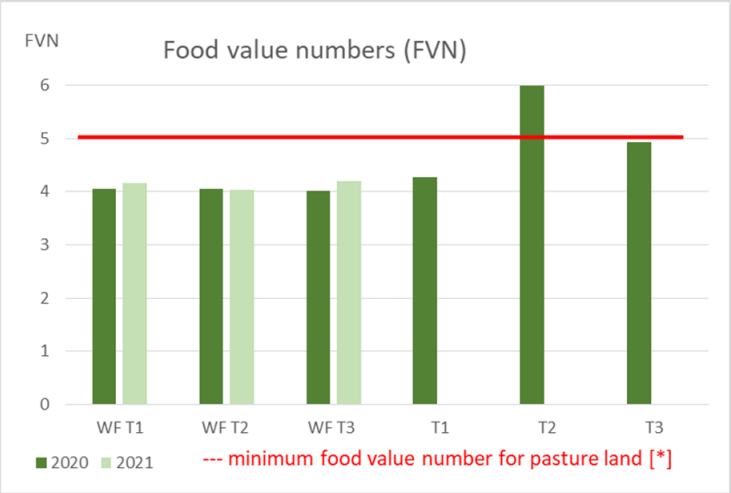
The vegetation at the grazing space was mapped in 3 transects (WF T1 20-WF T3 20). Apart of that, 3 transects outside the grazing space (T1 - T3), however in urban environment, were mapped (**Figure 3**).



[*] https://www.agrarschulen.at/unterrichtsmaterial/futterwertzahlen-der-futtergraeser

Figure 3: Results of the vegetation mapping – grass/herbage/legume ratio

From the vegetation stock, the Food Value Numbers (FVN) of each transects were determined.



[*] https://www.agrarschulen.at/unterrichtsmaterial/futterwertzahlen-der-futtergraeser

Figure 4: Results of the vegetation mapping – food value numbers

Hay analyses

Grass was collected from defined urban green spaces and rural hay pasture land. It was dried to produce composite samples from "urban hay" and "rural hay", which was analysed for nutritional key parameters and pesticides. **Table 1** shows the results.

Table 1: Results of the hay analyses

parameter	unity	"urban hay"	"rural hay"	reference values
raw protein	g/kg dm	90	119	< 170*
crude fiber	g/kg dm	388	366	220-250*
net energy lactation (NEL)**	MJ/kg dm	4,60	4,62	> 6,4*
pesticide residues	mg/kg om	0	0	

dm-dry matter; om-original matter

* Agricultural Investigation and Research Institute of North Rhine-Westphalia; for cattle

** describes the energy content of the feed

Nitrogen analysis

Soil samples were collected from two spots within the grazing space right before and after the grazing period. Point 1 (P1) was supposed to be a resting point for the sheep because of its characteristics (next to a tree). Point 2 was a reference spot without special characteristics except a certain clover accumulation. The total nitrogen content in each sample was determined. The numbers of manure balls at each spot were counted within a reference area of 1m by 1m. The results are shown in **Figure 5**.

The counting of manure balls was continued monthly until their complete disappearance, which occurred after 4 months.

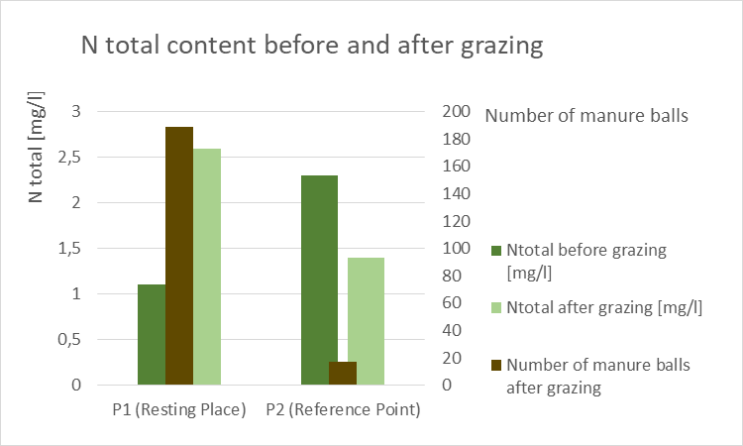


Figure 5: Nitrogen analyses and animal feces

Noise emissions

Volume measurements revealed 82 decibels at the fence and 55 decibels at a distance of 20 m from the fence. 82 decibels are equal to a passing train.

DISCUSSION

The results of the investigations carried out are categorised below with regard to the aspects considered. It should be mentioned that rotational grazing is not practiced in urban settings due to the increased labour required. However, it would be a very suitable form of management for the large contiguous green spaces in urban residential areas. It offers advantages in terms of livestock health and feed quality.

Agricultural aspect

Urban green spaces do not achieve the quality of grassland in terms of the composition of the plant population (see hay analyses in **Table 1** and plant stock mapping in **Figure 3**). They are therefore unsuitable for high-performance breeds, however suitable for common breeds. If a sufficiently large standing pasture or, better still, a fresh area is provided regularly, unfavourable plant compositions can be balanced out. Past and recent grazing in Freiberg (see **Figure 1**) proves that this is feasible.

Keeping animals in small flocks, as would be appropriate for urban grazing, reduces the risk of animal epidemics. Last but not least, the urban environment offers a certain, albeit not complete, protection against wolf predation.

Technical aspect

The accumulation of large quantities of fresh green waste in spring is manageable and in some cases also favourable for the operators of composting plants, although it is associated with somewhat increased labour and control costs. Removing the tops of the growth in spring and autumn by grazing could provide some relief in this respect.

Environmental aspect

Grazing contributes to the leaching (nitrogen removal) of grassland, provided that no other feedstuffs are introduced to the area. It also leads to a spatial nitrogen redistribution as shown in **Figure 5**.

In terms of soil conservation, grassland farming has clear advantages over arable farming: arable farming destroys the original vegetation and exposes the soil to erosion.

In terms of biodiversity it is favourable to graze the grassland at the very beginning of grass growth as that takes away strongly competitive plants which, again, fosters the growth of less competitive plants; however, this is opposed by the requirements of animal health, according to which rapid feed changes should be avoided [1].

Economic aspect

The estimations of time expenditure for mowing and rotational grazing showed a slight (93 % of the grazing time effort) to clear (14 %) advantage of the mowing based management.

Social aspect

In the past, grazing animals were not an unusual sight in urban areas, and even today they are well established, see **Figure 1**. However, most land owners consider grazing to be unfeasible for reasons of time expenditure or simply that there is no provider for this service.

Grazing is largely viewed favourably by the local population, although there are sometimes considerable concerns about animal well-being and noises emanating from the sheep. Nevertheless, some statements reveal a decoupling of livestock farming from one's own existence, and there is a suspicion that rural livestock farming is being romanticised. Urban grazing and fodder production could counteract this tendency.

An unacceptably long period of 4 months was found for the decomposition of the dung balls, after which an area can be used again without soiling. Post-pasture mowing is a good option here, which, on the other hand, would reduce the overall financial balance of grazing.

Sustainability analysis

Both kinds of management are reviewed with regard to their relationship to the sustainability pillars (**Table 2**).

Table 2: Comparison of management forms regarding the sustainability components

Criterion	Rotational grazing management	Mowing
Impairment of the green space fauna	no	presumable
Protection of floral diversity	no or little demage under favourable grazing management	no or little demage under favourable mowing management
No or low emission management	yes	no
Waste-free management (closed cycle)	yes	yes, but subject to improvement
Ecological function of green spaces kept	yes	limited
Eutrophication (nitrogen input)	no	no
Economic efficiency of management	poor	fair - good
Green spaces generally accessible and usable	most of the time	yes
Visually appealing and 'well-maintained' green spaces	yes when post-pasture mowing applies	depending on mowing frequency
Perception of near-natural areas in the urban area	yes	limited
Impairments caused by grazing animals	yes	no
Impairments caused by mowing	no	yes

(Sustainability components: ecological, economic, and social component)

In terms of ecological concerns, grazing performs better than mowing with disposal. There are hardly any differences in terms of social concerns, but from an economic perspective, traditional mowing with disposal performs better. However, the refinement of the biomass into food is not taken into account here. If traditional mowing with disposal is cheaper than grazing, this may be the result of unrealistic pricing for meat.

Table 3: Comparison of management forms regarding the sustainability strategies

Criterion	Rotational grazing management	Mowing
Use of fuel-efficient mowing tools and methods	yes	presumable
Selection of an efficient mowing or grazing regime	feasible	feasible
Short distances to disposal/composting	not applicable	no
Multiple use of space	yes	yes, but subject to improvement
Integration of the mown material into a waste-free material cycle	yes	yes, but subject to improvement
Integration of the mowing tool into a waste-free material cycle	yes	no
Integration of the fuel for the mowing tool into a waste-free material cycle	yes	no
Reduction of mowing intervals and areas	yes	yes
Tolerance of visual 'defects' of the green spaces	yes	depending on mowing frequency

(Sustainability strategies: efficiency, consistency, and sufficiency strategies)

In terms of sustainability strategies, i.e. the realisation of sustainability goals, grazing performs much more favourably than traditional mowing with composting.

CONCLUSION

Urban grazing is a way of producing organic meat and has the potential to connect urban dwellers with agriculture. It is a step towards better sustainability.

Although, from an economic standpoint, urban grazing currently performs less favourably than conventional mowing, it provides significant ecological advantages. As such, it should be integrated into urban green space management strategies.

To promote urban grazing, targeted support from public policy is essential, alongside the creation of a suitable working environment for livestock farmers. One possibility could be the development of a web-based GIS portal that provides a pool of suitable grazing areas, which landowners can register and livestock farmers can access.

From the perspectives of feed composition and animal well-being, grazing in small groups of 4-5 low-performance animals is optimal [2], with daily rotations between grazing areas. Such a system ensures a balanced feed composition and minimizes drastic changes in plant populations. By continuously moving the herd within residential areas, any disruption or noise impact is limited to just a few days for the local community, thereby increasing overall acceptance.

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THE INFLUENCE OF CLIMATE CHANGE ON THE BEGINNING OF FLOWERING OF PEAR (*PYRUS COMMUNIS*, L.) AND CHERRY (*CERASUS AVIUM*, L.) AND THE PROBABILITY OF SPRING FROSTS IN SLOVAKIA

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ABSTRACT

Climate change is not the future, it is a hard, tangible and uncompromising present. Globally, the risk of crop reduction is increasing. Production shocks that used to occur once every 100 years or so in the past may occur every 30 years or more in the future. The development of fruit growing, as part of agricultural activities in the countryside, must record the impacts caused by climate change and apply the species structure of fruit trees in the regions of Slovakia, which will fully respect the biological requirements of the species. The aim of this contribution is the analysis of the average onset of the phenological phase – first flowering (BBCH 60) in the period 1931 – 1960 and 1991 – 2020 and the analysis of the occurrence of spring frosts in the last 20 years in selected locations in Slovakia. The results show that the beginning of the flowering of pears (*Pyrus communis*, L.) has now shifted and starts on average 5 – 6 days earlier in the Danube Lowland and 4 days earlier in the Eastern Slovak Lowland. The beginning of the flowering of cherry (*Cerasus avium*, L.) also starts earlier by an average of 3 – 5 days in the Danube Lowland and 6 – 7 days earlier in the Eastern Slovak Lowland. Due to the fact that flowering starts earlier, there is a high risk of spring frost in these dates. Therefore, it is necessary to adapt to the current situation with agrotechnical procedures and passive measures, for which we advise the selection of frost-resistant species or the application of chemical substances to delay budding.

Keywords: climate change, first flowering, spring frost

INTRODUCTION

Climate change is not the future, it is a hard, tangible and uncompromising present. One that gradually began to take away from Slovakian sources of drinking water, reduces about a third of the crops grown, etc. The climate crisis is clearly underway and is progressing much faster than previous scenarios predicted [1].

Globally, the risk of crop failure is increasing. Production shocks that used to occur once every 100 years or so in the past may occur every 30 years or more in the future. The consequence of the production shock is rising food prices, which demonstrably cause instability in countries and lead to forced population movements across continents, including Europe and Slovakia [2].

The development of fruit growing, as part of agricultural activities in the countryside, must record the impacts caused by climate change and apply the species structure of fruit trees in the regions of Slovakia, which will fully respect the biological requirements of the species. The change in the species diversity of Slovak orchards is a topic that responds to the requirements of practice in terms of shifting the onset of individual phenophases, as a reaction to temperature changes, etc. In this way, it is possible to minimize economic losses and eliminate disproportionately increasing production costs [3].

The aim of this article is to analyse changes in the beginning of the phenological phase first flowering (BBCH 60) of pear (*Pyrus communis*, L.) and cherry (*Cerasus avium*, L.) in the years 1931 – 1960 and 1991 – 2020 and the probability of the occurrence of spring frosts in the years 2001 – 2020 in selected localities in Slovakia.

MATERIALS AND METHODS

Input data for the analysis of climatic and phenological factors for the period 1931 – 1960 were used from the publication Agroclimatic conditions of the Czechoslovak Republic [4] and for years 1991 – 2020, the data were obtained from the Slovak Hydrometeorological Institute.

The phenological data were processed and the missing values for the entire territory of Slovakia were calculated in ArcGIS Pro (ESRI) using the interpolation method. Several authors compare the suitability of different interpolation methods [5]. For the interpolation was chosen the Topo to Raster method, which uses an iterative finite difference interpolation technique. After the interpolation, data were reclassified – the onset of BBCH 60 (first flowering) was divided into categories with five days for pear and with three days for cherry. The areas above 400 m a.s.l. (pear) and 500 m a.s.l. (cherry) were excluded, because up to these altitudes are two areas - areas with optimal conditions and areas with less suitable but satisfactory conditions for growing [6].

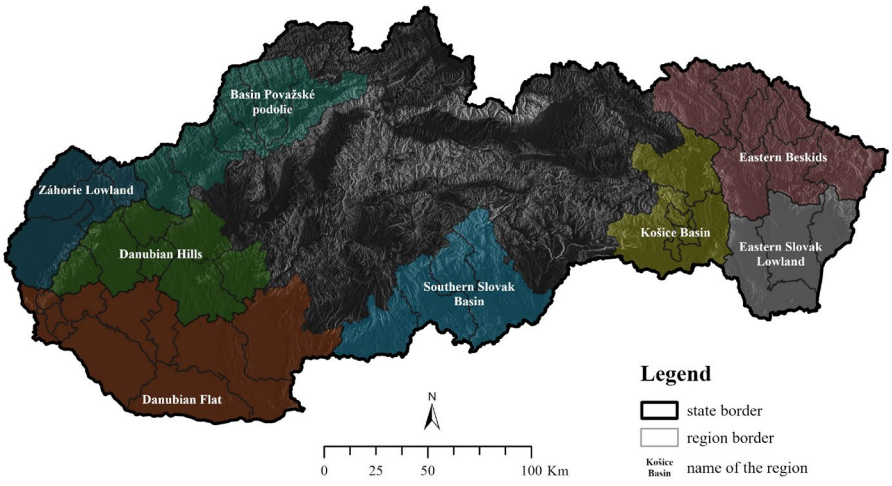


Figure 1 Locations where the probability of spring frosts was calculated

The probability of occurrence of spring frosts (minimum temperature below 0 °C) was assessed in several locations in Slovakia (Figure 1). Probability determines frequency

based on experimentation and determines the number of times an event may occur by considering a specific number of opportunities:

$$P(A) = f / N$$

where:

P(A) – the probability of occurrence

f – the number of times an event may occur

N – the number of opportunities

RESULTS

The average onset of the phenological phase first flowering (BBCH 60) of pear in the period 1931 – 1960 (Figure 2) began at the end of the second decade of April in the Danube Lowland – Horný Bar (17.4.), Komárno (18.4.) and the third decade of April – Trnava (20.4.), Čachtice (25.4.), Adamovské Kochanovce (26.4.). There was a similar onset in the Košice region, especially in the Eastern Slovak Lowland – Bánovce nad Ondavou (24.4.). In the Banská Bystrica region, the onset began depending on the location - Rimavské Brezovo (28.4.), Víľaš-Pstruša (30.4.). Later, in the first decade of May, also in the Prešov region - Hermanovce (6.5.). At the end of the first decade of May, the pear blossomed in the northern locations of the Žilina Region – Oravský Podzámok (8.5.). Compared to the years 1991 – 2020, we observed an earlier onset of flowering for pears in the south of the Danube Lowland in 5 – 6 days – Kravany nad Dunajom (12.4.), Trnava (15.4.). In the northern parts in 7 days earlier – Adamovské Kochanovce (19.4.), or 9 days – Čachtice (16.4.). An earlier onset of 6 days was also recorded in the south of the Banská Bystrica region and in the Eastern Slovak Lowland by 4 days – Bánovce nad Ondavou (20.4.). In the Prešov region, the average beginning of flowering is first (from the first decade of May to the current last decade of April) – Hermanovce (April 29). Also, in the Žilina region, flowering started earlier in the last decade of April.

The average first flowering of cherry in the period 1931 – 1990 (Figure 3) began in the south of the Danube Lowland in the second decade of April – the earliest in Kamenica nad Hronom (8.4.), later Horný Bar (11.4.), Trnava (15.4.), Adamovské Kochanovce (18.4.). Similarly, at the end of the second decade of April, flowering also began in the Eastern Slovak Lowland - Bánovce nad Ondavou (18.4.) and in the south of the Banská Bystrica region - Číž (20.4.). At the end of the third decade of April and the beginning of the first decade of May, flowering also started in the locations of the Žilina region - Žilina (26.4.), Turčianske Teplice (1.5.) and Prešov region - Štefanovce (1.5.).

In the current period 1991 – 2020, the average start was 3 – 5 days earlier in Horný Bar (8.4.), Trnava (11.4.) and Adamovské Kochanovce (13.4.). In the south of eastern and central Slovakia, flowering was 6 – 7 days earlier in the locations of Bánovce nad Ondavou (12.4.) and Číž (13.4.). In the northern parts of the Žilina and Prešov regions, there was a shift of 6 – 8 days depending on the location - Žilina (20.4.), Mošovce (23.4.) and Hermanovce (23.4.).

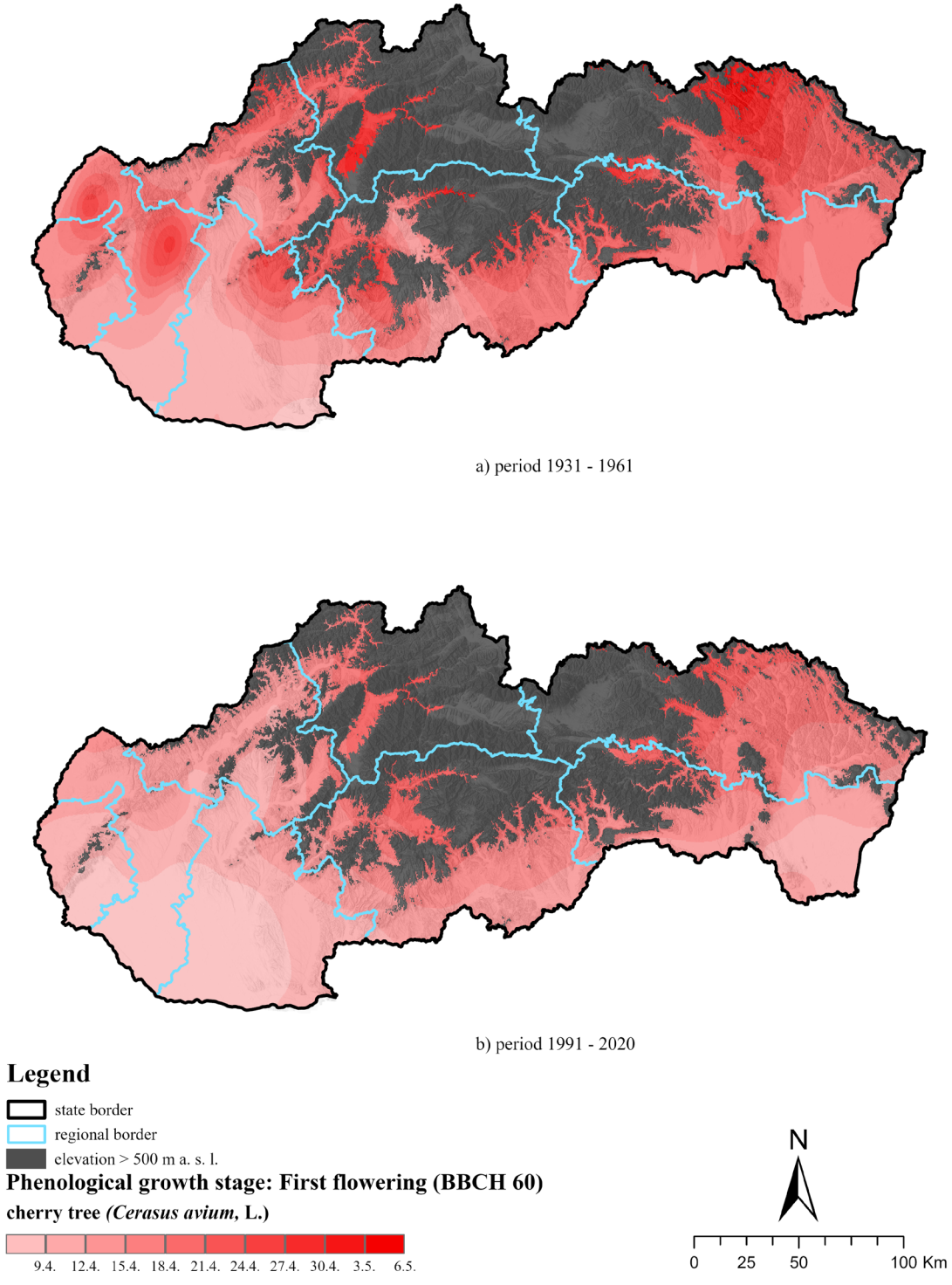


Figure 2 The onset of the phenological phase BBCH 60 for cherry (*Cearasus avium*, L.) for period a) 1931 – 1960 and b) 1991 – 2020

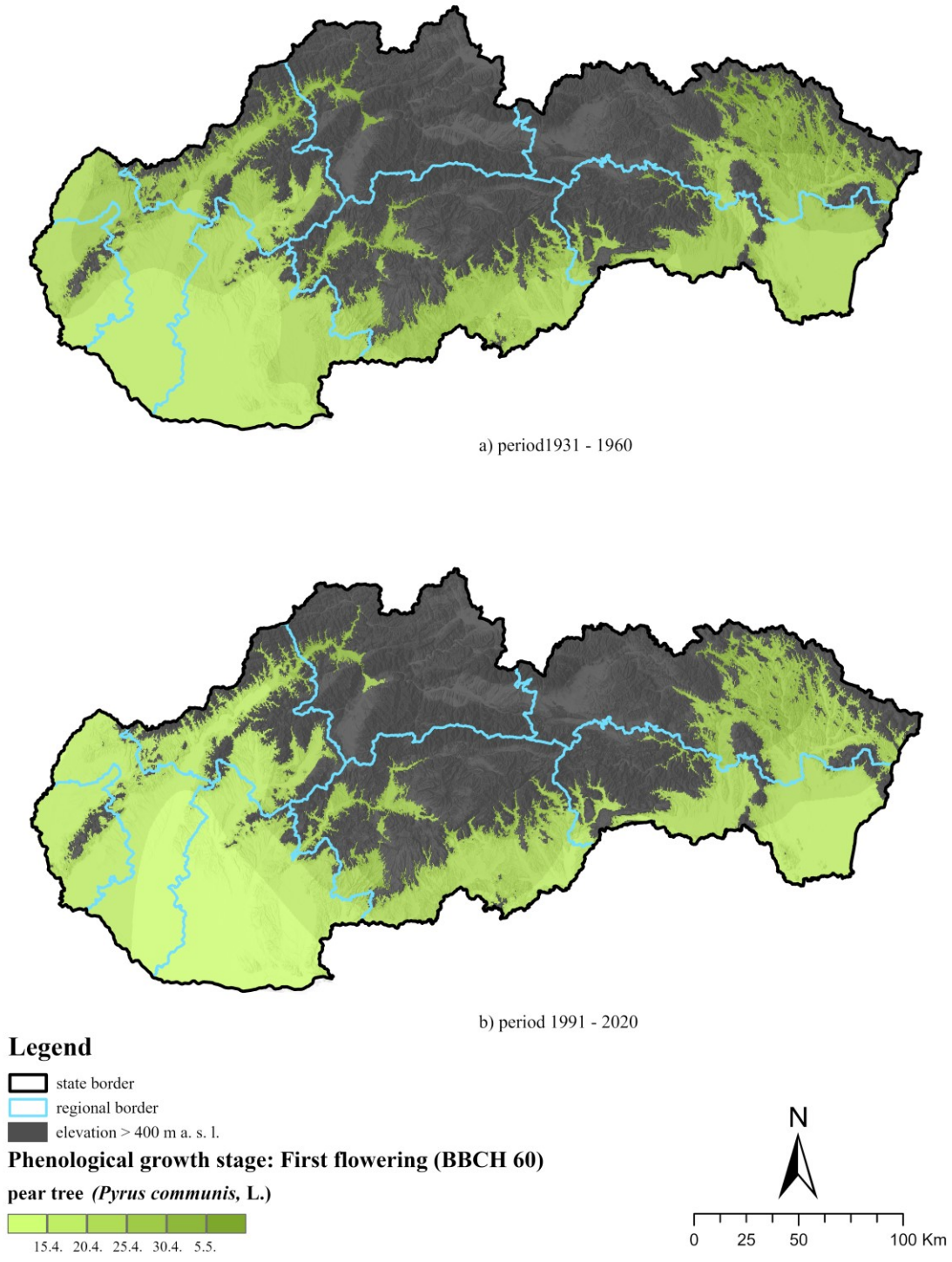


Figure 3 The onset of the phenological phase BBCH 60 for pear (*Pyrus communis*, L.) for period a) 1931 – 1960 and b) 1991 – 2020

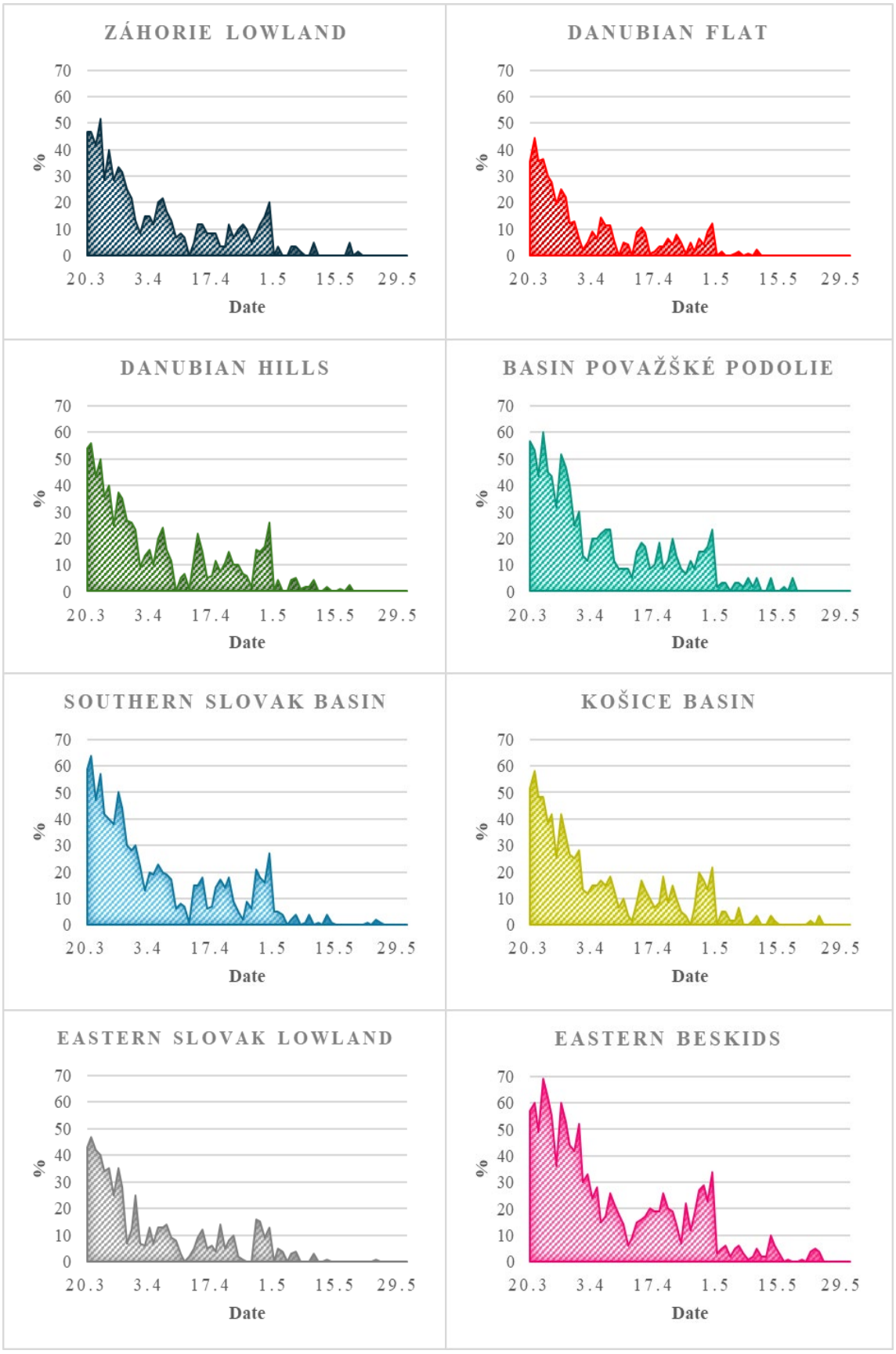


Figure 4 The probability of occurrence of spring frosts in selected locations in Slovakia

On the Záhorská Lowland (Figure 4), flowering begins on 6th April on average, and on this day, there is also a 20 % chance of frost. During April, the probability of frost in this area is up to 10%, only on the last day of April it is higher – 20 %. On the Danube Plain, where the earliest onset of flowering occurs, the threat of frost is greatest at the beginning of April - the first decade of April (15 %), from 13th to 15th April (11%) and the end of April (12 %). In the same dates, frosts are also likely to occur in the Danube Hills, but the probability is more than 20 % and for the end of April 25 %. The situation is similar in the areas of Považské podolie, Juhoslovenská kotlina and Košická kotlina, where the highest probability of frost is in the first decade of April (15 – 20 %) and on the last day of April (22 – 27 %). In the Eastern Slovak Lowland, the probability of frost in this period is up to 15 %. The riskiest is the Beskydy region, where the onset of flowering has been delayed by 3 – 6 days, but the risk of frost, especially at the end of April, is almost 35 %.

DISCUSSION

The results show a shift in the beginning of the phenological phase of the first flowering (BBCH 60). Spring frosts also affect this earlier onset. Similar analyses were made by several authors. Phenological responses to climate change are highly siutable bioindicator of climate change. In the area of southern Europe, a clear trend towards an earlier onset of leaf development, flowering and fruiting of deciduous trees due to the influence of temperature was found [7]. In Slovakia, the shift of phenophases is recorded in vineyards, when Bernáth et al. [8] reported earlier flowering by several days. Hájková et al. [9] observes the earlier onset of cherry blossoms in various locations of the Czech Republic and the risk of spring frosts, especially in higher areas of the territory. Although winters in the southern parts of Slovakia are not as intense as in the past [10] and overall, a decrease in the number of frosty days is observed in Europe [11], the fact that flowering starts earlier presents a problem for fruit growers.

CONCLUSION

In the years 1931 – 1960, the average date of the onset of flowering in pears (BBCH 60) began at the end of the second decade of April. Compared to the years 1991 – 2020, we observed an earlier onset of flowering. The first flowering of cherry trees in the years 1931 – 1990 began in the south of the Danubian Lowland in the second decade of April. At the end of the second decade of April, flowering also began in the Eastern Slovak Lowland and in the south of the Banská Bystrica region. At the end of the third decade of April and the beginning of the first decade of May, flowering began in the Žilina and Prešov regions. In the years 1991 – 2020, the average onset in southwestern Slovakia was 3 – 5 days earlier (in the northern parts of the Žilina and Prešov regions, the start was 6 – 8 days earlier). Some fruit species begin to bloom earlier and therefore the probability of frost is a significant risk factor. On the Záhorie Lowland, in the first decade is the probability 20 % and on the last day of April also 20 %. In the Danube Lowland, where flowering starts earlier, the risk of frost in the first decade of April is 15%, from 13 to 15 April 11 % and 12 % at the end of April. On the same dates, the occurrence of frosts is 15 – 20 % in the Danube Hills, in the area of the Basin Považské podolie, the Southern Slovak Basin, the Košice Basin and the Eastern Slovak Lowland (22 to 27 % at the end of April). In the Eastern Beskids region, the risk of frost at the end of April is high, up to 35 %. It is important to focus on varietal conditioning as an important biological factor reducing the risk of spring frost damage.

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THE SPREAD OF ASCLEPIAS SYRIACA L. IN THE ROMANIAN BANAT

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ABSTRACT

Introduced in Europe for the first time as a medicinal plant (around the 1630) and later as an ornamental, Asclepias syriaca L. has escaped from culture and became subspontaneous. Today, this species raises serious threats of invasion in some European countries, such as Hungary, for example. In this paper, we discuss the spread of the species in the Romanian Banat, especially in the spontaneous vegetation. The first reports in the region are those from the Romanian Flora. We found this species in different habitats: roadsides, wastelands, railways, wetlands, meadows, the proximity of some wine farms, in several localities and their surroundings such as: Timisoara, Covaci, Dumbravita, Remetea Mare, Buzias, Recas, Satchinez, Surduc, Fardea, Pischia, Jebel, Sacalaz, Sannicolau Mare, Bezdin, Cenad etc. Even if it appears isolated and the populations are generally small, we believe that the species must be attentively monitored, because in recent years it has been reported in almost all of Romania and considering the impact it can have on local habitats and flora. Our data, corroborated with those published by other authors show that we are most likely in a preliminary stage of the consistent spread of this species in the Romanian Banat.

Keywords: Asclepias syriaca, alien plant species, Romanian Banat, distribution

INTRODUCTION

Systematic: *Asclepias syriaca* L. was published with this name in Species Plantarum 1: 214 (1753). She was first identified as *Apocynum majus syriacum rectum*, and Linne classified it as *A. syriaca* L. [6]. According to The World Flora Online (https://www.worldfloraonline.org/taxon/wfo-0000551803), she belongs to the Kingdom *Plantae* Haeckel, Subkingdom *Pteridobiotina* Britton & Brown, Phylum *Angiosperms*, Order *Gentianales* Juss. ex Bercht. & J. Presl, Family *Apocynaceae* Juss., Genus *Asclepias* L. The latter includes 207 accepted species. In our flora, the genus *Asclepias* is represented by a single species, *A. syriaca*. This name has 18 synonyms. Popularly, *Asclepias* species are known under different names, such as: *milkweed, beeswax, cotton weed, wild cotton, bloodflower, butterfly flower, parrot plant*.
Botanical description: Hemicryptophyte with vigorous rhizome, with high propagation capacity. Bagi [4] chooses to call rhizomatic roots, because these rhizomes do not originate from shoots. Pubescent stems, pale-green in color, 1-2 m high. Large, simple, short-petiolate leaves, arranged oppositely, rarely whorled, elliptical in shape, obviously tomentose on the lower side. The venation of the leaf is peculiar, they have a prominent median vein, sometimes reddish, while the lateral veins are pinnate or arranged almost

parallel to each other and perpendicular to the median one, not touching the edge of the leaf. The inflorescences are spherical (figure 1), large umbels, pink-red-purple, fragrant, arranged laterally or terminally.



a) b) c)

Figure 1. Budding, flowering, fruiting-seed dispersal (Photo: a, c - G.-G. Arsene, b - Ilinca Imbrea)

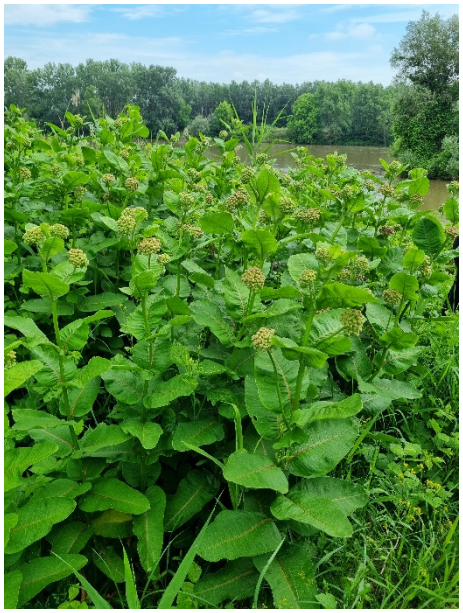


Figure 2. Population of *Asclepias* plants on the Mureș Riverbank, at Cenad (2023) - Photo: G.-G. Arsene

The flowers are small and numerous (20-130), with a specific structure. They have a rotated corolla, with recurved lacinia when blooming and a corolla with 5 horn-shaped nectariferous glands, with a high nectar content. It attracts butterflies and birds. The stamens fuse with the stigma disc, forming the gynostegium. Pollen is collected in pollinia. The follicle fruits, sometimes twins, are tomentose, elongated and bent at the tip like a parakeet's beak (hence the French name *herbe aux perruches*). These are dehiscent on the ventral suture line. Seeds are small and numerous, ovoid, with long, silky hairs. A plant can produce 1-6 fruits, each fruit containing 150-425 seeds [9]. The plant contains latex in all organs.

Asclepias syriaca L. could possibly be confused with *A. speciosa* Torr., a species with low cloning capacity and with slightly different flower morphology.

Worldwide distribution: According to Plants of the World Online (https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:319076-2), the native range of this species is Central and Est Canada to Central and Est U.S.A. Was introduced into: Altay, Austria, Baltic States, Belarus, Belgium, Bulgaria, Central European Russia, (former) Czechoslovakia, France, Germany, Gulf of Guinea Is., Hungary, Italy, Kirgizstan, Krym, Netherlands, Newfoundland, North Caucasus, Oregon, Poland, Romania, South European Russia, Spain, Sweden, Switzerland, Ukraine, Uzbekistan, West Siberia, (former) Yugoslavia.

In Romania, it was introduced deliberately, as an ornamental species. First reports as a cultivated species are since 1836 and as subspontaneous, since 1939 (https://invazive.ccmesi.ro/wp-content/uploads/2020/02/POIM_120008_Subactv.-1.1.1_Baza-de-date-15082019.pdf)

Ecology: First of all, *A. syriaca* is a plant of disturbed habitats, where soil characteristics are of much less importance than other environmental factors, such as the absence of natural competitors and the disturbed nature of the habitat [4].

Use: Ornamental, melliferous and medicinal species. It is used in the textile industry, in the rubber and plastic industry, in the pulp and paper industry, in the soap industry etc.

MATERIALS AND METHODS

Our study is a review of the distribution of the species *Asclepias syriaca* L. in Banat. We have included here the results of our observations, some published, others not. Corroborating our data with reports from recent publications, we update the chorology of the species in this region. In a few cases, we have also included data from unpublished documents, which served as the basis for the preparation of public documents (e.g., the Management Plan of the Mureș Floodplain Natural Park). The chorology is provided by mentioning the commune (administrative-territorial base unit) in whose territory we found the *Asclepias* population or populations. By the Romanian Banat, we understand the territories of Timiș and Caraș-Severin Counties (although, in some interpretations, the territories from the current Arad County, located at the border with Timiș, south of the Mureș River, are also included).

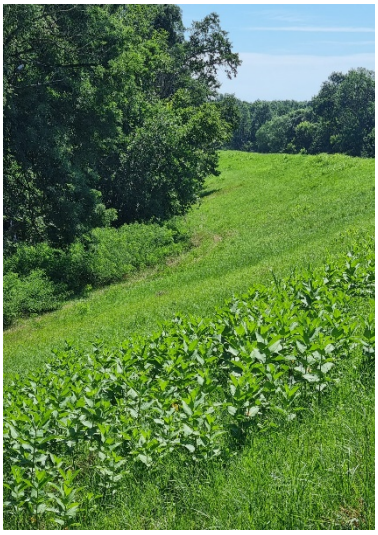
RESULTS

This species caught our attention in 2004, when we encountered a small population, consisting of a few individuals, in the anthesis period, on the Nădrag Valley (Timiş County). In 2005, we found it near Surduc Lake, in Fârdea, not far from the first sign. In the summer of 2006, we found some specimens (in the budding-flowering phase), in the perimeter of the protected area Mlaştinile Murani-Pişchia. In the following years, we found the species again in Pişchia. Another population, which we identified at Satchinez (at the entrance to the reserve, near the railway), in the fall of 2011, was more numerous (20-30 individuals). The plants were in the fruiting-dissemination phase. In summer of 2022, we found a few individuals, at Jebel, on a vacant lot. We also found the species in Cenad, near the Mureş River (2023, figure 2). In the last four years, we observed an expanding population, on a vacant land, on the Timişoara belt, the bifurcation to the

airport. In Dumbrăviţa, on a land under construction, in the vicinity of a wholesale store, we observed another small population, with very vigorous individuals (in the vegetative phase).



Island Ostrov in Moldova Veche (Photo: Ilinca Imbrea)



Lunca Muresului Natural Park - Prundul Mare (Photo: G.Arsene)



Southern Great Plain - Szeged, Hungary (Photo: Alina Neacşu)

Figure 3. Habitats with *Asclepias syriaca*

Last summer, we encountered the species in Buziaş and Recaş, at the edge of the roads in the respective vineyards. We also observed the species in Săcălaz (2023), in a residential neighborhood under construction, at the exit from the locality. The month of August, this year, we saw *Asclepias* (in bloom) near the border with Hungary, at Sânnicolau Mare, on the roadside.

DISCUSSION

Although during the observations made in the perimeter of the Sânandrei lake (2005-2010), we did not find the species, it was also reported here later, from the site of community importance Valea din Sânandrei [5]. Turcuş & Dărăban [14] found the species at Igriş (Timiş County), while Sărățeanu et al. (2020) studied *Asclepias* in disturbed grassland from Pecica (Arad County). Stef et al. [13] reports it in different agroecosystems in the western part of Romania: Cărpiniş, Pădureni, Jebel, Ghiroda, Săcălaz, Victor Vlad Delamarina, Uivar (Timiş County), Glimboca, Obreja, Iaz, Jupa (Caraş-Severin County).

Sîrbu & Oprea [12] consider it sporadic and subspontaneous in Maramureş, Transylvania, Banat, Muntenia and Moldova and mention the signal made by Sârbu et al. (2007) in the Nera Mini-Delta (Caraş-Severin County) and by Drăgulescu (2003) along the River Mureş, at the Romanian-Hungarian border (Arad County). For Timiş County, the authors do not give references.

Analyzing the distribution map of the species, drawn up by Pioarca-Ciocanea et al. [8], it is observed that the species is present in all regions of the country, except a part of Dobrogea (Constanța County). Several reports of the presence of *Asclepias syriaca* in Timiș and Caraș-Severin counties can be found in the reports of a research grant

focused on mapping invasive plant species [1], coordinated by Prof. Paulina Anastasiu (University of Bucharest): Variaş, Saravale, Lovrin, Coșteiu, Remetea Mare, Foeni, Uivar, Cenei, Cenad, Sasca Montană, Doclin, Dognecea (here was found the only population with over 500 individuals), Ghertenis, Baziaș. The observation regarding the population size at Dognecea is consistent with our observations (Arsene, unpublished); thus, we encountered populations larger than 500 stems in only two locations in Timiș County, at Covaci and Cenad, on the banks of the Mureș River.

In the synthesis *Flora and vegetation of Banat (Part I Flora),* Ardelean et al. [3] indicates it on the Romanian-Hungarian border, on the Mureş, at Igriş, in the Nerei Mini-Delta, on the Island of Ostrovul Moldova Veche, between Valea Mraconiei and Depresiunea Dubova. A few years ago, we found here too (Imbrea, figure 3). At the northern limit of the area we studied, in the Mureș Floodplain Natural Park, *Asclepias syriaca* was reported in several locations, both in the study that formed the basis of the 2013-2014 Management Plan (Ceala Forest near Arad and other unspecified locations in the Natura 2000 habitats 91F0, 92A0, and 6440), as well as in the study conducted for the update of the same management plan in 2023 (at Sânpetru German, Pecica, Bezdin, Igriș, Bodrogu Vechi, Nădlac). This concentration of points in the Mureș Floodplain can be explained by the presence of areas undisturbed by plowing (meadows, shrubs, forests), by its proximity to the border with Hungary, where large populations have been found, from which the Romanian populations most likely originated, and also by the intensive study of the territory of this natural park (Mureș Floodplain).

Considering the latest research, we believe that the species must be carefully monitored. In the framework of the national research grant, which we mentioned above, Anastasiu et al. [1] perform the alien plant species distribution in Romania and find that of the 41 plant species of EU concern, 4 are established and widespread. One of these is *Asclepias syriaca* (the other are *Ailanthus altissima, Elodea nuttallii* and *Impatiens glandulifera*). According to the distribution database, 7 invasive alien plant species of EU concern are present in Romania: *Ailanthus altissima*, *Asclepias syriaca*, *Elodea nuttallii*, *Heracleum sosnowskyi*, *Humulus scandens*, *Impatiens glandulifera* and *Ludwigia peploides*. *Asclepias syriaca* has already 271 occurrence records from Romania, in 2019-2022 period [2]. The authors consider, among others things, that it is necessary the increase of public awareness, the revision of the legislation and the involvement of public institutions for the management of invasive species.

CONCLUSION

The species *Asclepias syriaca* has spread in recent years in almost the whole Romania and that is a reason why it is an invasive alien plant species of EU concern in Romania.

In the Romanian Banat, the locations where we found the species and the locations reported by other authors are in the plains and hilly areas, predominantly near rivers or lakes.

In almost all cases, the identified populations are small, under 500 stems, which, compared to the situation in Hungary, where much larger populations are found, raises questions about the factors that have led to this difference. We can assume that *Asclepias syriaca* found better conditions for establishment in Hungary (especially in tree plantations on more or less sandy soils, where we also observed large clusters). Additionally, we can assume that in the Romanian Banat, *Asclepias syriaca* does not

produce consistent clonal development-this was also noted by Ricono et al. [10] in the study of populations in the United States.

We did not identify the presence of the species in arable crops (with the possible accidental presence of a few individuals at the edge of cornfields); therefore, unlike Stef et al. [13], we do not currently consider *Asclepias syriaca* a threat to arable crops, especially row crops in Banat. In a normal crop rotation (without years of fallowing), *Asclepias syriaca* has little chance of withstanding soil tillage. It is likely that on sandy soils, the plant could establish itself as a weed through seeds, but only persist for one year.

The presence of small populations of *Asclepias syriaca* in the Romanian Banat, often hundreds of meters or kilometers apart, combined with the situation of the plant in neighboring Hungary, calls for close monitoring of the identified populations, continued field observations to obtain a detailed map of the species' distribution, as well as conducting genetic and ecological research to clarify the situation of the species in Western Romania.

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TOPIC OF ECOLOGY IN RIGA STENCIL GRAFFITTI

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ABSTRACT

The relationship of contemporary human beings to the nature is in the centre of the public debate worldwide and in particular countries because of climate change. Different social groups develop different perspectives on the issue based on ideologies, values and lifesyles. They express it through verbal arguments, but also through visual messages that use well known symbols and emotionally louded images in public spaces one of forms usual for supposedly muted groups beeing stencil graffiti.

The aim of this research is to explore and describe the care of environment ideology within subcultural communication in the framework of cultural studies using visual semiotic analysis of stencil graffiti within the urban space. It is done by exploring the key elements of subcultural communication as an artistic response to contemporary global and local challenges/ecological problems. By my research We hope to demonstrate the presence of the social critique potential of care of environment in the dialectical cultural semiosis (emerging and circulation of signs within society) between counter-culture and “the mainstream”.

The article aims at showing the relationship between counter-culture ideology and mainstream via co-optation of DIY (Do It Yourself) and ALT (alternative media ideological messages) ideas by commercialisation.

Keywords: ecology, environment, stencil graffitti, sign, counter-culture

INTRODUCTION

The relationship of contemporary human beings to the nature is not only a philosophical question, it is one of the central topics of the social and political debate worldwide and in particular countries. Not only governments care for measures aimed at climate change mitigation, society in general is concerned with it as well, even if its different groups represent oppositional attitudes towards climate change issues and ecology in general. Part of the debate is going on the streets – in urban environment most radical statements come through in the form of rebelious countercultural medium of graffiti. Theoretical literature on counter-culture [23], [24] emphasizes that an extended critical description of capitalist technocracy is the necessary basis for research. This already includes a countercultural point of view. Brittish tradition of the study of subcultures [21], [22], [23] and [18], in particular, look for messages that consist from deeply content full signs to decode in the everyday environment of social living.

Richard Sennett describes the transformation of the public space from a philosophical perspective, “With an emphasis on psychological authenticity, people become inartistic in daily life, because they are unable to tap the fundamental creative strength of the actor, the ability to play with and invest feeling in external images of self.” [13]

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Subcultures, and youth subcultures in particular, are the answer to this challenge of the socio-psychological age described by Sennett. To a certain extent, this is a perspective geared towards the audience in subculture communication similar to the scenic metaphor developed by Erving Goffman in his fundamental work, "The Presentation of Self in Everyday Life"[16]. The ritual function in subculture communication is emphasized by the best-known researcher of youth subcultures Stuart Hall and his colleagues in a joint work with subtitle is "Resistance Through Rituals" [18]. The communication there is portrayed as a process through which a shared culture is created, modified and changed. However, it should be noted that "resistance through rituals" should not be fully interpreted as a blatantly irrational rebellion. It is also a game providing instant gratification and playfulness (see Johan Huizinga's treatise *Homo Ludens* [17]).

Countercultural rebellion against the technocratic order of society as a given totality is directed against the hegemony of one-sided rationality (according to J. Habermas functioning in the scheme of goal-means and subordinate to the imperatives of efficiency and productivity contrary to the communicative rationality: the distinction first emphasized in his *opus magnum* "The Theory of Communicative Action" back in the year of 1981. by its German title *Theorie des kommunikativen Handelns*). This totality has outgrown the initially reasonable institutes of its rationality and now embodies pure irrationality - the shallowness of consumption and the subordination of technological and scientific progress to military and control objectives, etc. Thus, the upper hand is gained by trends that slow down human progress and/or cause it to stagnate, inviting corresponding opposition from worldview systems loaded with countercultural values. "Whatever contributes to small scale social forms and personal empowerment nourishes the ecological ego. Whatever strives for large-scale domination and the suppression of personhood undermines the ecological ego. Eco-psychology therefore deeply questions the essential sanity of urban-industrial culture, whether capitalistic or socialistic in its organization. It counsels that we scale down, slow down, decentralize, democratize, " T. Roszak wrote in his text "The voice of the earth: Discovering the ecological ego"[24]. The importance of nature, ecological focus here is close to H.Thoreau's ideas- via introducing the "downshifting of lifestyle" ideas in modern hermitage living in cabin by legendary Valden's pond [19]. So, how is the ecological ego able to live in the city?

In the case of the subculture of graffiti, a battle is taking place for the "aestheticization" of the public space, making it a living environment.

This is the answer provided by the rebellious sons to the "fathers of the city" who possess money and power to shape urban space by architecture means. The generation of sons excluded from this real estate discourse due to a lack of financial means are forced to put into play the only thing they own, i.e. one's physical body. They subject themselves to the danger of imprisonment because graffiti considers being an illegal activity (i.e. in judicial terms interpreted as "vandalism"- a point of view prevailing within the mainstream mass media). The point of view, in turn, forms a point of view, which is essential in the methodological development of the creation and exchange of semiotic signs, which we will take as the basis for this study.

The objectives of our research are to analyze ecological topics appearing in the signs contained at the graffiti stencils within the urban space of Riga, capital of Latvia. I will

answer the research question: How the counter-cultural ecological ego is expressed in the urban space and how it is coopted in the commercial marketing?

In this study, the most important approach is semiotics - i.e. the aspect of semiosis as the creation and circulation of signs. It is methodologically impossible to bypass or underestimate the structuralism approach in the culture studies overall and in our visual analysis particularly (which transfers the models of analysis of linguistic signs to the social field, in which, in turn, the domain of culture and counterculture is arranged) contribution to the field of human sciences, which we will also have to take into the account of theoretical arsenal for our research.

The idea of the role of the sociocultural context in the construction of the structure of meaning permeates structuralism theory since its inception; although the explanation of this role has different models and different terms, the most popular explanation – the modern outlines of this concept in philosophy, sociology and communication science is marked precisely by the approach developed in the tradition of literary structuralism, which is related to the concept of discourse.

If Barthes in the mid-1950s Barthes solved the question of how socially accepted and culturally based ideas become "natural" with the help of the concepts of mythology, ideology and the second-order system of signification,- then later on Michel Foucault (see our research on this post-modernism founding father's evolution of ideas in the early, i.e. so called "structuralist" period of writing's approach in Kozlovs (1995-2020 years publications)[9],[10],[11],[12]) about ten years later, still defending structuralism, even though by distancing himself from it, vividly shows how certain assumptions and knowledge- episteme that the set the rules in accordance to which the statement is considered true, respectively, reliable. So called regimen of truth that shapes the discourse (not necessarily solely linguistic but rather in our case- pictographic).

In the given study, when "reading" and interpreting the counter-culturally ideological messages in the analysis of stencils in Riga, capital of Latvia, it is essential not to forget their inclusion (or, more precisely: "embedding") in the city space, which can also be conceptualized as a text/context, - however at the level of perception and lived experience (i.e. in the "psycho-geographical" aspect) exceeds the boundaries of culture as a mere readable (i.e. literary) text.

MATERIALS AND METHODS

The aim of this research is to explore and describe the counter-culture ideology within subcultural communication in the framework of cultural studies using visual semiotic analysis of stencil graffiti within the urban space. It is done by exploring the key elements of subcultural communication as an artistic response to contemporary global and local challenges/social problems. Research demonstrates the presence of the social critique potential of counter-culture in the dialectical cultural semiosis (emerging and circulation of signs within society) between counter-culture and "the mainstream". The material of the research is a collection of Riga stencil graffiti photos (approximately 2000 items) where all the basic themes of counter-culture ideology appear. 10 items with visual and verbal elements related to ecology were selected for semiotic analysis. Riga – capital of Latvia - is seen as a unique case in urban and semiotic studies where this particular form of street art flourished enormously during the tide period in between

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the fashion of street murals and later- the sticker art. The methodological basis for research is visual semiotics developed in the structuralism tradition combined with cultural studies approach developed in youth subculture communication research that gives context and reveals the main ideological discourse of so called "counter-culture". Stencils are multimodal messages with very dense meanings. This is why for every stencil contains both visual (images, objects, backgrounds, colours) and verbal messages (written language [Latvian, English, Russian] based).

TABLES AND GRAPHS

The following section includes graphical representations of stencil graffiti in the qualitative part of the analysis.

	Figure 1. Industrially alienated worker		Figure 6. (FUR is MURDER)
	Figure 2. "You got warmer but someone died"		Figure 7. Commercial barcode
	Figure 3. GO VEGAN!		Figure 8. Collective suicide
	Figure 4. www.peta2.com		Figure 9. LIFE IS BETTER THAN TV
	Figure 5. Suicidal hand		Figure 10. Do not eat me.

RESULTS

The analysis identified some topics related to the ecological aspects in everyday life as central in the messages in public space.

Figure 1. gives the most creative critical account of the everyday life in capitalism. It provides critique of technocracy. In the image we see the industrially alienated worker who is performing a monotonous operation. The scene is set as a usual working scene in the factory with an exception that his/her head is screwed with a machine's hand. This symbolizes the lack of thinking and (self)reflexivity of the most people that allow capitalism to work. In addition, the machine and the simple instrument used to fix mechanical production tools and lines is also metonym pointing on to whole model of production and consumption – main object of criticism for many counter-culture statements. In this image there is no verbal text, but what is interesting is the colour used in stencil – green connotated as natural and as life vs. lack of life in capitalism that destroys life in order to make it serve the capitalist. So this picture can be seen as a countercultural critique inspired by the Freudo-Marxist Frankfurt School of a technocratic society, where the subjugation of nature is transformed into the subjugation and manipulation of man. This ambiguous connection with the world of technology allowed the development of genres such as cyber-punk literature and aesthetics or the new media ethic of "hacktivism" [8] if we paraphrase Tim Jordan's slogan as a form of counterculture in the era of the information society.

Three following figures contain the statements regarding industrial killing of animals. Here the critique is going beyond the distinction between a man and an animal (like it is in the philosophical ideas of specie-ism (discrimination by specimen on anthropoid-centric planetary hegemony basis) and many esoteric teachings that had an influence on variety of sub- and counter- cultures as an alternative form of knowledge). It is criticizing the idea of domination (of one species above other), classification and hierarchies in the worldview. In Figure 2. the message is constructed on the parallelism. Below the link is integrated to the website www.FurIsDead.com (opens peta.com animal rights webpage). Text in green colour (connotated as nature and "green" movements) means in Latvian "You got warmer but someone died".

Following messages contain relatively simple expressions. Using red on white background, the messages in Figure 3 and Figure 4 allows a connotation with blood, however, red is also signalizing an emergency. Figure 3 calls "GO VEGAN!" underlining animal rights with pig head over slogan; in Figure 4 the stencil consists of the website address only: www.peta2.com. Same content, but in other colours is expressed in Figures 7 and 10. Black letters on the wall (in Figure 7) are clearly stating – "Fur equals Murder". Symmetric composition of the written text underlines the equation, but also brings forward the aesthetic of black - death. Another (Figure 10) is a green bust of an animal (goat) on the dark surface with a written line under it saying: "Do not eat me" – bringing together idea of eating of meet with an image of living animal is one of the strongest tools to create negative emotions through contradicting perceptions.

Red is also used in Figure 5. Here the suicidal hand wrist with razor blade and odorous hamburger is painted in white colour on red background. The hamburger symbolizes globalized consumer culture, that endangers nature in favour of comfort, speed of life and satisfaction. The image with no words is suggesting that the consumer society is not conscious, so that what it is doing every day is pushing it closer to suicide – death and

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disappearance. A razor is a metaphor of sharpness of the feeling, idea or the statement and at the same time stands for countercultural attitude. This is not the only place were suicide appears when explaining contexts of nature – society relationships. Suicide is depicted very clearly in another picture – in Figure 8. Collective suicide pictured lemmings running amok from the rock and falling down in smashed corpses pile. The absurdity of the event and at the same time impossibility to stop this event strikes the viewer (who is in power position of seeing the happening from outside), so that he/she develops emotional attitude towards dying animals that need help/care. The green colour underlines the connectedness to nature. At the same time it is obvious, that this image is a simile – the viewer recognizes that the images smashed are humans being "blind" (following the group/other members of society and not asking questions) and approaching edge of the rock – the ecological catastrophe.

Two remaining stencils are using subversion as its means of expression. Figure 7 shows a realistically depicted commercial barcode that is a typical visual element for every consumer. However, because it has text written under the bar code saying in Latvian: "Buy or die!" we can recognize it as an anti-consumerist statement. Figure 9 underlines importance of living and life in the era of mass media consumption. In Latvian it is commented verbally: "Life Is Better Than TV" under a picture of banned tv-set. The sign of banning looks realistically so that the message works as reminder of banning of other things in other contexts. Subversion of the forbidding sign and the dark grey colour used indicate the media as part of technocratic society where everything is a dark illusion.

The results of the analysis of selected stencils show that the meanings of the messages spread out in the urban space of Riga that involve ecological topics mainly 1)criticize lack of critical, reflexive perspective in the mass technocratic society oriented on consumption, 2) propose change of attitude based on the assumptions of veganism, 3)

DISCUSSION

The thematic diversity of the ideology of counterculture is most clearly evident in the alternative media space. As far as the semiotic partisan activity of graffiti is concerned - it is a vehicle for a certain socio-critical ideology in which the main ideological themes of counterculture are manifested in visual and laconic form. From the perspective of interdisciplinary research we arrive at a point where several academic problems clash, i.e. three principal thematic blocks are: subcultural identity, the creative energy of self-expression and the critical vector of street art. Here I refer to semiotic rebelliousness (i.e. a revolt aided by signs or symbols). The discourse of messages created using the medium of graffiti (e.g. stencils) undoubtedly belongs to subculture, because, even though it is found in the public space- on the façades of surfaces forming urban landscape, the majority of the city inhabitants fail to notice it or else - even interpret it contrary to culture's ordered world of meanings rather chaotic "dirt" more closely associated with Nature than Culture. The decoding of these messages is automatically connected to acceptance in the subculture - if you don't know the code - you're disqualified. Therefore it is possible to talk about a triadic communication mode within the subculture discourse comprised of three components. One is the sender, the second – recipient of message, and the third one can be referred to as the "the uninitiated audience". In the new Latvian language there are special designations for those who are

not “initiated” but rather clearly demonstrate their active desire to acquire the status of the “initiated”. Those designations are clearly evident within the virtual world of computer-mediated communication (CMC) Argo (new- media and internet slang): “the lamer” or “pokemon”.

Thus, one can argue that in the discourse of subculture- visual, musical and other codes are used not specifically, in order to be readable and understood, but rather to remain hidden. The gnostic impulse is retained in subculture communication, i.e. knowing the secret code of restricted network of communicators that separates the inner circle from the mainstream mass. How can you remain hidden when you’re on view for all to see? “Hiding in the light” to quote the metaphor that is the title of one of the key works in this field by the notable researcher of youth subcultures Dick Hebdige. This communication takes place along vectors in two perpendicular directions: the mutual one and the one facing outwards. It can be noted in practically all the alternatives to values, which are articulated and symbolically played out in the counterculture ideology, which manifests itself in different youth subcultures. It is true also regarding the topic of ecology and signs and symbols calling to re-consider the attitude towards nature in the contemporary phase of capitalism.

At the same time all the “alternative” values have conventional and institutionalized substitutes that are more or less integrated into the commercial marketing. The aspect that dissuades young people and puts them off fitting into the functioning of given existing social institutes is the conventional nature of the institutes themselves and their perception of this sort of “fitting in” as a distinctly bad “un-sexy” conformist step. As many researchers have already stressed: counterculture is characterized by infantile rebelliousness. There is protest against routine and discipline traits of the responsible world of grown-ups (i.e. psycho-analytically labeled “Father Figure”). In place of disciplined crowds leading to mastery must come a game providing instant gratification and playfulness (see Johan Huizinga’s treatise *Homo Ludens*) [17].

Use of the street as an alternative and independent media in the form of civil disobedience manifested through the translation of radical political ideas, thus to a certain extent performing the work of propaganda, is an example of creative idealism. The motivating ideas of sustainability of life (veganism, anti-fur movement, “green” philosophy) are put in sharp opposition to the dominating rule of capitalist production and profit gaining. Still, it is important to remember that graffiti is a non-violent protest, whose theoretical basis is Henry David Thoreau’s treatise on “On Civil Disobedience” (appearing on various compilations of important political thought texts alongside with his almost contemporaries like Gandhi, Lenin, Mussolini or Hitler) that become an essential part of anthologies for political and social philosophy [19]. Ecological thinking is one of its elements. To a certain degree, in its visual form, graffiti could be interpreted as continuation of the *“samizdat”* (Russian term for soviet time underground desk-top-publishing, that has illegal circulation) tradition dating back to the Soviet era, both in the sense of a socially critical message and in the use of an alternative media. Parallels of historical development exist and, accordingly, the hope that this idealism could lead to the radical democratization of Latvian society in one generation after the fall of a totalitarian regime - similar to the way this occurred in Western Europe or as a result of the idealistic youth social movement in the United States in 1960-ies. If we

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look at the carnivalesque activities of the “green” movement – such as attacking museum artworks - it would appear that the contemporary tradition of the protest or “postmodern politics” is striving for the “aestheticization”. It is true also regarding graffiti stencils that is in the center of this paper. Many of them seem to be inspired by graphic arts and a potential to be regarded as art in other place of appearance.

Indeed, advertising and other commercial institutions are also keeping track of the *Zeitgeist*, and especially those marketing strategies that target the youth audience. Commercial organizations are gradually trying to master the graffiti- stencil medium in order to advertise corporate products. Thus, a process in which counterculture is co-opted and commercialized is already under way. This is true also regarding topics regarding ideology – vegan products are a normal set of products in every modern supermarket, there fashion industry promotes extensively artificial fur etc.

CONCLUSION

Youth subculture itself is closely linked to rock music that explains why the first examples of graffiti appearing on the streets of Riga were mainly abbreviations of the more extreme icons of Western popular music if one counts the examples of phallocentric pictographs that have existed since the age of cave drawings and can mainly be found on the walls of public toilets (this genre has specific academic designation: *latrinalia*). In contemporary competitions of visual poetics, which are comparable to singing poetry slam “battles” or hip-hop rhymes [6], graffiti writers point out the lack of artistic quality at each other’s works of art by branding them with the diagonal label “TOY” (taken from the English noun “toy”). According to Theodor Roszak’s classic definition, youth counterculture is “opposition to a technocratic society” within the sub-title of coining the culture studies concept of counter-culture in its first publishing [24]. Another important theoretician of counterculture, so called “academic LSD guru” Timothy Leary points to the “symbol of the electric guitar” belonging to the youthful opposition ambivalent attitude towards technological innovation [3]. This equivocal link to the world of technology fostered the development of genres such as cyberpunk (the style evident as well on Riga’s stencil scene) literature and aesthetics. In cultural semiosis of information age the younger generation is creating a “creative class” turning the ideology of counterculture into the mainstream. The world of the playful generation with the flower-power amenities provokes passionate resistance from the various populist movements. Contrary to “the resistance by rituals” it drives the whole of civilization with its futuristic technical and emancipatory achievements back into the un-modern past. Unfortunately, as a populist politics grows in political communication, greenwashing is developing, and green ideas become just another component in the mix that provokes controversial communication and polarization instead of ecology of self.

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([Pictures accessed 30 October 2019]. Access through Internet:jeremy.lv/stencils)

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USING SCANNING ELECTRON MICROSCOPY TECHNIQUES IN THE ANALYSIS OF STRUCTURAL DIVERSITY OF VARIOUS PLANTS ORGANS

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ABSTRACT

In this paper, the applications of Scanning Electron Microscopy (SEM) in plant histology and anatomy research are highlighted. Traditionally, SEM is used in plant biology to analyze the surfaces of various vegetative and reproductive organs in order to investigate micromorphological aspects. Vegetative and reproductive organs from 12 species of angiosperms from various habitats in Romania were analyzed (*Adonis vernalis* L., *Primula halleri* J.F.Gmel., *Oxytropis halleri* Bunge et. Koch, *Oxytropis campestris* (L.) DC, *Pulsatilla alpina* (L.) Chaz., *Gentiana acaulis* L., *Ranunculus montanus* Willd., *Dryas octopetala* L., *Gymnadenia conopsea* (L.) R.Br., *Epipactis helleborine* (L.) Crantz, *Ardisia crenata* Sims, *Dioscorea polystachya* Turcz.). This study presents the anatomical aspects of the plant organs, with observations based on images obtained using SEM. To clarify some structural details, comparative images from the same biological material, obtained either through SEM or a classical light microscopy (LM), were also provided. The advantages and disadvantages of using this technique in plant anatomy to reveal structural particularities are discussed.

Keywords: Scanning Electron Microscopy, anatomy, plant organs.

INTRODUCTION

Scanning electron microscopy (SEM) is an important tool of investigation in different scientific fields: biology and medical sciences, materials science, nanowires, semiconductors, forensic investigations, geology, restoration of heritage objects, etc [1].

The preparation techniques of the materials used for analyses are very specific, they mostly depend on the consistency and the physico-chemical characteristics of the sample, but also on the final objectives of the investigations [1].

In Plant science, investigations using SEM are very common. Usually, SEM studies are used to analyse the micromorphology of the leaf, the structure of the glandular and non-glandular trichomes, the micromorphology of the pollen (in both actual and fossil plants), etc. Compared to the very large number of scientific works and books that address these topics, the use of SEM in the study of the anatomical structure of plants is found only in a very small number of papers, with a limited illustration [2-6].

The usual sample preparation techniques in plant histo-anatomy research, followed by observations with a light microscope (LM) (simple, with fluorescence, with polarized light or phase contrast) are represented by:

- free hand sectioning of the vegetative organs (rarely of the reproductive organs) with a razor blade, followed by colouring the sections with different combinations of dyes (especially for histochemical research).

- sectioning of vegetative and reproductive organs after prior infiltration in various media: paraffin, resin, glycol methacrylate, and others. Due to the unique structure of plant material, which consists of cells always protected by a cell wall of varying thickness and potentially modified by secondary chemical changes (such as lignification, suberization, or mineralization), the hardness of plant tissues can increase significantly. As a result, not all plant organs can be included in embedding media for sectioning. This method is generally used for plant organs with lower hardness, such as the tips of stems, roots, floral primordia, floral parts, etc.

- cryomicrotome sectioning of the frozen plant material, without prior processing. This method allows sections to be made through a greater variety of vegetative organs (of different hardness), but it is not suitable for reproductive organs.

SEM uses a beam of accelerated electrons, that usually operates in a vacuum (except for the Environmental scanning electron microscopy - ESEM) to form the images. Backscattered electrons (BE) and secondary electrons (SE) are produced following the interaction of the electron beam with the analysed sample and are the two main signals used to form images [1]. Biological samples are weak conductors; therefore, to obtain quality images, they must be covered with thin layers of metals (Ag, Au, Pt). One of the significant advantages of SEM is that it can analyse relatively large specimens (this depends mainly on the size of the stub on which they are fixed and the size of the microscope chamber). The magnification power of an SEM is clearly higher than that of a light microscope (20-1000000x for SEM vs 4-2500x for LM) [1].

In this paper, examples of the use of the SEM techniques in histology and plant anatomy investigations are presented. The types of information that can be obtained through this technique, compared to the classic techniques, the advantages but also the limitations of the method compared to LM observations are discussed.

MATERIALS AND METHODS

A. Plant material

The plant material presented in this paper was collected in the last 13 years from various habitats located in Romania (2 plant species was obtained from culture). *Adonis vernalis* L. from Valea lui David" natural reserve Iasi, *Primula halleri* J.F.Gmel., Oxytropis halleri Bunge et. Koch, *Oxytropis campestris* (L.) DC, *Pulsatilla alba* Rchb., *Gentiana acaulis* L. and *Ranunculus montanus* Willd. from Bucegi natural Park, Prahova district, *Dryas octopetala* L. from Ceahlau natural Park, Neamt, *Gymnadenia conopsea* (L.) R.Br.B and *Epipactis helleborine* (L.) Crantz from Barnova Forest, Iasi, *Ardisia crenata* Sims and *Dioscorea batatas* Decne were purchased from the flower shop, they being ornamental plants.

The investigated material consists of small pieces from roots, stems, leaves and floral buds. The plant material was fixed and stored in 70% ethanol.

Scanning Electron Microscopy observations

To observe the anatomical details of the analysed vegetative and reproductive organs, pieces were sectioned under the stereomicroscope with a new razor blade. After dehydration in a graded ethanol series (80%, 90% and 100%) and acetone p.a., the material was critical point dried with CO_2 (using a EMS 850 Critical Point Dryer), sputter-coated with a thin layer of gold (30 nm) (using a EMS 550X Sputter Coater).

Samples examined by scanning electron microscopy (Tescan Vega II SBH, from the Electron Microscopy Laboratory, Faculty of Biology, "Alexandru Ioan Cuza" University of Iaşi). All the photomicrographs in this paper are original, made by the author (who carried out both the processing of the samples and the taking of the photomicrographs).

Ligth microscopy sample preparation

For some analyzed samples, to compare the information obtained by the two methods (SEM and LM), sections were made through various organs of the plants. Free hand sections were performed using a razor blade and were colored with Iodine Green and Ruthenium Red. In the case of the reproductive organs, the material was embedded in paraffin, sectioned with a rotary microtome, and stained with Ruthenium Red and Methylene blue. Photographs were taken with an Olympus E-330 photo camera, using an Olympus BX41 research microscope.

RESULTS

Microphotographs obtained using SEM, taken from transverse or longitudinal sections through the organs of the different species investigated, provide relevant information on their histo-anatomical structure

- Root structure

Cross sections through the root with secondary structure from *Adonis vernalis* were analyzed using SEM and LM. The secondary structure is acquired only by cambium activity. The vessels from the secondary xylem are narrow but have thick and lignified walls. The endodermis remains of primary structure even at the root basis (Figure 1A-C).

- Stem structure

The *Pulsatilla alba* stem is in the stage of transition from the primary to the secondary structure (Figure 1 D, E). At the periphery it is delimited by the unilayered epidermis, the cortical parenchyma is made up of 6-7 layers of small, spherical, compact cells, with small air spaces between them. In the central cylinder, the conductive tissues are arranged in bundles. Each bundle has a multi-layered sclerenchyma sheath, made of fibers with thickened and lignified walls. Between the vascular bundles, at the top, the medullary rays are sclerified. The xylem is both primary and secondary in nature (some secondary xylem vessels appear as a result of cambium activity).

Dryas octopetala has woody, twisted stems, with an obvious secondary structure that comes from the activity of the cambium and phellogen (Figure 1 F, G). At the periphery of the stem, a thin periderm can be observed; the cortical parenchyma is reduced to a few layers of flattened cells. The cambium is very well developed, consisting of 6-7 layers of flattened cells. The ring of secondary wood is thick, with small vessels, characteristic of plants in alpine areas.

Oxytropis campestris presents the stem with secondary structure (Figure 1 H-J); the vascular bundles have primary and secondary tissues in their composition; a sclerenchyma sheath is observed at the phloemic pole. The epidermis is covered by numerous, long, non-glandular trichomes, with a striated wall surface.

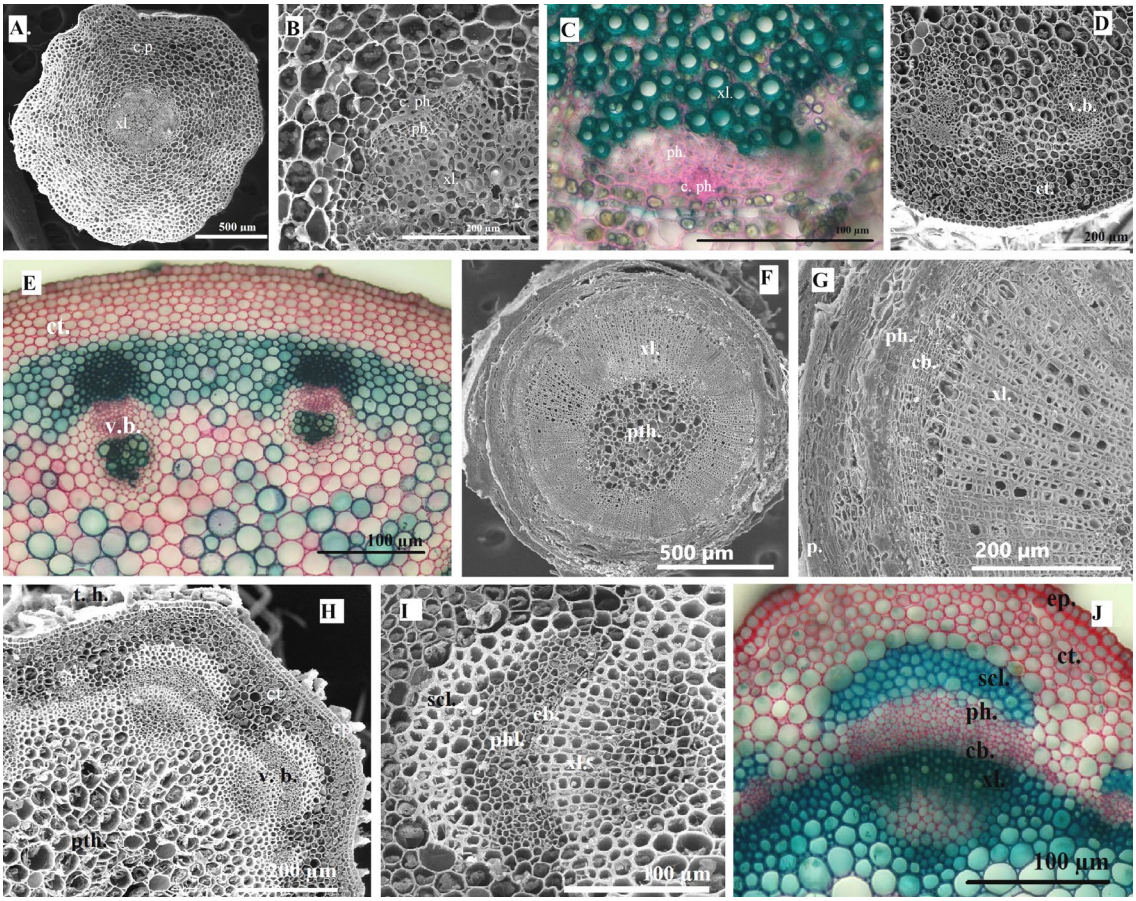


Figure 1 - Cross sections through the root of *Adonis vernalis*: SEM (A, B) and LM (C) images. Cross sections through the stem of *Pulsatilla alba*: SEM (D) and LM (E) images. Cross sections through the stem of *Dryas octopetala*: SEM images (F, G). Cross sections through the root with of *Oxytropis campestris*: SEM (H, I) and LM (J) images: c. ph - crushed phloem, cb - cambium, cp - cortical parenchyma, ct - cortex, ph - phloem, pth - pith, scl - sclerenchyma, vb - vascular bundle, xl - xylem.

- Leaf structure

The leaf of *Primula halleri* has a homogeneous structure, consisting only of spongy parenchyma (Figure 2 A, B). Vascular bundles are devoid of mechanical tissue; on the epidermis, numerous glandular trichomes with a single secretory cell can be observed. The leaf of *Gentiana acaulis* has a similar structure, but in this species, the glandular trichomes are absent on both the lower and upper epidermises (Figure 2 C, D).

A different structure is observed in *Oxytropis halleri*, where the leaf has a mesophyll differentiated into a single layer of palisade parenchyma beneath the upper epidermis and spongy parenchyma beneath the lower epidermis (Figure 2 E, F). Numerous long non-glandular trichomes are present on both epidermises. In *Ranunculus montanus*, the leaf has the same configuration of assimilative tissue, but the trichomes are absent on both epidermises (Figure 2 G, H).The leaf of *Ardisia crenata* has a bifacial heterofacial structure, with palisade parenchyma beneath the upper epidermis, which is predominantly exposed to light (Figure 2 I, J). In contrast, the leaf of *Dioscorea polystachya* has a bifacial isofacial structure, with the mesophyll composed entirely of spongy parenchyma (Figure 2 K). Within the mesophyll, numerous cells containing raphides of calcium oxalate can be observed (Figure 2 L).

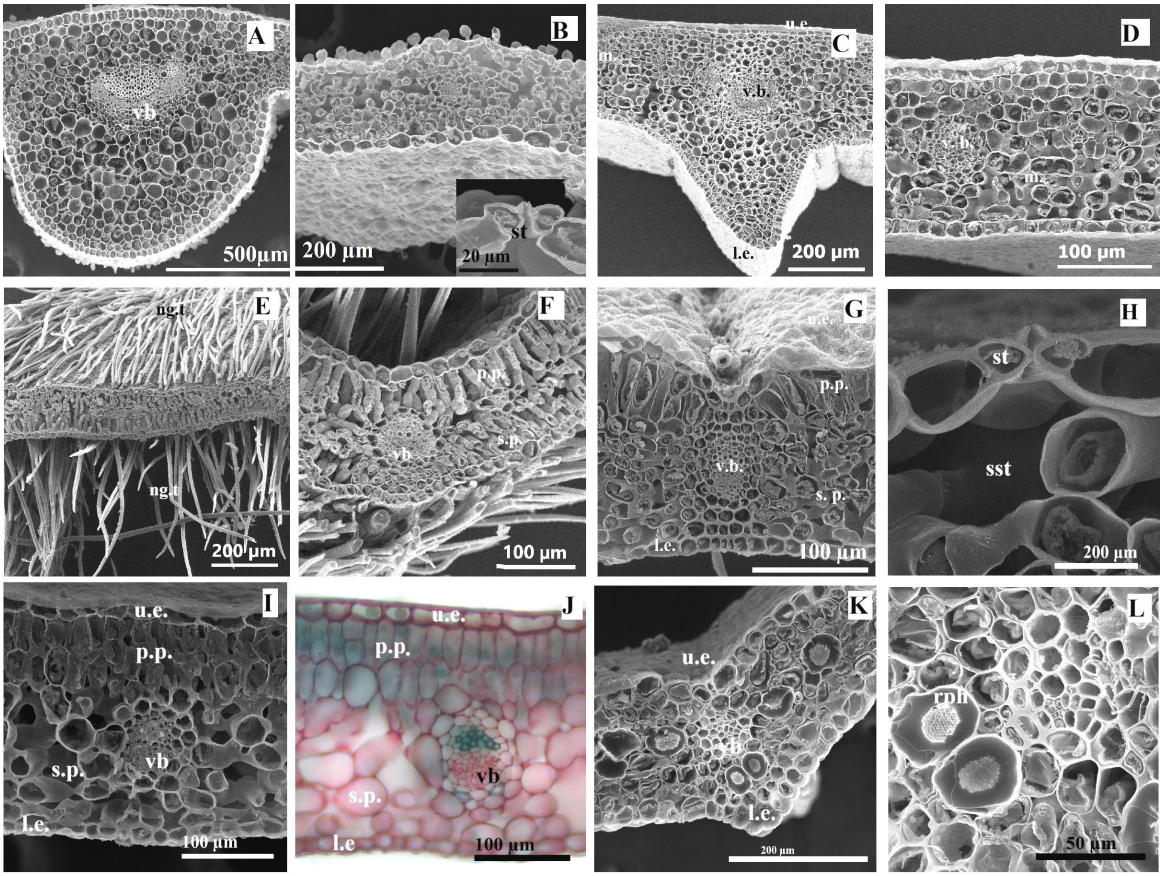


Figure 2 - Cross sections through the leaf of *Primula halleri*: SEM images (A, B). Cross sections through the leaf of *Gentiana acaulis*: SEM images (C, D). Cross sections through the leaf of *Oxytropis halleri*: SEM images (E, F). Cross sections through the leaf of *Ranunculus montanus*: SEM images (G, H). Cross sections through the leaf of *Ardisia crenata*: SEM image (I) and LM (J). Cross sections through the leaf of *Dioscorea polystachya*: SEM images (K, L): l.e. - lower epidermis, m - mesophyll, ng.t. - non-glandular trichomes, p.p. - palisadic parenchyma, s.p. - spongy parenchyma, st - stomata, rph - raphides, u.e. - upper epidermis, vb- vascular bundle.

- Reproductive organs structure

Young pollen grains of *Gymnadenia conopsea* are grouped in tetrads, visible within the pollinia (Figure 3 A, B). The ovary is unilocular, syncarpous, with parietal placentation; the ovules are numerous, anatropous, and small (Figure 3 C, D). In *Adonis vernalis*, the young ovule is anatropous, and each carpel is unilocular, containing a single ovule (Figure 3 E, F). Calcium oxalate crystals (raphides) can be observed in the ovarian wall of *Epipactis helleborine* (Figure 3 G, H).

DISCUSSION

The application of scanning electron microscopy (SEM) in plant histo-anatomy represents a significant advancement over traditional light microscopy (LM) techniques. SEM provides much higher magnification capabilities which is an important advantage when investigating the fine details of plant structures [1]. Our experience in recent years demonstrates the importance of using SEM techniques to highlight the anatomical features of plants, not only for investigating micromorphological characters, for which it is traditionally used in botany [7, 8].

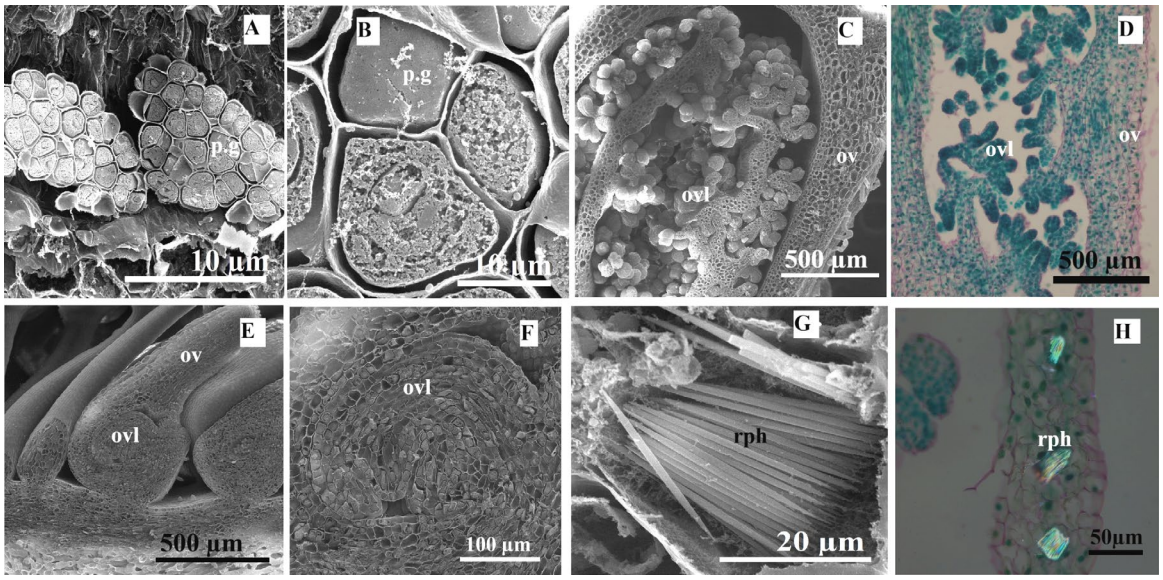


Figure 3 - *Gymnadenia conopsea*: young pollen grains are grouped in tetrads: SEM images (A, B) and longitudinal section through the ovary: SEM image (C) and LM (D). Longitudinal section through ovary with ovules from *Adonis vernalis*: SEM images (E, F). Longitudinal section through the ovary of *Epipactis helleborine* (raphides): SEM image (G) and LM - polarized light (H): ov - ovary, ovl - ovule, p.g - pollen granules, rph – raphides.

This high-resolution imaging allows for a detailed observation of plant anatomy at the cellular and subcellular levels, providing valuable insights into the organization and specialization of plant tissues, structures that might otherwise be difficult to visualize using conventional microscopy.

The fixed plant material exhibits sufficient structural stability to allow the cutting of high-quality sections (using a razor blade), particularly through organs with a fragile structure, as well as through organs of medium consistency. The obtained images clearly present the structure of different tissues; with the help of three-dimensional images obtained using SEM, the distribution of various tissues within the organs, their relative positions, and their cellular structure can be more easily interpreted.

One of the key strengths of SEM is its ability to generate detailed three-dimensional images of plant samples. In the context of plant anatomy, this is particularly useful for studying the micromorphology of various plant organs, such as roots, stems, leaves, and reproductive structures. For instance, the study of *Adonis vernalis* roots using SEM revealed a detailed secondary structure that includes narrow vessels with thick, lignified walls, an important feature for understanding the plant's vascular development and function in its native environment [7]. Similarly, SEM images of the stem structure in species like *Pulsatilla alba* and *Dryas octopetala* provide valuable information on secondary growth, vascular tissue organization, and the development of sclerenchyma, essential for understanding plant adaptation to different ecological niches [8].

When compared to LM, SEM allows for a more comprehensive understanding of the fine anatomical details, particularly in the study of tissues that are difficult to assess with traditional methods. For example, the three-dimensional images obtained from *Oxytropis campestris* demonstrate the distribution of non-glandular trichomes on the epidermis, which might not be as clearly visible with LM [8]. In reproductive structures, SEM proves invaluable in revealing detailed characteristics that are often overlooked

using LM. For example, the arrangement of pollen grains in *Gymnadenia conopsea*, as well as the anatomical features of ovules in *Adonis vernalis*, can be clearly distinguished and analyzed at the microscopic level. Such insights are important for studies of plant reproduction, pollination biology [9], the role of plants in phytoremediation [10] and even phylogenetic relationships [3].

However, SEM also has limitations that must be considered when interpreting results. The black and white images obtained by SEM do not allow interpretations on the chemical nature of the cell walls in the analyzed organs, proving their usefulness especially when such details are known or less important for the histo-anatomical analysis. Furthermore, the preparation techniques required for SEM can be quite labor-intensive and may necessitate extensive sample processing, such as dehydration, critical point drying, metallization, which can be time and resources consuming [1].

Moreover, SEM is limited by its need for samples to be placed in a vacuum chamber, making it unsuitable for live plant tissue imaging without specific adaptations, such as environmental scanning electron microscopy (ESEM) [11]. The ESEM allows for the analysis of samples in their natural hydrated state, but it is not as widely available as conventional SEM, which may limit its accessibility in routine plant histology research.

Despite these limitations, SEM has proven to be an invaluable tool in the field of plant science, particularly for detailed histological and anatomical studies. The ability to study the structural aspects of plant tissues at such high magnification and resolution opens new perspectives for research in areas like plant development, functional morphology, and adaptation to environmental stresses. If the identification of secondary changes in the cell wall is not necessary, SEM can replace classical analysis using LM. [7, 8, 12]. Also, anatomical analysis using SEM facilitates qualitative energy-dispersive X-ray microanalysis (EDX) investigations, which can be done on the same samples [13], if the electron microscope is properly equipped. The examples presented in this paper highlight the usefulness of SEM in gaining a deeper understanding of plant structure.

CONCLUSION

In conclusion, while traditional histological techniques still play a major role in plant research, SEM provides a higher level of precision and detail could be important for studying the fine structure of plant tissues. It complements existing methods by offering a new perspective on plant morphology and anatomy, allowing researchers to explore previously inaccessible aspects of plant biology. The use of SEM techniques in the histo-anatomical study of various vegetative or reproductive organs is particularly valuable for examining fragile structures, which often require embedding in different media for sectioning. In these cases, obtaining SEM images is faster, and their quality is satisfactory for this type of investigation [12].

Future advancements in SEM technology, including the development of more efficient sample preparation techniques and the broader application of ESEM for live plant studies, will likely further enhance our understanding of plant structures and their functional significance in diverse ecological contexts. Our experience in recent years demonstrates the importance of using SEM techniques for highlighting the anatomical features of plants, and not only for the investigation of micromorphological characters, for which it is usually used in botany.

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VALIDATION OF REFERENCE GENES FOR RT-QPCR IN PORCINE OOCYTES CULTURED IN ANTIOXIDANT-ENRICHED MEDIA

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ABSTRACT

Reference genes are essential for normalising data in RT-qPCR experiments and are critical in reducing technical variability. This study aimed to identify and validate stable reference genes for accurate gene expression analysis in porcine oocytes matured in culture media supplemented with antioxidants. Five commonly used reference genes were assessed: PPIA, RPL4, GAPDH, YWHAZ, and TBP, [2, 3] in oocytes cultured under oxidative stress conditions induced by Vitamin C. The experiment involved four experimental groups, analyzed in triplicate using SYBR Green RT-qPCR. PPIA exhibited the lowest SEM, indicating high precision and stability across different experimental conditions. GAPDH showed the most variability, confirming its unsuitability as a reference gene in this context. Differences between groups were statistically significant ($p < 0.01$) for most genes, with some exceptions for PPIA, YWHAZ, and TBP in specific conditions. The gene stability was evaluated using the NormFinder algorithm, which provided a ranking based on the stability of gene expression across experimental groups. PPIA was found to be the most stable, demonstrating minimal variation in expression levels, while GAPDH was identified as the least stable gene. The findings emphasize the importance of selecting appropriate reference genes for each specific experimental condition to ensure the accuracy of gene expression data.

Keywords: reference genes, porcine oocytes, gene expression normalization

INTRODUCTION

Critical insights into cellular processes, mechanisms of gene regulation, and responses to environmental stimuli are fundamental for advancing our understanding of biological systems. Real-Time Quantitative Polymerase Chain Reaction (RT-qPCR) stands out as one of the most robust and sensitive methods for gene expression analysis, ensuring precise and reproducible quantification [1], [2]. However, the accuracy of RT-qPCR relies heavily on effective normalization strategies that account for experimental and technical variations, such as RNA quality, cDNA synthesis efficiency, and amplification consistency [3]. Selecting appropriate reference genes is thus crucial for minimizing errors.

Reference genes, or housekeeping genes, are essential for the normalization of RT-qPCR data. These genes are generally expected to exhibit stable expression across different cell types and experimental conditions, providing a consistent internal control for reliable comparisons of gene expression levels [4], [5]. By offering a stable baseline, reference genes correct for discrepancies in starting material or reaction efficiency, making the choice of these genes vital for accurate data interpretation [6], [7].

RT-qPCR typically uses fluorescent dyes like SYBR Green, which binds to double-stranded DNA, allowing real-time monitoring of DNA amplification. The fluorescence signal correlates directly with the amount of DNA produced, offering a sensitive and specific method for analyzing gene expression across various biological contexts [8], [9]. Yet, this method's reliability is contingent on the careful selection of reference genes.

While commonly used reference genes like GAPDH and ACTB have historically been favoured for normalization, recent evidence indicates that these genes may not exhibit the required stability under all conditions [3], [10]. Their expression can vary significantly with tissue type, developmental stage, or environmental changes [11]. Consequently, the validation of reference genes tailored to specific experimental settings is necessary to avoid data misinterpretation [4].

This need for precise reference gene validation becomes even more pronounced in reproductive biology, particularly in oocyte development. Oocytes are specialized cells that undergo extensive physiological and biochemical transformations during maturation, influenced by factors such as oxidative stress and culture conditions [7], [9]. Therefore, it is imperative to evaluate the expression stability of candidate reference genes in the context of oocyte maturation.

Porcine oocytes, due to their physiological parallels with human oocytes and relevance in agricultural research, serve as a valuable model for studying reproductive processes [12], [13]. Investigating the impact of oxidative stress on oocyte maturation, often mitigated by antioxidants like Vitamin C, has gained research interest. Oxidative stress can significantly compromise oocyte quality and subsequent embryonic development, emphasizing the importance of accurate gene expression data [8], [10]. Thus, reliable reference genes are needed to interpret molecular mechanisms underpinning these processes [5].

This study focused on identifying and validating stable reference genes for RT-qPCR in porcine oocytes exposed to antioxidant-supplemented media. Five reference genes (PPIA, RPL4, GAPDH, YWHAZ, and TBP) were chosen based on their established use in reproductive studies and reported stability [14], [15]. The *NormFinder* algorithm, known for its robust statistical approach to ranking gene stability, was used to evaluate expression consistency across experimental groups [5], [16]. This analysis revealed PPIA as the most stable gene, with minimal variation, while GAPDH was identified as the least stable, reaffirming the necessity of condition-specific gene validation [9], [10].

Ultimately, this research emphasizes the universal importance of validating reference genes in gene expression studies. The findings caution against the uncritical use of traditional housekeeping genes and advocate for a tailored approach that accounts for specific experimental conditions [3], [8]. A multifactorial normalization strategy, incorporating multiple validated genes, is advised to enhance the reliability and statistical power of RT-qPCR data [9], [14].

MATERIALS AND METHODS

Biological Material

The biological material used in this study comprised cDNA suspensions derived from four experimental groups, which consisted of porcine oocytes matured under various culture conditions. The groups included: Ov. I (Control Group): Class I oocytes matured in culture media without the addition of antioxidant substances; and CV I: Class I oocytes, CV II: Class II oocytes, CV III: Class III oocytes, all matured in media supplemented with Vitamin C.

Those classifications were chosen to maintain variability in the biological material while ensuring uniformity in terms of antioxidant supplementation. The cDNA solutions from these groups served as templates in SYBR Green RT-qPCR reactions, employing primers specific to five candidate reference genes for this study. The primer sequences for each gene are detailed in Table 1.

Table 1. Primers pairs corresponding to gene expression markers used in this study

Gene	Sens primer 5'-3'	Antisens primer 3'-5'	Reference
GAPDH	ACACTCACTCTTCTACCTTTG	CAAATTCATTGTCGTACCAG	Kim et al., 2022
PPIA	AAAACTTCCGTGCTCTGAGC	TTATGGCGTGTGAAGTCACC	
RPL4	CAAGAGTAACTACAACCTTC	GAACTCTACGATGAATCTTC	
YWHAZ	TGCTTCCTTTGCTTGCATCC	TCAGGGTAGGCAGGGTTTATAG	
TBP	AACAGTTCAGTAGTTATGAGCCAGA	AGATGTTCTCAAACGCTTCG	

The complexes oocyte-cumulus (COCs) were collected from porcine ovaries in Dulbecco's PBS (D8662, Sigma Aldrich), supplemented on the day of use with the following components: 500 mg glucose, 18 mg pyruvate, 10 mg penicillin, 20 mg streptomycin, 5.6 mg heparin, and 150 mg bovine serum albumin (BSA) in a final volume of 0.5 ml. The media were pre-warmed in a water bath at 35°C to maintain optimal conditions. Vitamin C (L-Ascorbic Acid, Calbiochem): solution was freshly prepared at a concentration of 0.5 mM by dissolving in ultrapure water, from chemically pure substance.

Oocyte maturation was conducted as described by Boldura, 2021 [17] TCM-199 medium, containing 220 mg $NaHCO_3$, 5 mg gentamicin, 2.2 mg sodium pyruvate, and 1510 mg of modified TCM-199 Hepes media. The medium was equilibrated for at least four hours in a CO_2 incubator at 38.5°C with maximum humidity before use. Following washing in PBS, the oocytes were classified into three morphological classes and transferred into 400 µl of TCM-199 medium, enriched with 10% FSH. Maturation took

place in four-well culture plates covered with mineral oil to prevent evaporation, and oocytes were incubated at 38.5°C, 5% CO_2, and maximum humidity for 44 hours.

Post-maturation, the COCs were examined under a stereomicroscope equipped with a heating plate to assess the degree of cumulus cell expansion as described by Torda, 2022 [18].

RT-qPCR Analysis

Total RNA was extracted from cumulus cells using the SV Total RNA Isolation System (Promega, Oregon, USA) following the manufacturer's protocol. RNA was quantified and assessed for quality using a NanoDrop 8000 spectrophotometer (ThermoScientific, Wilmington, DE, USA), measuring the absorbance ratios at 260/280 nm and 260/230 nm. High-quality RNA was indicated by a 260/280 ratio of approximately 1.8 and a 260/230 ratio close to 2.

Complementary DNA (cDNA) synthesis was performed using the SuperScript™ IV VILO™ Master Mix Kit (Invitrogen ThermoScientific, Carlsbad, CA, USA) in a reaction volume of 10 µl as indicated by the producer. The reaction mix was incubated at 25°C for 10 minutes, followed by 20 minutes at 37°C. The process was terminated by heating at 85°C for 5 minutes.

The expression levels of candidate reference genes were quantified using SYBR Green-based RT-qPCR with the GoTaq qPCR Master Mix Kit (Promega, WI, U.S.A.), which includes SYBR Green and the passive reference dye ROX. Each 25 µl reaction mixture was prepared according to the manufacturer indications and 200 ng of cDNA were used as a template. Amplification was monitored using the ABI 7500 Real-Time PCR System (Applied Biosystems Foster City, CA, USA), and Ct values were recorded in triplicate for each sample.

The ΔΔCt method was used for relative quantification [19]. Statistical analysis was performed with Microsoft Excel's *ANOVA* function and *NormFinder* software (MOMA, Aarhus, Denmark) to assess the stability of reference genes. Statistical significance was set at $p < 0.01$ for differences between experimental batches. Cycle threshold (Ct) values were collected from the RT-qPCR experiment. Each experimental group was analyzed in triplicate, and the mean Ct values for each gene, along with the standard error of the mean (SEM), were calculated using Microsoft Excel software.

RESULTS

The data collected from RT-qPCR experiments focused on evaluating the stability of five reference genes: PPIA, RPL4, GAPDH, YWHAZ, and TBP. Cycle threshold (Ct) values for each gene were obtained from porcine oocytes matured in different antioxidant-supplemented media. Mean Ct values ± standard error of the mean (SEM) for each gene across the four experimental groups (Ov. I, CV I, CV II, and CV III) were calculated, revealing significant differences ($p < 0.01$) in most cases.

Table 2. Ct values and statistical interpretation for each gene in experimental batches of porcine oocytes matured in Vitamin C-enriched media.

Gena	Control Ov I	CV I	CV II	CV III
PPIA	26.20 ± 0.33	25.66 ± 0.15	29.80 ± 0.16	30.04 ± 0.18*
RPL4	35.77 ± 0.36	34.77 ± 0.18*	36.96 ± 0.14*	32.23 ± 0.24*
GAPDH	26.34 ± 0.45	35.62 ± 0.2*	29.22 ± 0.21*	28.51 ± 0.19*
YWHAZ	29.93 ± 0.35	36.37 ± 0.17	32.70 ± 0.16*	31.30 ± 0.16*
TBP	34.26 ± 0.34	33.93 ± 0.17	34.10 ± 0.15*	31.59 ± 0.17*

* indicates significant differences ($p < 0.01$) between oocytes matured in environments without added vitamin C and other experimental batches (oocytes of classes I, II and III matured on media with added vitamin C).

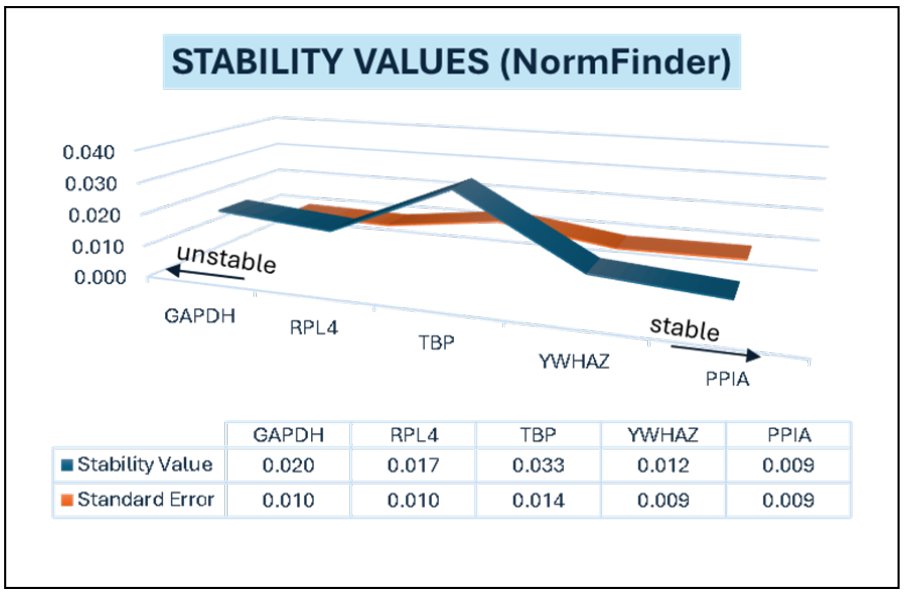
The detailed Ct values and their statistical interpretations are summarized in Table 2. These values highlight significant variations between the control oocytes (Ov. I) and those treated with Vitamin C (CV I, CV II, CV III). Notably, the gene PPIA demonstrated the smallest SEM, indicating a higher precision and stability, whereas GAPDH showed high variability, confirming its unsuitability as a reference gene under these conditions.

The stability of each reference gene was further analyzed using NormFinder software, which calculates stability values by assessing intra- and inter-group variations. The transformed natural logarithm (LN) values from Ct data are presented in Table 3. This analysis identified PPIA as the most stable gene, with TBP and YWHAZ also showing acceptable stability under certain experimental conditions.

Table 3. LN-transformed Ct values of studied genes across experimental groups.

Genă	Ov. I	CV I	CV II	CV III
PPIA	3.284535	3.245093	3.288501	3.286248
RPL4	3.57708	3.548725	3.609773	3.47305
GAPDH	3.271226	3.572909	3.374738	3.350309
YWHAZ	3.399028	3.593717	3.487385	3.443685
TBP	3.534052	3.524275	3.529176	3.452696

A graphical representation of the relative stability of the reference genes is shown in Figure 1. PPIA demonstrated the highest stability, whereas GAPDH emerged as the least stable, corroborating the statistical data and *NormFinder* analysis.



	GAPDH	RPL4	TBP	YWHAZ	PPIA
Stability Value	0.020	0.017	0.033	0.012	0.009
Standard Error	0.010	0.010	0.014	0.009	0.009

Figure 1. Assessing the stability of the five reference genes with the *NormFinder* program

DISCUSSION

The findings of this study highlight the critical role of selecting and validating appropriate reference genes for RT-qPCR analysis. The superior stability of PPIA across all experimental conditions emphasizes its reliability for normalizing gene expression in porcine oocytes exposed to oxidative stress. This stability is likely attributed to PPIA's involvement in essential cellular functions, such as protein folding and response to cellular stress, making it less susceptible to experimental fluctuations [10], [15] .

The observed instability of GAPDH aligns with previous research, which has documented the gene's variability, especially in reproductive tissues and under stress conditions. GAPDH's expression has been linked to metabolic and cellular stress responses, explaining its unsuitability for studies involving oxidative or hormonal treatments [4], [16]. These findings underscore the limitations of relying on traditional housekeeping genes without rigorous validation.

NormFinder results further support the use of PPIA as the primary reference gene while suggesting that the combined use of TBP and YWHAZ could improve normalization accuracy. This approach addresses the inherent biases that may arise from single-gene normalization and provides a more robust framework for gene expression analysis. Such strategies are increasingly recommended in the literature, as they mitigate technical and biological variability [14].

The results of this study are consistent with previous findings in porcine and mammalian tissues. For instance, TBP has been identified as a stable gene across various physiological states, including different stages of ovarian development [5]. Similarly, YWHAZ has demonstrated stable expression in several reproductive contexts, although its stability can still be influenced by the biochemical environment, highlighting the necessity of context-specific validation.

The impact of environmental factors, such as the presence of antioxidants like Vitamin C, on gene expression profiles was also evident in this study. Oxidative stress is known to induce significant biochemical and physiological changes in oocytes, which can alter the expression of both target and reference genes. Therefore, selecting reference genes that are unaffected by such conditions is essential for generating accurate and reproducible data [20].

CONCLUSION

This study provides a comprehensive analysis of the stability of five candidate reference genes (PPIA, RPL4, GAPDH, YWHAZ, and TBP) for RT-qPCR normalization in porcine oocytes cultured in antioxidant-enriched media. Using rigorous statistical evaluation with *NormFinder*, the findings revealed critical differences in the stability of these genes, emphasizing the importance of validating reference genes under specific experimental conditions. PPIA emerged as the most stable reference gene, demonstrating minimal expression variability across all treatment groups.

In contrast, GAPDH exhibited significant instability, confirming its unsuitability as a reference gene under oxidative stress conditions. This variability highlights the limitations of traditional housekeeping genes and the necessity of careful validation before their use in gene expression studies. The findings are consistent with previous research showing that the expression of common reference genes like GAPDH can be influenced by factors such as tissue type, experimental treatment, and environmental conditions.

The analysis also underscores the importance of using multiple validated reference genes to enhance the accuracy and reliability of RT-qPCR data. While PPIA alone proved to be the most stable, the combined use of TBP and YWHAZ may offer additional benefits for normalization, as indicated by the software's analysis.

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WASTE REDUCTION FOR CLIMATE CHANGE MITIGATION: THE TUPPERWARE CASE STUDY

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ABSTRACT

Currently, the most advanced countries in terms of green thinking and production are Scandinavia, Switzerland, the Netherlands, Australia and New Zealand. The Baltic States also have adopted a joint Climate Declaration with a commitment to climate neutrality. The global production and consumption of plastics have doubled over the last two decades, yet only approximately 30% of plastic waste is recycled and reused, while the rest ends up in the environment. We all must play a role in protecting the environment at home, at work and in our free time. Sorting waste is the easiest way, yet it is not the only way. In the case of plastic tableware, it could also translate into new practices, habits and the reuse of tableware made of plastics containing no substances harmful to health, which could be used for buying food or drinks. In Latvia too, several companies offer discounts, e.g. if buying coffee and pouring it into one's own thermal mug. One such plastic tableware manufacturer is Tupperware, which defines sustainability as a core value from production to product sale. The research aims to describe a system Tupperware has put in place to reduce waste and educate people to mitigate climate change. The research results revealed that cooperation was key to the system. Cooperation was important in obtaining information, procuring raw materials, selling products, and transferring knowledge into preservation practices.

Keywords: climate change, sustainable plastics, plastic waste reduction.

INTRODUCTION

Climate change is one of the major global challenges today. Limiting global temperature rise requires comprehensive action by all countries to reduce greenhouse gas (GHG) emissions [1]. Science is therefore increasingly focusing on nature conservation, seeking a trade-off between biodiversity preservation and economic growth. Climate change policy has become an international policy and is institutionalized. For example, the Intergovernmental Panel on Climate Change (IPCC), which brings together scientists from all over the world specifically concerned with climate change, regularly publishes reports and guidelines that are alarming, but nevertheless based on scientifically verified research. One of the projections is that global warming could reach 1.5°C between 2030 and 2052 and continue to increase, with significant consequences for nature and humans [1]. One of the key components in this "global pollution puzzle" is plastic consumption and waste. Plastics play an important role in modern human life. It is therefore necessary to consider how to move towards a more circular and sustainable plastics system, while maintaining the usefulness of plastics. This transition could be accelerated by adopting best practices and making improvements along the entire plastics value chain [2].

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Plastics are harmful because they release toxic additives, toxic substances and environmental pollutants that enter the biosphere and affect the marine ecosystem. Plastic waste also affects the economy. Marine litter also affects fisheries and tourism, as the aesthetic degradation of coastlines is starting to scare off tourists. Several key environmental initiatives were launched in 2023, including the Water Action Agenda, the Global Framework on Chemicals – For a Planet Free of Harm from Chemicals and Waste and a landmark agreement by 175 countries to develop a legally binding treaty on plastic pollution [3]. In the context of plastic use, the cult of people acting and consuming without considering nature encourages the development of an economy that is not in harmony with ecological principles. Equally important are the tools that can be used to prevent environmental damage, preventive measures and education. These are the priorities that need to be declared globally, e.g. by the UN, regionally, e.g. as objectives of the European Green Deal, and nationally through the adoption of strategic frameworks for climate neutrality and climate resilience. However, the authors want to put more emphasis on the micro level – each person, each organisation and their actions in the context of plastic use. The organisation selected was Tupperware (hereinafter TW), a customer-oriented and environmentally friendly company operating in 70 countries. The present research aims to identify, based on a case study, whether the company's activities are educational and have an impact on shopping habits and consumer behaviour with regard to the use of plastic tableware.

MATERIALS AND METHODS

A qualitative research strategy based on qualitative data collection and analysis was applied to describe the system TW has put in place to reduce waste and educate people to mitigate climate change. A general-to-specific approach was applied to describe plastic pollution and test available data, concepts and models in the context of TW's activities. The research employed deductive qualitative content analysis, which allowed us to put an emphasis on information and an integrated perspective in the specific context and also to interpret the specific problem in a subjective yet scientific way. To identify subjective opinions rather than standard reactions, semi-structured interviews were conducted with two target groups: customers and salespersons. The principles of purposefulness and accessibility were applied in sampling. The interviews were conducted with the informants who agreed to cooperate during the research period in September 2024. The case study involved semi-structured interviews with salespersons from three distribution outlets in Latvia and TW customers. After 28 interviews with customers and 12 interviews with salespersons, no significant differences in the responses were identified, and there was no need to continue the interviews. The informants were female, aged 20-65, permanent TW customers (5-25 years of shopping experience) and TW salespersons (3-17 years of job experience).

RESULTS AND DISCUSSION

The abundance of plastic waste on land and in oceans, seas and freshwaters is one of the most visible aspects of plastic production and use. Of the total plastic items, e.g. bottles and food packaging, found in the European freshwater environment, 40% come from consumers [4]. Single-use plastics have played an important role in limiting the spread of Covid-19. However, the production, consumption and disposal of single-use plastics led to increased environmental and climate impacts, air pollution and greenhouse gas emissions, waste and littering. Nevertheless, the EU Single-Use Plastics Directive accepts

the use of single-use plastics in cases the cleanliness of reusable products cannot be guaranteed [4]. However, this should not be extended to households. Unfortunately, research studies indicate that, overall, human needs are not yet in harmony with ecological principles. Every year, approximately 40 billion plastic forks, spoons and knives are used and thrown away. For example, in Latvia it is illegal to sell single-use plastic tableware, which often appears on the shelves as "reusable" [5].

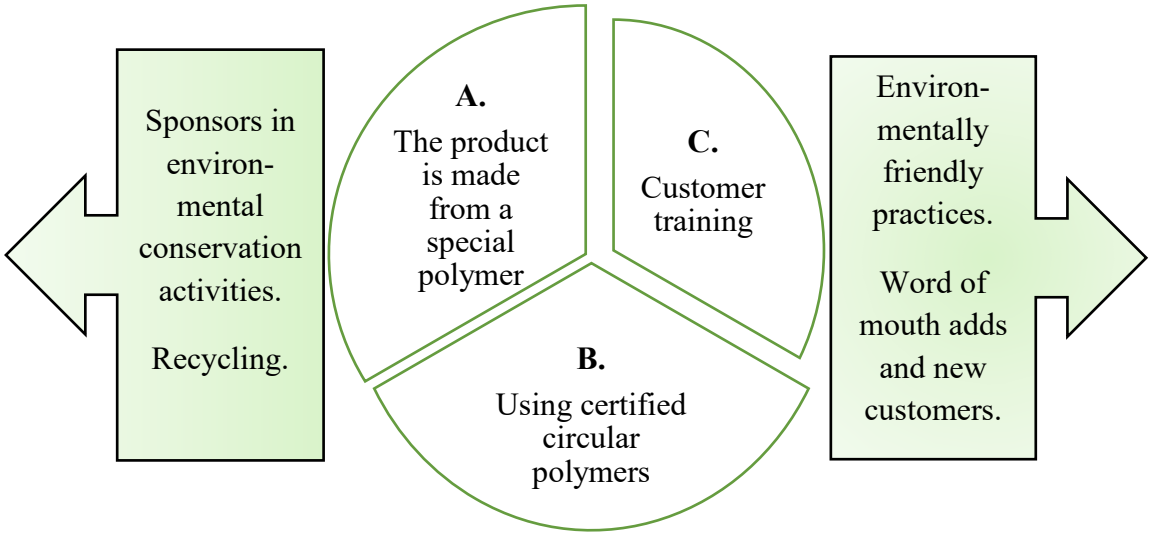
European countries implement various practices to reduce the use of plastic products. For example, France has banned plastic packaging for some fruits and vegetables as well as their use at public events. The deposit system is growing in popularity; under the system, for example, an individual can buy a reusable cup from a seller and then return it for a refund. The system is in place in Switzerland and often at events in Latvia. Reusable tableware is offered to consumers, i.e. large café chains offer discounts to customers who use their own personal cups. In Latvia, petrol stations and retail chains also offer a discount on coffee if it is refilled in a takeaway thermal mug [5].

In Europe and in Latvia, public and non-governmental organisations, as well as private companies, are actively involved in educating the public about the circular economy, waste sorting and the Green Deal. The Ministry of Smart Administration and Regional Development in Latvia is the leading public authority in environmental protection and monitoring. In the private sector, the organization Latvijas Zaļais punkts (Latvian Green point) operates as a producer responsibility scheme managing the recycling of packaging waste. One of the objectives of Latvijas Zaļais punkts is to educate the population about resource efficiency through various educational campaigns [6]. Unfortunately, some research studies conducted in recent years found that the campaigns held both on waste sorting and on informing the population about resource efficiency and the circular economy were insufficient. A research study conducted in 2023 by Getliņi EKO Ltd, one of the largest and most modern waste management companies in the Baltics, concluded that the majority of the respondents (63%) who did not pay attention to waste reduction on a daily basis, **did not see the motivation** for it, did not want to change their habits or found it burdensome. A third (35%) who did not think about reducing waste **lacked practical advice** [7].

Regarding this situation and what is needed to change the public's habits without sacrificing the convenience of everyday life, the authors believe it is important to understand both the nature of the circular economy and the possible alternatives to plastic tableware. An important idea in ecological modernisation theory is the ecological transition of industrialism – the large-scale restructuring of production and consumption cycles through the use of new, sophisticated, clean technologies and efficient environmental clean-up processes and environmentally friendly solutions. The circular economy is a new way forward in this context. Under the linear economy, we source raw materials, produce things and then throw them away, thus damaging the environment, whereas under the circular economy, we try to use resources in ways that do not harm the environment: sorting, recycling and repairing so that they last longer. The case study revealed that according to the objectives set by the European Union to promote the circular economy, the amount of waste to be landfilled must be reduced to 10% by 2035 [8]. This means that at the national level, some ways will have to be found to reduce the waste amount, and everyone in Latvia can contribute to it. Our consumer culture is a characteristic of our times, the consequences of which can change the culture of every individual – every individual's actions, performance, thinking, ideas, behaviour, values

and attitudes towards the natural environment. Public information campaigns are a powerful tool to encourage the public to listen and learn. It could be compared to "collective information programming", which can influence various groups through mass media and advertising, but measuring this impact would also require regular research.

Nevertheless, producer responsibility is also important. Producers of goods and service providers are increasingly becoming more "green", taking care of ecology and the environment, and generating less waste in their various production processes. For private sector organisations, the culture is market-oriented – suppliers, customers and competitors – where competitiveness (including among employees), productivity, success are key values. Organisations are results-oriented. Customer relationship management, if implemented and enforced correctly, can help to achieve a number of important objectives, including education on how to reduce plastic waste. To describe the private sector system for reducing waste and educating the public about climate change mitigation, the research targeted a company that manufactures and markets plastic products in particular, but positions itself externally as environmentally friendly – Tupperware –, which is a customer-oriented company founded in 1946 in the USA.



Source: authors' construction based on Tupperware documents.

Fig. 1 Tupperware as the basic elements of an environmentally friendly system.

A and **B** represent cooperation between the company and scientists working to find solutions to reduce the negative health impacts of plastics. The products are made from a special polymer free of polyvinyl chloride, bisphenol A, artificial colours and phthalates. As regards element B, the company uses certified circular polymers produced by SABIC, a world leader in the chemical industry. This innovative material is made from a raw material known as TACOIL, a patented product made by recycling mixed plastic waste, which is broken down to its original state and turned into a high-quality plastic that maintains purity and meets quality and safety standards. The third element of the TW system, **C**, involves working with customers, as the salespersons also give advice on how to change habits in food shopping and storage, as well as how everyone can reduce plastic waste by consuming reusable tableware instead of disposables. Figure 1 also includes the company's activities in the external environment, allocating profits to various programmes and support activities. For example, from 2020 to 2023, TW was a major

sponsor for the resilience and sustainability pillar of the National Park Foundation, which resulted in the installation of 70 water refilling stations in seven national parks across the USA, thereby helping to divert nearly 11 million single-use plastic bottles from landfills each year [9]. In addition, TW customers appreciated an opportunity to return their obsolete products to the company for recycling. The main focus of customer relationship management was placed on increasing the value of the company by acquiring the right customers and developing and maintaining mutually beneficial relationships with them. This in turn could be achieved by identifying customers, differentiating them by value and needs, describing the customer interaction situations and creating a personalised approach and offer for each customer. The responses to 15 questions by TW **customers** were systematised, thereby identifying three kinds of **opinions on plastic waste**.

1. Knowledge and new knowledge.

Every interviewee knew about an increase in waste and the need to sort the waste. The main sources of information were the Internet, TV, radio, local authorities and newsletters. In their opinion, waste sorting was necessary and beneficial, and some individuals were motivated by "*... a decrease or no increase in costs by introducing waste sorting into their lives*". The availability of clear and understandable information on the benefits of waste sorting was very important, and it was also important to emphasise this problem in some situations. All but two customers had heard this point in their meetings with TW salespersons: "*Using Tupperware products reduces plastic waste because they are reusable, for example, when buying cream, milk or bulk products in the shop*". The salespersons' advice helps to understand the role of reusable plastics in reducing waste: "*...I hope we are keeping ourselves from drowning in our own waste*". The relationship between consumer behaviour and consumption, as well as environmental problems and individual solutions, are important and consequential. "*The amount of resources needed to produce new products is decreasing...*". Both the consumers and salespersons appreciated the tableware causing the least possible environmental damage. "*We do not use single-use tableware in our daily lives. Rarely at garden festivals, but only paper plates and glasses*". "*Rarely... if we have dinner at McDonalds, which is only about three times a year*". New knowledge and ethical issues related to consumption are also becoming important at an individual level.

2. Shopping habits in the context of plastic tableware.

Shopping habits are a key social phenomenon, reflecting societal values, economic trends and individual preferences. Social norms and values can also contribute to certain consumption paradigms. The customer responses revealed two trends:

- **There have been no major changes in habits**, as the plastic tableware was "*not used in principle*", yet the TW products were bought because they could be reused: "*... the tableware was long-lasting, both for microwaves and for storing products in the fridge and freezer...*".
- **The habits towards plastic tableware have changed**, as "*... Tupperware product quality is what drives me to buy it*", "*I am more focused on the ecological aspects and functionality, which also saves money in the long term*". Shopping can also be a collective activity that shapes group identity. Various social groups might share common values and use certain brands or products to express their belonging and loyalty to that group. Symbolic capital theory holds that individuals consume products and brands as symbolic objects to express their identity and social status.

For example, purchasing TW products can symbolise attitudes towards the use of plastic in everyday life. The interviews revealed that organisational culture and customer management at TW were indirectly oriented towards promoting environmentally friendly consumption.

3. Actions regarding the use of plastic tableware.

After analysing the behaviour of customers in the responses regarding the use of plastic tableware, two more phenomena could be distinguished:

- **Change in daily habits.** It was characterised by simple activities directly linked to the use of plastic tableware. If the initial associations with plastics were not environmentally friendly, the customers' daily habits revealed the opposite. If the product was of good quality, it could be used for a long time: "*I have been using it for 20 years and not a single tableware item has been thrown away*". The daily habits when leaving the home: "*Tupperware bottles are highly respected in our home and used by the whole family. We practically do not buy water from the shop anymore, but pour water at home or in public places, at work, for the children at school, when travelling in airports, so we save money both by not spending it on water and by not having empty plastic bottles*", "*...I always buy my coffee in my own mug*". Anthropologist Daniel Miller, researching individuals' relationships with objects of various materials, from everyday household items to art objects, pointed out that the objects influenced our way of life and our daily routines. Goods are not simply practical objects but also symbols and forms of expression [10].
- **Transferring one's own knowledge to others.** All the customers interviewed directly and indirectly pass on their knowledge about using plastic tableware in an environmentally friendly way to others both through talking about the benefits of the tableware and by giving it as a gift: "*I have recommended plastic tableware, emphasising the quality, eco-friendly material and functionality of it, also as a way to save money in the long term*". Direct communication dominated when transferring this knowledge. This reinforces the role of customers in the structure of Tupperware's environmentally friendly system (Figure 1). The interviews also confirmed that organisational culture and customer management at TW were indirectly oriented towards promoting environmentally friendly consumption. As early as 1970, French sociologist and philosopher Jean Baudrillard identified how the consumer society contributed to the development of a commodity and brand culture and how individuals' identity was shaped and expressed through consumption. Individuals are fully involved in the consumption of goods, and this has become the main way in which they express their social position, personality and identity [11]. Half a century later, we still consider the way how to reduce consumption and plastic waste, and recognisable brands are also engaged in such activities.

The salespersons were an important element at TW. A total of 12 salespersons responded to the interviews. The salespersons educated their customers in the following areas in the context of reducing plastic waste:

1) the role of quality and sustainable plastics for environmental protection,
2) the various types of plastics and their harmful effects on health,
3) the advantages of reusable tableware,

4) the reduction of food waste and plastic waste by consuming reusable tableware produced by TW,
5) the possibility of returning used and damaged tableware to TW for recycling,
6) climate change problems.

There were slight inconsistencies between the message delivered by the salesperson and the way it was perceived by the customer. The customers interviewed did not emphasise the knowledge acquired about differences between the types of plastics, food waste reduction and climate change. The customers better perceived the benefits of tableware and the reduction of plastic waste in their daily practices. However, a salesperson's job is to sell and the producer's goal is to make a profit. Under this system, customer relationship management aims to attract and retain profitable customers by initiating and improving relationships with them, to increase customer satisfaction, as well as to increase customer loyalty. The present research did not focus on the quantitative performance of TW: the number of customers and the number of salespersons, as the aim was to describe the system established by a plastic company to reduce waste and educate the public to mitigate climate change. If we assume that each salesperson has 100 customers and 80 of them have changed their plastic tableware consumption habits, this number is in the millions worldwide. The organisational culture of TW acts as a framework for any organisation's strategy, which includes not only the functions of global culture in the environmental context but also the behavioural patterns shaping the organisation's specific activities with its customers, with environmental objectives running parallel to profit.

CONCLUSION

1. The research results revealed that Tupperware's activities were not only focused on marketing its products but also on educating the public and having an impact on shopping habits and consumer behaviour with regard to the use of plastic tableware.
2. Tupperware demonstrates itself as a strategist and long-term planner through its environmentally friendly way of thinking. Its business activities are planned to minimise environmental damage and make the most efficient use of resources. The principles of sustainable development are based on economic growth and also on increasing the level of earnings for its salespersons in several countries, while respecting social factors and caring for the quality of the environment.
3. Today, the need to compete with each other is being challenged, and each economic entity needs to use its strengths and cooperate with others to achieve its goals. To add value to goods and services, entrepreneurs must also innovate in the field of environmental protection. The Tupperware case study in Latvia revealed that even a single company's cooperation system aimed at environmental protection can contribute to, for example, the number of individuals who change their practices to reduce plastic waste.

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ARTIFICIAL INTELLIGENCE USAGE POSSIBILITIES FOR ENVIRONMENTAL MONITORING

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ABSTRACT

Designing the multitude of technological applications in various activity fields of human society has without question had the direct result of increasing humanity’s quality of life. Nevertheless, besides the positive intended impact of technological advance several negative effects have emerged, especially regarding environmental pollution on different levels. In this regard a lot of debates have primarily started on a scientific level with the goal of finding the best strategies for trying to solve complex created situations and to succeed in keeping good environmental quality. After understanding that technological advance could also be connected to undesired impact, many debates have been carried out, resulting that the concept of “sustainable development” has been raised as a potential solution. It was clearly pointed out that registered advances in technical, economic, as well as environmental and social fields shall be kept by mitigating emerging environmental challenges. In this regard, technology can play an important role by the usage of Artificial Intelligence (AI) to successfully emphasize and thus mitigate various potential impacts of technological applications especially on the environmental field. Registered advance in the field of Artificial Intelligence has pointed out applying possibilities in many fields as well as in the environmental field. Going into details, applying Artificial Intelligence (AI) for environmental monitoring with the help of appropriate weighting strategies represents an innovative scientific approach, bringing advance in the environmental protection field and, in doing so, contributing to sustainability of human society.
Keywords: technological advance, artificial intelligence, environmental monitoring, environmental sensors, sustainability, holistic approach.

INTRODUCTION

Concerning currently debated strategies for assuring sustainability of human society has been pointed out several times with various occasions that different fields must be simultaneously considered as technical, economic, environmental and social ones, playing a main role regarding operationalizing sustainability on different levels [5, 12]. To get desired future development not only technical and economic aspects have to be considered, but also environmental, social, political and cultural ones connected to available infrastructure. This request is imposing the vision of shaping in the future all over the world the necessary technical infrastructure and also the appropriate mentality for living in the so-called ”sustainable city” with low environmental impacts [9]. Therefore, a while ago debate began on scientific, political and social levels for finding best solutions for assuring low environmental impacts in cities, which could be

applicable on global level for different countries by paying attention to regional differences [1, 9].

Because of the worldwide debates regarding the most appropriate concept assuring high living conditions but considering regional differences the concept of sustainable development has been defined, firstly in the widely known Brundtland Report of the World Commission on Environment and Development [3]. After this several debates have followed, for instance in 1992 during the Conference for Environment and Development in Rio de Janeiro that have as a result the much discussed document „Agenda 21“ [1]. It was more than clear that there is a need to simultaneously consider several fields to succeed in the successful operationalization of sustainable development on different levels, on global, national, regional as well as on a local level [9]. The vision is to find best strategies for assuring especially the local sustainability, by taking into account the multitude of aspects related to the technological, economic and social activities, where land use planning strategies do play a considerable role [5].

After the release of the Brundtland Report in 1987 defining for the first time the concept of sustainable development [8], ongoing debates followed 1992 during the Conference for Environment and Development in Rio de Janeiro, that ended with adopting the much discussed document called „Agenda 21“ [1, 5, 8]. Direct consequence after all these events represented the fact that it became more than clear the need for simultaneous consideration of several aspects from diverse fields for successfully succeeding sustainable development operationalization on different levels, as on global, national, regional as well as on local level [5, 8]. The vision is to find the best strategies to assure local sustainability by considering several aspects related to technological, economic, and social activities on a local and regional level [10].

In this context technology plays a main role concerning operationalizing sustainability especially related to environmental aspects starting with environmental monitoring on different levels. Concerning usage possibilities of Artificial Intelligence (AI) to successfully emphasize potential environmental impacts of applying diverse technological applications especially the field of environmental monitoring must be pointed out in this context. Registered progress in the field of Artificial Intelligence has supported applying odds in many fields, inclusively in the environmental field [11]. Observing the existing situation in a very detailed manner, it follows that applying Artificial Intelligence (AI) for environmental monitoring needs appropriate sensors in this regard. Applying AI in environmental field represents an innovative scientific approach, succeeding in allowing progress in environmental field by mitigating environmental impacts because of applying manner of various technological applications.

MATERIALS AND METHODS

To search manners of applying AI in the environmental field, there is a need to clearly state artificial intelligence fields. In this regard related to applying odds of AI in environmental monitoring, following fields of artificial intelligence should be especially considered [2]:

- Robotics
- Machine Learning
- Computer Vision

- Neural Network
- Expert System
- Fuzzy Logic
- Natural Language processing
- Genetic Algorithms
- Cognitive Computing
- Speech Recognition

1. Neural Network

A neural network, also called artificial neural network, represents a model inspired by the structure of biological neural networks in animal brains. As emphasized in Figure 1, an artificial neural network represents an interconnected group of nodes. In this network each circular node represents an artificial neuron, and an arrow represents a connection from the output of one artificial neuron to the input of another one [2,4].

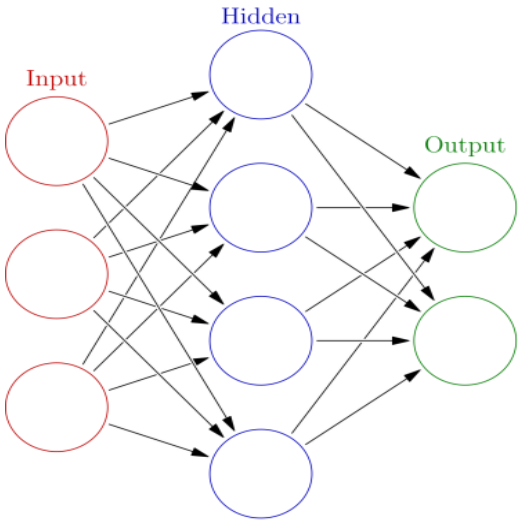


Figure 1. Artificial neural network.

Artificial neural networks can be applied for approaching various tasks, such as adaptive control and predictive modelling as well as releasing challenges in the field of AI. These neural networks can learn from experience and can derive conclusions from a complex and seemingly unrelated set of information. Related to neural networks it is to be mentioned that they have to be trained by using the so-called *empirical risk minimization*. This method is based on the idea of optimizing the network's parameters to minimize the difference, or empirical risk, between the predicted output and the actual target values in a given dataset. For such networks the training phase is very relevant. During the training phase, ANNs learn from labeled training data by iteratively updating their parameters to minimize a defined loss function. The efficiency of designed neural network depends on used training data, what means that the quality of the training data is decisive in this context.

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2. Fuzzy Logic

Fuzzy logic is based on the fact that reality is rather inexact than precise, because in usual cases affirmations have a certain free interpretation domain. Traditional binary logic is part of fuzzy logic as a special case operating only with two values of interpretation. Compared to the well-defined sets of the set theory, real existing sets are rather fuzzy limited, because of uncertainties which appear in usual communication manner. A set is called "fuzzy set" if assignment of one cannot be given to all set members. A fuzzy set is defined by the generalized characteristic function, called the *membership function* μ. This real function can take on any value, but usually it is normalized into the interval [0, 1]. When designing Fuzzy Logic based models it is important to define each variable as a *linguistic variable*. The main difference from variables generally applied for mathematical description of processes which require a precise quantitative presentation of considered aspects is that verbal rules contain fuzzy formulated knowledge, which is generally more intelligible. In addition, linguistically defined variables have a higher aggregated information content, that is why it is more difficult to quantify them, and usual classic mathematical descriptions of such variables bring an information loss [5, 13].

In this context the concept of linguistic variables links descriptions of verbal and therefore fuzzy information with mathematical precision. The values of a linguistic variable are verbal expressions, called *linguistic terms*, for instance *small* or *high*. Contents of linguistic terms are identified with fuzzy sets and assigned to related numerical scales of basic variables by specific membership functions. It follows that fuzzy sets create connections between linguistic expressions and numerical information [6]. To succeed in processing fuzzy formulated knowledge linguistic variables, must be linked by linguistic operators where connecting rules represent the knowledge stored in developed rule-base needed in single steps when operating with fuzzy systems. These are fuzzification, inference and defuzzification as presented in Figure 2, where single steps are emphasized when operating with fuzzy logic applications [5, 7].

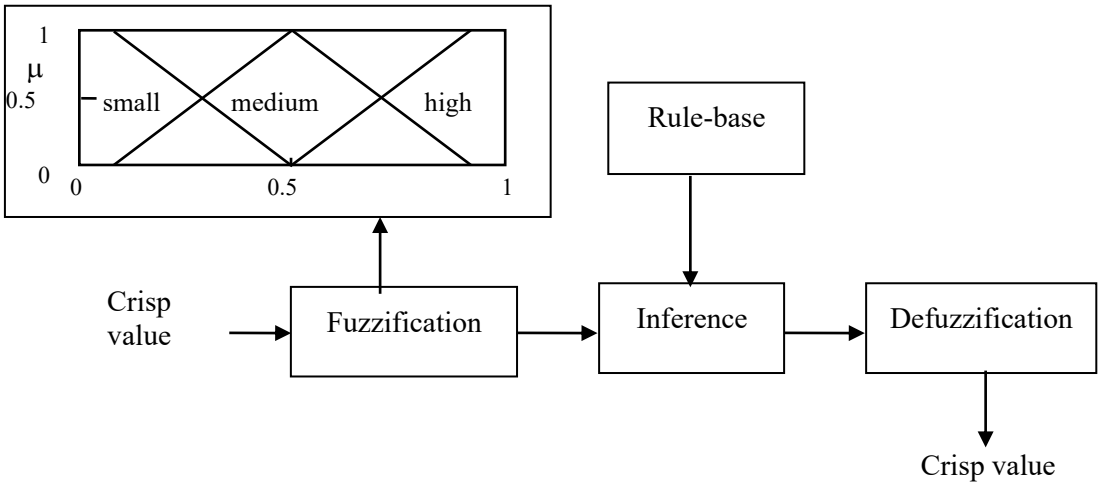


Figure 2. General operational chart by fuzzy logic applications [13].

The fuzzification step is the linguistic interpretation of any crisp input value of a basic variable as pointed out in Figure 2. This means, for determination of membership values of each crisp input to all linguistic terms the basic numerical interval, the number of

linguistic terms and the according verbal expressions of the linguistic variable must be previously established as presented in Figure 2, where there are three linguistic terms. Thereafter, the inference must draw conclusions from the propositions about the knowledge base formulated as IF-THEN-rules. Inference consisting of aggregation of IF-parts of each rule, implication and accumulation of the results of the rules THEN-parts, causes a weighting of each single rule on the total result [7]. For further operational purposes a crisp output value is needed from the resulting membership distribution which is got by determining the center of gravity of the area representing the resulting membership distribution of the participating linguistic terms [7, 13]. This knowledge-based approach using one field of artificial intelligence, namely fuzzy logic, means the methodical attempt to substitute missing or inefficient algorithmic procedures by using human knowledge. Thus, even partially fulfilled conditions result in partially fulfilled conclusions, so these conditions are considered also in the result [5]. By this considering uncertain information in systems modelling by artificial intelligence is assured which encourages applications also in the field of environmental systems [5, 7].

3. Air Pollution Index

The efficient integrating manner of highly aggregated entities by fuzzy logic into mathematical models is emphasized by the Air Pollution Index, API [7]:

$$\mathrm{API}(x,y,z,t) = \frac{1}{\sum_{i=1}^{n} w_i} \cdot \sum_{i=1}^{n} \frac{C_{real,i}(x,y,z,t) \cdot w_i}{C_{ref,i}} \quad (1)$$

where: $C_{real,i}$ - pollutants concentrations at a certain place and time [ppm or mg/m^3];

$C_{ref,i}$ – references values of pollutant concentrations [ppm or mg/m^3];

w_i - weighting coefficients.

The interpretation is that when API = 1 means that pollutants concentrations in the approached system have reached their limits, API > 1 means that concentrations are above the limits and API < 1 means that they are below the limits [5, 7]. Establishing weighting coefficients is challenging because a big amount of knowledge from different fields must be integrated in this process, anyway, using weighting coefficients is emphasizing that the environmental impact of different pollutants is not the same. In this context a fuzzy logic-based model can be used for establishing single weighting coefficients. Basic criteria which determine single values for the weighting coefficients are *impact on health, impact on ecosphere and emitted quantity,* which are defined as linguistic variables. As presented in Figure 3, the way their description influences the values of weighting coefficients is given by the mentioned fuzzy logic-based system [7].

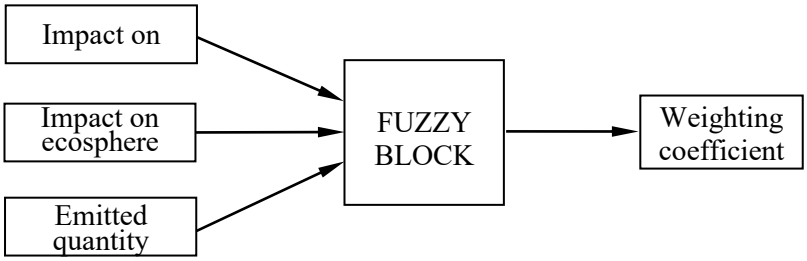


Figure 3. Aggregation level for the weighting coefficient.

Chosen input criteria defined on the interval [0, 1], as stated in Figure 2, are formulated as linguistic variables each with three linguistic terms called: *small, medium* and *high*. The weighting coefficient as output variable has seven linguistic terms, and the connection between all these linguistic terms is given by a rule-base, which has 27 rules in this case [7].

RESULTS

The weighting coefficients for API, which are established with the following input values for the basic criteria are mentioned in Table 1. To establish single input values knowledge regarding the *impact on health* and *on ecosphere* of each considered pollutants was considered [5]. Input values corresponding to the basic criterion *quantity* are related to single reference values of considered pollutants and given as relative values in the interval [0, 1]. The reference values are represented by emissions of CO_2 for each country as being the maximum value of 1 on the interval [0, 1]. In the given example the approached pollutants emissions for different countries are normalized on the interval [0, 1] in dependance of the CO2 emissions in each country [7].

Table 1. Inputs of the basic criteria for the weighting coefficients for API.

	Impact on health	Impact on ecosphere	Emitted quantity				Weighting Coefficients
			B	D	H	PL	
CO_2	0.1	0.95	1.0	1.0	1.0	1.0	0.67
NO_x	0.7	0.6	0.0026	0.0025	0.011	0.0078	0.46
SO_2	0.7	0.5	0.0030	0.0034	0.0027	0.0032	0.42
CO	0.9	0.05	0.079	0.0074	0.018	0.0064	0.33

To point out advantages of using AI in this context of environmental monitoring, the working way of fuzzy logic is emphasized by proposed method which has been applied to some European regions for which needed environmental data had been found [7, 11]. Following this idea in Table 2 the annual average pollutants concentration for 2015 in the approached regions are mentioned for (https://www.eea.europa.eu/en) as well as admissible values of these pollutants (after German standards) and resulting values for the Air Pollution Index, API for n=4.

DISCUSSION

As it can be noticed from Table 2, the values of API in analyzed regions are below the admissible limit value which is API = 1. By this registered advance concerning air quality in some towns such as Budapest or Katowice can be emphasized by mentioned Air Pollution Index.

Table 2. Pollutants concentrations as annual average values [mg/m^3] for some European regions and resulting API by applying the fuzzy logic-based model.

	CO_2 [ppm]	NO_X	SO_2	CO	API
Berlin	350	0.033	0.02	1.1	**0.508**
Budapest (1990)	350	0.028	0.03	8.5	**0.639**
Budapest	350	0.036	0.03	2.8	**0.563**
Frankfurt	350	0.046	0.012	2.3	**0.556**
Katowice (1990)	350	0.080	0.09	7.4	**0.874**
Katowice	350	0.028	0.057	1.15	**0.553**
Krakow	350	0.032	0.03	3.6	**0.565**
Warsaw	350	0.029	0.018	0.92	**0.49**
Admissible limit value	350*	0.08	0.140	10.00	**1.00**

* Not as admissible value in standards but chosen as example by the authors.

It would be interesting to apply this methodology and mentioned Air Pollution Index to other regions too to allow establishing best strategies for environmental monitoring by applying Artificial Intelligence as presented in this scientific contribution [11]. Applying Artificial Intelligence, AI in the field of environmental monitoring allows especially precise forecasts, as well as if needed pollution source detection, and comprehensive air quality monitoring [2, 6].

CONCLUSION

A fuzzy logic-based method as an example of usage possibilities of Artificial Intelligence for environmental monitoring has been presented and debated by the possibility of defining new environmental indicators. Introduced methodology allows defining new procedures by its potential to integrate complexity expressed by linguistic description and terms in the systematic and exact mathematical approach and by this ensures a transparent assessment. An implementation way concerning air quality characterization has been envisaged by presenting the Air Pollution Index API, which is defined as the sum of the weighted relative pollutants concentrations where for establishing the weighting coefficients a fuzzy logic-based approach has been applied. Following the same algorithm other indicators could be defined, environmental as well as social or political ones making advantage by the new possibilities offered by Artificial Intelligence especially Fuzzy Logic for integrating unstructured linguistic characterizations in mathematical models allowing transparent assessment when available knowledge is diffuse, unstructured and disorderly. Several AI applications in environmental monitoring are already known emphasizing in this way the substantial contributions of AI to succeeding in carrying out an effective environmental monitoring and by this environmental management. Technologies based on AI improve processes related to environmental monitoring by enabling more suitable prediction, better understanding, and by this mitigating environmental risks. Nevertheless, applying AI in approaching the full potential of AI is hardly possible although it would be very advantageous because of several challenges especially connected to lack of experts in

the field of AI experts simultaneously having deep knowledge in environmental sector. Even if there are still unsolved challenges, applying possibilities of AI in the field of environmental monitoring are very promising. Considering registered advance in the field of AI, concretely regarding algorithms, data collection techniques, and computing power there is the vision that in the future AI will for sure make possible further improving of precision and efficiency regarding pollution monitoring and management.

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SECTION

ECONOMICS OF SUSTAINABILITY AND ENVIRONMENTAL POLICIES

AN EXPERIMENTAL AUCTION APPROACH TO REDUCING FOOD WASTE: CONSUMER WILLINGNESS TO PAY, PERCEIVED CONTROL, AND PERCEIVED RESPONSIBILITY

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ABSTRACT

Food waste contributes significantly to climate and environmental degradation. According to recent estimates, food loss and waste account for 8–10% of all anthropogenic greenhouse gas emissions. A number of studies have investigated individuals' willingness to pay (WTP) in relation to voluntary certification schemes pertaining to various ethical attributes, including locally grown, fair trade, organic, and so forth. The impact of a voluntary certification scheme about reducing food waste–and the higher price people might be willing to pay for it—have not been thoroughly studied. In order to determine whether participants in the current study (N = 80) would be willing to pay more for bread certified against food waste than for non-certified bread, a non-hypothetical auction was conducted. Furthermore, we investigated the impact of the individual sense of control, which can be defined as either perceived behavioral control or perceived responsibility. Results show that participants are willing to pay more for bread that has been certified to reduce food waste. In addition, perceived behavioral control has a significant positive impact on the premium price for the certified product, whereas perceived responsibility has no effect on it. Results are robust to participants' gender and income. Practical implications related to control-based and responsibility-based communication strategies for reducing food waste are discussed.

Keywords: consumer behavior, sustainability, food psychology, ethical consumerism, green attribute.

INTRODUCTION

According to the Food Waste Index 2024, 13% of food produced for human consumption is lost during the supply chain's production, postharvest, and processing phases, while the remaining 19% is lost in the retail, food service, and household tiers [1]. This indicates that a significant portion of all food that is accessible for human consumption is lost or wasted. Twenty percent of food production in the European Union, or 88 million tons of food, is wasted annually, with households accounting for 53 percent of this waste. The European Union loses 143 billion euros every year as a result of this [2]. Food waste has detrimental effects on the environment and food security in addition to the financial costs associated with the products' value and those associated with storage and landfill disposal. Food loss and waste worsen the adverse effects of food production on the environment. The global food system produces

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greenhouse gas emissions that fuel global warming and demands a great deal of resources, including land, water, and fossil fuels [3]. For these reasons, food waste contributes significantly to climate and environmental degradation by wasting important and valuable resources that are used to provide food to consumers and by producing additional greenhouse gas emissions during the food waste treatment process [4-5]. According to recent estimates, food loss and waste account for 8–10% of all anthropogenic greenhouse gas emissions [1]. Additionally, millions of people worldwide suffer from hunger or malnutrition despite the fact that tons of suitable and healthful food are wasted [6]. The paradoxical relationship between food waste and food security is becoming more widely recognized; the amount of food wasted could be used to feed the hungry and solve the world's growing food demand [7]. Therefore, ensuring food security involves more than just raising production; it also takes into account the efficiency of the food system, which could be enhanced by lowering food waste. The World Health Organization refers to this as "the double burden" of global food insecurity [8], as over 1 billion people go hungry and roughly the same number are overweight. This clearly shows that the current food system is not sustainable. A specific target for food waste reduction, aiming to cut per-capita global food waste at the retail and consumer levels in half, is part of the 2030 Agenda for Sustainable Development, which was adopted by the UN on September 25, 2015. This goal is part of the Sustainable Development Goal 12: "Ensure sustainable consumption and production patterns." Furthermore, cutting down on food waste is essential to achieving the social, economic, and environmental aspects of the Sustainable Development Goals (SDGs), such as Zero Hunger (SDG 2), Sustainable Cities (SDG 11), and Climate Action (SDG 13).

Scientific interest in minimizing food waste has steadily grown in recent years. To maximize resource use and promote food system efficiency, efforts have been made to find ways to minimize food loss and waste during the production and processing stages [9]. Even though waste happens at every stage of the food supply chain, it mostly occurs at the retail and final consumption stages, particularly at the household level. In order to prevent and minimize food waste overall, household food waste must be addressed. A hierarchy of waste management priorities is established by the Waste Framework Directive, which was adopted by the European Union in 2011. These principles include (a) prevention, (b) re-use, (c) recycling, (d) other recovery, and (e) disposal. The most effective course of action is to prevent waste generation; this is followed immediately by re-use, which is the second-best option, recycling, and other recovery methods. In contrast to other options, this model suggests that preventing food waste is the best strategy to lessen the impact on the environment and society [10].

Research provided insight into the primary factors that account for food waste at both the individual and household levels. Several studies indicate that household food-related routines significantly influence the quantity and probability of food waste [11]. There is widespread agreement that household food waste results from various behaviors that elevate the likelihood of food being wasted [12], including practices and habits related to planning, shopping, storage, preparation, and consumption of food [13]. Certain personal abilities can mitigate food waste, such as meal planning and estimating food safety risks. Researchers also found that individuals frequently underestimate both global and personal food waste levels, along with their adverse effects [14]. Nevertheless, some studies indicate that increased awareness does not necessarily result

in reduced food waste. Economic considerations often outweigh social or environmental concerns [15], and heightened awareness of the negative impacts of food waste does not consistently correlate with lower waste levels [16].

Reducing food waste in households is a complex and challenging issue that involves multiple disciplinary fields and is influenced by institutional, social, cultural, economic, and individual factors [11]. The market as a whole, as well as the food market and businesses, are greatly impacted by the decisions made by consumers [17]. In this context, researchers and businesses have expressed a great deal of interest in people's willingness to pay (WTP) for food that has labeling schemes associated with "green" attributes like organic, fair trade, locally grown, and so on. Conversely, there is a dearth of applications of this strategy and little research on consumers' willingness to pay for certification programs based on food waste prevention. People's willingness to pay more for a voluntary certification about waste containment has been studied by La Barbera and colleagues [18]. They tested three levels of anti-waste certifications—waste contained at 10%, 5%, and 1%, respectively—through experimental auctions. According to the results, people are willing to pay more for products that are certified to prevent food waste than for those that are not. Furthermore, as the anti-waste threshold rises, the impact of anti-waste certification on premium price tends to increase and is more pronounced for participants who have a more pro-environmental attitude. Del Giudice and colleagues [19] focused on communication strategies and found that when food waste is presented in terms of carbon footprint rather than water footprint, consumers are more willing to pay a higher price for retailers' voluntary certification regarding waste reduction.

Investigating the significance and magnitude of the premium price individuals are willing to pay for a food product that has been certified against waste in comparison to one that is not, as well as the effect of personal sense of control—defined as either perceived behavioral control or perceived responsibility—on this premium price were the goals of the current study. The importance of control over food waste has been shown in earlier studies [20], but the distinct effects of perceived behavioral control and perceived responsibility have never been investigated. Here, perceived behavioral control refers to a person's conviction that they can carry out a behavior, like cutting down on food waste. Instead, perceived responsibility is the individual's belief that they bear some direct or indirect responsibility for a particular circumstance or behavior.

MATERIALS AND METHODS

An experimental auction was performed with 80 university students to evaluate their willingness to pay (WTP) for food characterized by a voluntary certification scheme regarding food waste prevention. Consistent with prior studies by La Barbera et al. [18] and Del Giudice et al. [19], two distinct products were presented in the auctions: one baguette featured a label detailing ingredients, additives, and weight, while the other baguette bore an identical label, supplemented by a voluntary certification ensuring that waste during distribution and sale is limited to 1%. The auction was non-hypothetical and subjects received an endowment to participate. The experimental design was within-subject: each participant was requested to bid on both products. One participant failed to complete the experimental procedure, leaving a final sample of N = 79 (51 females; M_{age} 24.52).

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Five items have been used to measure perceived behavioural control (control) and perceived responsibility (responsibility). Participants indicated their agreement or disagreement on a scale from 1 to 7. An exploratory factor analysis was conducted on the five items (extraction method: Maximum Likelihood; rotation method: Oblimin with Kaiser Normalization), yielding two factors with eigenvalue > 1 corresponding to the theoretically expected dimensions (control and responsibility). Table 1 reports the items and their loadings on the two factors, that cumulatively explain a substantive proportion in total variance equal to 59.25%. Hence, the items corresponding to control and responsibility were averaged and recoded so that higher values indicate higher control and higher responsibility. Both subscales proved reliable: Control, Spearman-Brown rho = .61; Responsibility, Cronbach alpha = .79.

Table 1. Exploratory factor analysis.

	Control	Responsibility
I could reduce waste, but it would be too difficult to actually implement the needed behaviors	.992	
Even if I made an effort, I would not be able to waste less food	.457	
I feel personally responsible for food waste		.830
I contribute to food waste, so I am responsible		.758
I feel at least co-responsible for the waste of food		.670

RESULTS

Participants are willing to pay more for bread certified against food waste (M = 0.97 €; SD = 0.39), compared to non-certified bread (M = 0.67 €; SD = 0.37), with a significant average premium price – that is, the mean difference between WTP for certified product and WTP for non-certified product – corresponding to 0.30 €, t (78) = 6.21, p < .001. The effect size of the mean difference is large, Cohen's d = .70, CI [.451, .943].

In order to investigate the effect of control and responsibility, premium price was regressed on these two factors. Gender and income were entered in the regression model as statistical controls. Results of the regression model, R^2 = .14; F (4, 75) = 2.95, p = .025, showed that premium price for the certified product was significantly influenced by perceived behavioral control, whereas it was not significantly associated with perceived responsibility. Results are robust as regards participants' income and gender. Table 2 provides a summary of the regression model results.

Table 2. Multiple linear regression model (OLS) of the premium price for anti-waste certified food product.

Factor	β	*t*	*p*
Responsibility	.036	.317	.752
Control	.247	2.173	.033
Income	-.072	-.665	.508
Gender	.267	2.429	.018

DISCUSSION

Results show that individuals are willing to pay a substantive premium price for a certified product against food waste. The premium price, calculated as the mean difference between WTP for certified product and WTP for non-certified product, proved significant and the effect size of the mean difference is large. In addition, results indicate that those with elevated perceived behavioral control are more inclined to engage in behaviors that may mitigate food waste, such as paying a premium price for foods with anti-waste certification. Promoting a sense of responsibility about the problem of food waste may not provide the intended outcome.

The different impact of control and responsibility may be explained by the varying feelings and motives at play. Perceived responsibility may amplify emotions of guilt and shame that could not result in behavioral implementation, particularly if people feel incapable of mitigating food waste. Conversely, perceived behavioral control bolsters self-confidence, enabling people to undertake activities that mitigate food waste. Consequently, to mitigate household food waste, institutional and political measures should focus on people' perceived control rather than their sense of responsibility. For instance, offering pragmatic guidance to mitigate food waste at home (a control-oriented approach) may be more successful than just enhancing knowledge about the volume of waste (a responsibility-oriented approach), which may fail to encourage individuals to reduce food waste.

CONCLUSION

Several studies have shown that individuals are willing to pay a premium price for anti-waste certifications. Our study supports this idea with new evidence, also providing for the first time a formal test of the effect size of this premium price, which is significant and large in our study. Certification schemes are an underexplored and poorly applied paradigm; nevertheless, they seem promising in preventing food waste, similar to other certifications related to ethical consumerism that are more exploited indeed. Based on available empirical evidence, retailers may feel secure in the knowledge that food waste prevention strategies—such as voluntary certification schemes against food waste—will

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be well received by customers, particularly the growing number of environmentally conscious consumers in developed countries.

The study has been conducted in Italy with a convenience sample; therefore, results should be interpreted with caution, and further research involving cross-national samples is needed for the generalization of results. In addition, the post-hoc speculations we provided while discussing results need to be empirically tested by future research, that could fruitfully investigate emotional and motivational mediators of the anti-waste certification effect on individuals' WTP, as well as the effects of different types of communications based on control or responsibility.

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NATURAL RESOURCE MANAGEMENT IN THE CONTEXT OF REGIONAL DEVELOPMENT

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ABSTRACT

Natural resource management plays a crucial role in regional development as it affects the social, economic and environmental aspects of the region. Effective management of natural resources can contribute to the sustainable development of a region by ensuring the long-term availability of resources and by protecting the environment. An important aspect is the promotion of sustainable practices in the use of natural resources. Sustainable tourism practices are needed that minimize the impact on natural resources while generating economic benefits for the region. Effective management of natural resources in the context of regional development also requires strong commitment and cooperation of stakeholders. This includes working with local communities, industry stakeholders and other stakeholders to ensure that their needs and concerns are taken into account in decision-making processes. It also involves fostering partnerships and collaborations between different stakeholders to promote sustainable practices and address common challenges. Natural resource management is a critical component of regional development as it affects the long-term sustainability and well-being of the region. By promoting sustainable practices and engaging with stakeholders, politicians and other stakeholders can ensure that natural resources are used in a responsible and equitable manner, contributing to the overall development of the region. Various environmental and sustainable development policies have been adopted in the EU and various programs are being implemented to improve the management of natural resources. The purpose of the study is to identify 10 concrete steps that will lead to integrated environmental management in the context of regional development. The goal is to achieve a balanced and sustainable regional development consistent with the protection of natural resources and their management. These initiatives include the development of protected areas, reforestation programs, sustainable agriculture practices and the promotion of renewable energy sources. One of the main challenges facing natural resource management is coordination and cooperation between the various stakeholders. Effective management of natural resources requires the participation of local communities, government agencies, businesses and civil society organizations.

Keywords: Natural resource management, regional development, sustainable tourism, economic benefits

INTRODUCTION

Regional development is a complex and multifaceted process that involves the strategic allocation and utilization of natural resources to foster economic growth, social well-being, and environmental sustainability. Effective natural resource management is

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essential in this context, as it enables regions to capitalize on their comparative advantages, reduce development gaps, and ensure the long-term viability of their resource base [1]. Natural resource management plays a crucial role in regional development as it affects the social, economic and environmental aspects of the region. Effective management of natural resources can contribute to the sustainable development of a region by ensuring the long-term availability of resources and by protecting the environment. An important aspect is the promotion of sustainable practices in the use of natural resources. Sustainable tourism practices are needed that minimize the impact on natural resources while generating economic benefits for the region. Natural resource governance is a concept that has become embedded in the 21st century discourse on economic development. It is often used interchangeably with natural resource management, when in fact the two concepts are distinct but complementary: i.e. natural resource management deals with the interactions between humans and the natural environment, while natural resource governance addresses the systems and institutions that determine these interactions [2].

The arrangement of environmental permits in natural resource management is a critical component of this process, as it aims to prevent environmental damage and promote sustainable development [3]. Sustainable development, defined as "the development that constitutes meeting needs of the current generation without compromising the ability of meeting needs of future generations," is a supreme long-term goal that must be at the forefront of regional development strategies. The growth of the world economy and the growing population of the world mean that the natural resources of the planet are in the process of being rapidly depleted. This largely applies to different regions of the world where the population is growing at a faster rate than others. Resources such as water, soil, clean air and ecosystem services are vital to health and quality of life, but they are only available in limited quantities. Increasing competition for some resources will create shortages and increase prices, which will affect the regional economy. At a regional level, resources must be managed more efficiently throughout their entire life cycle — from extraction, transport, processing and consumption to waste disposal.

The management of natural resources is essential for the sustainable development of regions. Natural resources, including water, forests, minerals, and energy sources, are a major factor in the economic and social well-being of a region. At the same time, their irrational use can lead to serious environmental and economic problems. Therefore, the integrated and sustainable management of these resources is the key to the long-term stability and prosperity of the regions.

The purpose of the study is to identify 10 concrete steps that will lead to integrated environmental management in the context of regional development. The goal is to achieve a balanced and sustainable regional development consistent with the protection of natural resources and their management. Sustainable utilization of natural resources is essential for achieving this objective, as it enables regions to reconcile the often conflicting aims of economic development and ecological sustenance [4]. This involves careful planning, coordinating and assessing actions at the regional scale, which is recognized as a crucial level of governance for promoting sustainable development [5].

The research methodology is based on the use of general scientific (scientific abstraction, unity of historical and logical, analysis and synthesis, induction and

deduction, methods of comparison and analogy) and special methods of knowledge (indicative method, method of expert assessments).

Effective management of natural resources in the context of regional development also requires strong commitment and cooperation of stakeholders. This includes working with local communities, industry stakeholders and other stakeholders to ensure that their needs and concerns are taken into account in decision-making processes. It also involves fostering partnerships and collaborations between different stakeholders to promote sustainable practices and address common challenges.

Natural resources are part of the natural ecological system, which has spatial and territorial boundaries that do not coincide with the borders of states. Transboundary natural resources - water bodies, mineral deposits, etc., have a special status, since they are located on the territory of two or more states. One of the mechanisms for regulating the use and protection of natural resources in transboundary territories is bilateral and multilateral international cooperation.

Natural resource management is a critical component of regional development as it affects the long-term sustainability and well-being of the region. By promoting sustainable practices and engaging with stakeholders, politicians and other stakeholders can ensure that natural resources are used in a responsible and equitable manner, contributing to the overall development of the region. Various environmental and sustainable development policies have been adopted in the EU and various programs are being implemented to improve the management of natural resources.

The presence of significant reserves of natural resources creates serious potential advantages over other regions. The characteristics of the main socio-economic problems of the region and the potential for their solution allows us to determine a set of forms and methods for regulating territorial development that can ensure the most efficient use of all types of natural resources, taking into account their specific features.

These initiatives include the development of protected areas, reforestation programs, sustainable agriculture practices and the promotion of renewable energy sources. One of the main challenges facing natural resource management is coordination and cooperation between the various stakeholders. Effective management of natural resources requires the participation of local communities, government agencies, businesses and civil society organizations.

Through analytical thinking so far, we have come to the decision to propose 10 steps to protect and manage our natural resources and integrate them into sustainable regional development:

1. Reduce, reuse and recycle

In the field of regional economic development in economically developed Western European countries, the approach - Reduce, reuse and recycle has been used in recent decades. This is one of the most effective ways to manage waste, and therefore to protect natural resources. Also, this approach is increasingly entering the regional development of countries in Africa. The value of reusing waste is increasingly being seen. Regional development and the circular economy in individual regions implies the reduction of waste to a minimum, as well as the reuse, repair and recycling of materials and products. The transition to a stronger regional circular economy will help protect the environment, increase security of supply of raw materials, support competition, development and growth, and create jobs. The regional circular economy is an

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alternative solution to the current regional linear economy, which is based on the "take, make, use and throw away" mindset. The regional circular economy is a model that is based on the principles of eliminating waste and pollution, preserving products and materials in use, and restoring natural systems.

2. Environmental education

Education and training policies and investments targeting the green and digital transition are key to Europe's future sustainability and prosperity. Illiteracy is one of the factors that promote the destruction of our natural resources. The more people are educated about the usefulness of these natural resources and the need to protect them, the more they will voluntarily do what is necessary to preserve them. Environmental education occupies a central place in the process of change towards sustainable development, incl. and in the development process of the regions. Environmental issues such as climate change threaten our prosperity and regional economic development. Environmental education, as well as education for sustainable development, is based on building awareness of and identification with the environment in which everyone lives. Natural resource management has grown in stature with the increasing concerns stemming from the global problems of climate change, poverty and hunger. Within this context, participatory development and knowledge management have been identified as important factors. In developing countries this raises the issue of indigenous knowledge, which is the knowledge that local people have built up over generations concerning agriculture and the management of local natural resources [6].

3. Environmental volunteering

There are various governmental and non-governmental organizations around the world offering opportunities for volunteering in the conservation and management of natural resources. Nowadays, the management of natural resources, especially through local communities leading regional policies, is impossible without local volunteers. In this way, one can join with the people of one's community to create laws that prohibit the overexploitation of natural resources while supporting sustainable regional development. The basics of environmental volunteering are very clear and precise. The main objective is to establish the need to protect the natural resources and the environment of the whole society. The aim is to disseminate vital information at the regional level for environmental protection. An example of this is the energy and water savings in homes in different settlements - especially in those with shortages.

4. Afforestation and reforestation

Climate mitigation efforts are increasingly involving forests [7]. In particular, forests in developing countries are seen as a key for both sequestering carbon and halting increased emissions from deforestation that threaten to undo achievements in emission reductions [8]. There are also opportunities to help with environmental management. One of them is afforestation. Afforestation is the way to create sustainable and stable green territory. Nature provides the planet's natural capital. Forests, for example, offer a variety of ecosystem goods and services, such as oxygen supply, reduced air pollution, quality water, fertile soil, raw materials, etc. Forests are interconnected with most ecosystem services and are of great importance in the natural cycles essential to life. Forests are valuable ecosystems that are home to much of Europe's biodiversity, and their ecosystem services regionally contribute to our health and well-being by regulating water, providing food, medicine and materials, reducing

and controlling disaster risk, stabilizing soils, control erosion and purify air and water. Forests are a place for recreation, relaxation and learning, as well as providing a livelihood.

5. Effective waste management

The development of regions around the world is always linked to the use of nature's resources. Effective waste management is another very good step in protecting our natural resources. In recent years, attention has focused on the security of supply of vital raw materials. However, waste prevention and management is a major part of the circular regional economy. A large amount of waste is still generated in Europe, although the growth in waste generation has stopped and the trend is to decouple waste generation from economic development. At the same time, waste is increasingly perceived as a valuable resource for the European regional economy. Regional effective waste management is in the direction of zero waste. Globally, the ways to manage waste differ from one country to another. Approximately 14% of the raw materials used by German industries are recovered waste, thus reducing environmental impacts and contributing a share of about 20% based on the German Kyoto agreement on reducing climate emissions [9].

6. Water conservation and management

There is an emerging need for integrating traditional and modern knowledge systems in order to derive maximum potential assistances for addressing concerns such as water conservation and management. If the local and traditional actions and strategies are incorporated and promoted through scientific action plans, the greatest benefits could be derived for addressing major environmental concerns [10]. Globally, there are regions with limited water supplies. One of the steps we can take to conserve natural resources is to make consistent efforts to conserve water. Policies for the protection of water resources are subsequently a valuable source for social and balanced economic development. The creation of regional plans for the protection of water resources is a modern necessity for the development of the territory. The scientists and the policymakers have the responsibility to ensure that the environmental management schemes cover elements that are both culturally relevant and scientifically useful in the context of regional development.

7. Use of renewable energy

With growing concerns about global warming and climate change, there is more and more talk about using renewable energy. On the one hand, the production of renewable energy should be perceived as protecting the environment, and on the other hand, as a contribution to balanced regional development in harmony with nature.

8. Create energy-saving home practices

Home education that includes a good attitude towards nature needs to include actions related to turning off lights when not in use, using energy-saving light bulbs that are energy efficient and also reduce greenhouse gas emissions. Saving energy doesn't just mean saving money. Lower consumption also helps conserve resources and reduce emissions. Even as renewable energy sources increase, a large proportion of private households' needs are still met by fossil fuels such as gas and oil. The problem: raw materials are burned to release the energy they contain. Among other things, it emits carbon dioxide, a greenhouse gas that is partly responsible for climate change. Everyone who saves energy in everyday life also contributes to climate protection.

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9. Composting and mulching

Fertilizing with organic manure is not only beneficial to the person using the compost, but also contributes many benefits to the environment. First of all, organic fertilizer limits harmful greenhouse gas emissions. Organic fertilizer improves soil quality and helps clean up contaminated soils. It also helps control erosion and saves money, as organically fertilized soil reduces water consumption by plants. Compost attracts underground organisms and microorganisms that support plant growth, reducing the need for artificial fertilizers that contain harmful chemicals. This, in turn, contributes to the development of local organic agriculture.

10. Reducing the use of fossil fuel energy

This is related to walking or cycling short distances, as well as using public transport. Using more electric and hybrid vehicles than gasoline ones are also steps we can take to conserve our natural resources. Realizing the ambitious commitments of the 2015 Paris Climate Conference (COP21) will require new ways of meeting human needs previously met by burning fossil fuels. Technological developments will be critical, but so will accelerated adoption of promising low-emission technologies and practices. National commitments will be more achievable if interventions take into account key psychological, social, cultural and organizational factors that influence energy choices, along with factors of an infrastructural, technical and economic nature. Broader engagement of social and behavioural science is needed to identify promising opportunities for reducing fossil fuel consumption [11].

These 10 steps will lead to integrated environmental management. This will make it possible to use the potential of the natural resources of the territory in such a way that the exploitation (mining, extraction) of a certain type of natural resource causes the least damage to other natural resources, and the economic or other activity in general has a minimal impact on environment. Integrated environmental management meets the growing needs of society through resource conservation, rational sustainable use of all natural resources, restoration/reproduction in the interest of public health and socio-economic development of environmental qualities affected by anthropogenic activities.

CONCLUSION

The study of the features of the functioning of regional systems of nature management is necessary for the development of a strategy for a balanced (sustainable) development of the region. The digital transformation of natural resource management has been identified as a priority in the context of pandemic, but it does not exclude physical participation (control) in resource use [12].

For many countries of the world and regions, natural resources are the most important factor in socio-economic development. The role and importance of natural resources in the economy of various territories largely depend on the institutional environment, an important component of which is the resource regime. In the new conditions, in relation to resource regions, it is necessary to focus on aspects of an expanded specific understanding of inclusiveness, which implies the possibility of active participation of regional authorities in the management and regulation of the natural complex, as well as the involvement of a wide range of local communities in the development of the complex: from organizations expressing the interests of indigenous

peoples , to professional communities - industry associations, environmental organizations, representatives of the innovation complex.

In conclusion, natural resource management is a process of planning, organizing, motivating and controlling the use of natural resources in order to achieve the goal of sustainable regional development. Success in changing planning processes and implementing science-informed natural resource management clearly requires transdisciplinary practices. Institutional and governance arrangements that are more accepting of the need for adaptive processes and option assessment tools are needed. This applies both to the planning process and to its implementation [13].

At the present stage of regional development, it is natural resources that play an extremely important strategic role in the regional economy and national security, as well as in individual regions. Therefore, it is quite acceptable to consider natural resource capital as a significant source of income. Proper use of these opportunities, setting reasonable goals make it possible to ensure the accelerated development of such a region.

Regional development can be measured through various indicators, such as the availability and sufficiency of facilities and infrastructure, improvements in public health and education, increased productivity and job opportunities, and enhanced economic access to resources [14]. Information technology can also play a significant role in facilitating coastal and rural development by improving access to production, processing, and marketing factors.

Policymakers and regional authorities must therefore adopt a holistic approach to natural resource management that aligns with the broader goals of regional development. This requires striking a delicate balance between economic, social, and environmental objectives, and leveraging the unique advantages and challenges of each region [15].

Integrated management of natural resources is based on the principles of sustainable use, conservation and restoration of resources. This means that when developing strategies and plans for regional development, not only economic benefits, but also environmental and social aspects should be taken into account. It is important to ensure that resources are used in a way that does not endanger future generations and preserve ecosystems.

DISCUSSION

When we write about natural resource management in the context of regional development, we consider the complex interrelationship between the sustainable use of natural resources and the socio-economic development of specific regions. This topic includes an analysis of how management practices of natural resources such as water, forests, minerals and land affect regional development and how regional policies and strategies affect the availability and quality of these resources. With these 10 steps, we support socio-economic growth and improve living standards in the regions. This includes integrated planning, community participation, effective policies and innovative solutions to balance development and environmental protection. Understanding and addressing the complex interrelationships between natural resources and regional development can lead to long-term prosperity and sustainability for communities and ecosystems.

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CONFISCATION AND SUSTAINABLE AGRICULTURE: LAW ENFORCEMENT AGENCIES AND LOCAL COMMUNITIES IN SOVIET KAZAKHSTAN (1927-1932)

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ABSTRACT

The article investigates the influence of Kazakhstan's law enforcement agencies on local communities in the 1920s and 1930s within the context of state-driven confiscation policies and sustainable resource management, demonstrating how these agencies emerged as powerful instruments for implementing governmental directives. This era is marked by extensive political repression and profound social transformations, which enforced the forced expropriation of lands, resources, and means of production. Such interventions disrupted established economic practices and social structures, leading to substantial shifts in the livelihood systems of the population and destabilizing their long-term resilience.

The relevance of this research lies in its potential to inform contemporary strategies by critically examining historical precedents. Specifically, it underscores the need to develop modern frameworks for state engagement with local communities, as well as principles for sustainable development that uphold the rights and interests of these populations. The primary aim of this study is to analyze the underlying causes and consequences of repressive policies, the roles and functions of law enforcement bodies in executing these policies, and to evaluate the long-term impacts, including resource depletion and ecological degradation.

The findings indicate that confiscation policies introduced novel social and environmental challenges, complicating local communities' capacity for adaptation. This analysis highlights the importance of historical insights as a basis for crafting approaches that promote both environmental sustainability and social welfare. Utilizing lessons from past state-community interactions can guide more effective, balanced policies that foster economic stability while ensuring sustainable community development and ecological integrity.

Keywords: confiscation, sustainable resource management, law enforcement agencies, local communities, Soviet era, Kazakhstan, political repression.

INTRODUCTION

Relevance of the Topic. Investigating the impact of law enforcement agencies on local communities regarding confiscation and sustainable management during the Soviet era is crucial. This study examines the socio-economic and political transformations in the

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USSR during the 1920s and 1930s, marked by state policies that confiscated land, resources, and production means. These policies drastically changed traditional farming practices, shifting from individual to collective methods, and caused significant social and environmental disruptions.

Law enforcement agencies, acting under party directives, enforced these repressive measures, leading to environmental degradation, depleted resources, and reduced biodiversity. Such changes significantly affected local farming practices, hindering communities' ability to adapt to new economic realities.

Understanding these impacts on livelihoods and sustainable development is vital for historical research and contemporary state-society analyses. This study emphasizes the importance of historical experiences in shaping modern sustainable development strategies that consider local community needs and environmental protection.

Objective of the Article. This article aims to analyze the role of law enforcement in shaping local communities through confiscation and sustainable management during the Soviet era. It will explore the historical context of confiscation, the functions of law enforcement agencies in implementing these policies, the consequences for sustainable practices, and the effects of repression on community resilience. This comprehensive approach reveals the complexities faced by local communities and offers lessons for current sustainable development and environmental policy.

The focus on 1927-1932 is due to the initiation of confiscation policies in Kazakhstan, which had profound effects on the local population and resource management, culminating in a catastrophic famine by 1931-1932 that claimed nearly half of Kazakhstan's population.

MATERIALS AND METHODS

The article analyzes the impact of law enforcement agencies on local communities in Kazakhstan from 1927 to 1932, focusing on confiscation and sustainable management practices. Historical-analytical and comparative methods are employed to assess the unique features of Kazakhstan's experience with confiscation and collectivization, drawing on archival materials and contemporary documents. Surveys, interviews, and residents' testimonies reveal the effects of repressive measures on traditional agricultural practices and social structures. Additionally, the study examines ecological consequences based on ecosystem degradation data. The findings provide a comprehensive understanding of how these processes influenced sustainable management and local livelihoods.

DISCUSSION

In the 1920s, the Soviet state viewed the rule of law as aligned with Marxism-Leninism, believing that legal organizations would eventually be abolished once communism was achieved [1]. Consequently, no attempts were made during the Soviet era to historically analyze Soviet legal organizations or assess law enforcement objectively, disrupting sustainable development in the traditional Kazakh economy. Until the 1990s, research on Soviet law enforcement presented a simplified view, following Lenin’s theory that these structures served the "ruling class" and disregarded local traditions, impacting Kazakh pastoralism.

Only post-Soviet studies began examining the actions of 1920s-30s law enforcement agencies. Notably, Moscow researchers critically analyzed Soviet power structures in *30-е годы: взгляд из сегодня* [2], while *Документы свидетельствуют* by Danilov and Ivitsky reviewed their role in political campaigns [3]. However, these works only partly covered the impact on Kazakhstan's traditional economy. Talas Omarbekov, among the first Kazakh scholars after independence, documented the use of law enforcement against peasants in *Шаруаларға шабуыл қалай басталды* [How the Attack on Peasants Began] [4], and in *Қазақстанда революциялық заңдылық қалай жүргізілді?* [How Revolutionary Legality Was Conducted in Kazakhstan?] [5], he explains "revolutionary legality" as actions targeting Kazakh pastoralism, justifying law enforcement's criminal activities that disrupted economic stability.

Further data can be found in T. Omarbekov's works such as *20-30 жылдардағы Қазақстан қасіреті* [Kazakhstan's Tragedy of the 20s and 30s] [6], and in collective studies by Kozybaev, Abilgozhin, and Aldazhumanov on the impact of collectivization on sustainable local practices [7], [8]. Other relevant works include Kazantsev's *Большая игра с неизвестными правилами* [The Great Game with Unknown Rules] [9], Sarsambekova's *Евразийство: теория и практика* [Eurasianism: Theory and Practice] [10], Rogalina's *Коллективизация в свете новых документальных публикаций* [Collectivization in Light of New Documented Publications] [11], Sukhorukova's *Этническая история России* [Ethnic History of Russia] [12], and Grozin's *Голод 1932–1933 годов и политика памяти в Республике Казахстан* [The Famine of 1932–1933 and Memory Politics in Kazakhstan] [13], providing deeper insights into collectivization and its consequences for Kazakhstan's traditional economy.

RESULTS

The political and economic situation in Kazakhstan during the 1920s and 1930s was characterized by significant transformations resulting from the transition to socialist reforms initiated by the Soviet government. This era began under the New Economic Policy (NEP), during which the republic experienced a temporary economic recovery. However, by the end of the 1920s, a stringent policy of centralized governance was instituted, leading to drastic changes in the lives of the Kazakh people. During this period, Kazakhstan became a theater for the implementation of aggressive collectivization policies, which had devastating consequences for the local population and traditional economic practices.

During this time, law enforcement agencies performed functions aimed at controlling and suppressing dissent among the local populace. They operated in accordance with the directives of party structures, actively participating in the confiscation of land and resources, as well as in monitoring compliance with collectivization plans. Law enforcement utilized repressive methods to ensure adherence to state decisions, often accompanied by violence and intimidation of the local population. These measures fostered an atmosphere of fear and discontent, undermining trust in the authorities.

The confiscation of private lands and resources in Kazakhstan occurred through various mechanisms, including legislative acts, orders from local authorities, and direct actions by law enforcement agencies. Confiscations were often executed with the use of force, leading to the violent appropriation of land and livestock from local residents. The confiscation processes left many families without means of subsistence, resulting in widespread dissatisfaction and social tension.

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One of the repressive policies of Soviet authority was the elimination of private landowners, which significantly impacted the sustainable development of Kazakh pastoralism. Starting in 1924, law enforcement agencies in the Kazakh Autonomous Soviet Socialist Republic (KazAKSR) began implementing this policy, affecting not only landowners but also the peasantry engaged in livestock breeding, who constituted a primary source of production in Kazakhstan. In November 1924, the Executive Committee of the Russian Soviet Federative Socialist Republic (RSFSR) sent a secret circular to regional and provincial land commissioners, mandating the confiscation of land from private owners. On January 3, 1925, a circular signed by the People's Commissar of Land, Smirnov, reaffirmed the procedure for confiscation, obligating representatives of the campaign to seize not only land but also all agricultural buildings and inventory, except for clothing. The completion of this campaign, initially scheduled for August 1, 1926, did not occur due to a lack of instructions for identifying wealthy Kazakh peasants. This situation hindered the traditional development of pastoralism, as many affluent livestock owners were compelled to abandon their lands or became targets of confiscation, adversely affecting their economic activities. On December 15, 1926, the prosecutor of the RSFSR, Krylenko, issued a secret circular indicating the urgent need to conclude the campaign [14]. Consequently, on August 27, 1928, a decree on the confiscation of property from affluent social strata was enacted, establishing a commission that included members of the State Political Directorate (GPU) and prosecutors with advisory voting rights. The task of identifying households subject to confiscation was assigned to the OGPU (the current Committee for State Security).

The policy of eliminating wealthy Kazakhs, implemented in Kazakhstan, was characterized by the Bureau of the Committee of the Kazakh Autonomous Soviet Socialist Republic (KazAKSR) of the All-Russian Communist Party (Bolsheviks) as a "revolutionary measure aimed at liberating villages from semi-feudal, patriarchal, and tribal ties," within the context of the ongoing process of confiscating property from large livestock owners in the region. The outcome of this campaign, as noted, was the establishment of the Soviet village. Consequently, Soviet legal authorities were tasked with punishing those who opposed confiscation. Legislative structures viewed the population's misunderstanding of this campaign as a criminal act. Specifically, expressions from individuals stating that "the government has deviated from the correct path," "the state needs livestock to settle debts with foreign countries," "the communists are trading confiscated property for alcohol," as well as concerns that "in the event of war, every citizen would oppose Soviet authority," were perceived as attempts to undermine trust in the Soviet government and to increase animosity toward it, regarded as propaganda against Soviet power.

Furthermore, on January 1, 1929, the People's Commissar of Justice of the RSFSR, Yanson, sent a strictly confidential circular to prosecutors of districts, regions, provinces, and districts, as well as to the justice departments of autonomous regions and republics. This document stated that "the intensification of class struggle in rural areas manifests through the terrorist activities of kulak elements against grassroots and party activists, which requires the attention of central and local party organizations, as well as the need for increased repression against them." Yanson proposed the following instructions to prosecutors and chairpersons of courts:

To notify the Central Prosecutor's Office of terrorist uprisings in each district of the prosecution, as well as the murders of Soviet and community workers, and of arson and other actions causing damage to property, recorded as a result of class struggle;

To establish cooperation with local OGPU authorities for the prompt resolution of such crimes;

Cases against those who resisted this campaign could be directed to the party commissions of the OGPU collegium without judicial proceedings [15]. Despite the legitimization of this document, public discontent against the Soviet authorities and party officials did not cease. The government's and party's policy of eliminating the wealthy landowners only intensified with each passing day.

At the end of 1929, there was an escalation of public discontent associated with the murders of Soviet officials and arson of state property. The prosecutor of the Syrdarya District, Pokrovsky, explained: "... The tolerance of class conflict during socialist and economic campaigns aimed at restoring the country along socialist lines requires further intensification of the struggle against 'capitalist elements,' i.e., the wealthy. The document contains directives stipulating that upon establishing the name of the accused, the accused's property shall be subject to confiscation, regardless of the victim's complaint. This is based on the understanding that wealthy segments of the population could destroy property. It is also specified that investigations into cases of this category should be completed within 7 days under the supervision of the district prosecutor, and such cases should be heard by courts at the crime scene as open, public trials [16].

Thus, this repressive policy directed against wealthy Kazakhs negatively impacted the sustainable development of livestock farming among nomadic Kazakhs. The elimination of prosperous Kazakhs, who possessed experience and knowledge in livestock breeding, not only undermined traditional methods of livestock management but also led to the destruction of the socio-economic structure necessary for its sustainable functioning. For achieving sustainable development in livestock farming, it is essential to preserve cultural traditions and the social organization that supports a nomadic lifestyle, which, in turn, contributes to ecosystem stability and the effective use of resources.

By the fall of 1930, as a result of the campaign to eliminate kulak farms, no farms exhibiting characteristics of kulak ownership remained. Nevertheless, legal authorities "continued to pursue individuals previously belonging to the kulak class; on the contrary, with the growing resistance from these individuals against the measures of the party and Soviet power, they decided to conduct the struggle against them more actively" [17].

The campaign to liquidate kulak farms in Kazakhstan in 1930, accompanied by brutal political repressions, resulted in the destruction not only of individual farms but also of the sustainable social and economic structure of the region. The policy of the Soviet state towards Kazakh wealthy people manifested in mass repressions and deportations, indicative of serious human rights violations. Judicial and prosecutorial authorities, under the control of a totalitarian regime, failed to ensure the protection of the rights of individuals who had not committed crimes, illustrating the low effectiveness of prosecutorial oversight and the potential for gross abuses of power. As a result of the campaign, a significant number of people were deprived of their voting rights, and many families were impoverished, adversely affecting the social structure and economic stability of the region. The use of violence and forced deportations became the norm, confirming systemic issues in governance. Many of the destroyed farms did not actually

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belong to the kulak class, underscoring the arbitrary actions of the authorities and the absence of clear criteria for identifying kulaks. The confiscation of property and livestock was carried out en masse and not always justifiably, worsening the living conditions of the local population and undermining the foundations of sustainable livestock farming. Despite the liquidation of kulak farms, the persecution of former kulaks continued, indicating an ongoing struggle against supporters of class opponents and highlighting the need to reconsider historical events in light of their long-term consequences for society and culture. In the context of contemporary development, it is crucial to take lessons from the past and strive for sustainable forms of livestock farming based on respect for human rights, social justice, and economic stability, which will ensure the successful development of rural areas.

The confiscation and collectivization significantly altered agricultural practices in Kazakhstan. Traditional pastures and arable land began to degrade, contributing to environmental issues. The forced consolidation of lands into large collective farms often disregarded local natural conditions and traditional agricultural practices, leading to decreased productivity and sustainability of agriculture. The campaign to eliminate prosperous farms in Kazakhstan had significant ecological consequences that negatively affected the sustainable development of livestock farming among the Kazakh people. Mass deportations and the destruction of farms resulted in the dismantling of traditional agricultural and livestock practices, disrupting the ecological balance in the region One of the key aspects of sustainable livestock development is adherence to the principles of rational resource utilization and the preservation of biological diversity. However, as a result of repressive policies, thousands of livestock farms were destroyed, leading to a significant decline in livestock populations. The annihilation of local animal breeds, which were well-adapted to the harsh conditions of the Kazakh steppes, jeopardized the sustainability of the ecosystem, as these breeds played a crucial role in maintaining agro-ecological balance.

The campaign to liquidate the farms of the affluent segments of the population also resulted in the loss of ecosystem services, such as ensuring food security, maintaining biodiversity, and restoring natural resources. The destruction of social structures and traditional practices related to livestock farming limited opportunities for the sustainable development of rural communities, making them more vulnerable to ecological crises. The breakdown of social resilience weakened the bonds between community members, complicating collective efforts to address challenges and restore ecosystems. The consequences of this policy had tragic implications for the population. As a result of the famine that engulfed the country in 1931-1932, nearly half of Kazakhstan's population perished, highlighting the catastrophic scale of the humanitarian crisis. These events were accompanied by approximately 400 uprisings against Soviet authority, which manifested the discontent and despair of local residents [18]. The issues arising from the repressions diminished the capacity of local communities to adapt to new conditions. Residents faced resource shortages and worsening ecosystem health, further exacerbating their plight. The depletion of natural resources and the degradation of ecosystems in Kazakhstan were consequences of poor management, jeopardizing the future of the local population.

In contemporary conditions, restoring sustainable livestock farming requires not only acknowledging historical mistakes but also implementing practices that promote ecosystem conservation, biodiversity restoration, and rational use of natural resources. This includes supporting local initiatives, integrating traditional knowledge into modern

agricultural practices, and actively involving local communities in the decision-making process.

CONCLUSION

The analysis of confiscations and their implications for sustainable agriculture in Kazakhstan during the years 1927 to 1932 underscores the devastating consequences of Soviet policies aimed at the liquidation of kulak farms. The repressive measures and violence employed during this period severely undermined the social resilience of communities and dismantled traditional livestock farming practices, thereby negatively impacting the region's ecosystems.

Firstly, the forced confiscation of property and the resettlement of populations deprived rural communities of access to essential resources and traditional knowledge, thereby complicating their ability to adapt and disrupting food security. Secondly, these repressive actions and the dissolution of agricultural holdings led to environmental degradation, resource depletion, and posed significant threats to agroecosystems. Thirdly, the famine of 1931-1932, which resulted in the deaths of nearly half of Kazakhstan's population, alongside the subsequent wave of uprisings, emphasized the critical necessity of incorporating social and environmental considerations into governance frameworks.

The historical experience of Kazakhstan during this era illustrates how repression and the disregard for traditional practices can precipitate the collapse of social and ecological structures. The restoration of sustainable agricultural practices necessitates the support of local initiatives, the integration of traditional knowledge, and active community participation in decision-making processes to establish a balanced approach to resource management.

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FINANCIAL INSTRUMENTS PROMOTED THROUGH COMMON AGRICULTURAL POLICY TO INCREASE COMPETITIVENESS AND SUSTAINABILITY OF AGRICULTURAL SYSTEMS

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ABSTRACT

The Common Agricultural Policy (CAP) 2023 - 2027 is currently the main instrument of the member states for the development of the agricultural sector and rural areas. CAP is focused on ten key objectives related to social, environmental and economic goals. EU agricultural policy covers all levels covers all levels of agri-food supply chain. The Romania CAP Strategic Plan was approved by the European Commission in December 2022 with a total allocation of 15.83 billions € (14,96 billions € from EU budget and 0,86 billion € national funding). The main type of interventions for direct payments to farmers promoted by Romanian Strategic Plan are: basic income support for sustainability, complementary redistributive income support for sustainability, complementary income support for young farmers, environmentally friendly practices applicable to arable land, practicing environmentally friendly agriculture in small farms (traditional households). These financial instruments are supported through the European agricultural guarantee fund (EAGF). According to the Romanian Payments and Intervention Agency for Agriculture, for the 2023 campaign, a number of 759,976 payment requests were submitted for an area of over 9.98 million hectares. European environmental and agricultural policies play a key role to increase competitiveness and sustainability of agricultural systems. Even if the agricultural policy instruments and strategic plans contribute to the development of the agricultural sector, there is still a need for simplification, diversification and specific measures depending on the particularities of the agribusiness field.

Keywords: agricultural subsidies, common agricultural policy, financial instruments, farmers, sustainability.

INTRODUCTION

Agriculture is an important global economic sector that ensures the production of food resources and has a great responsibility for food security. Romania, with an agricultural area of approximately 13.5 million hectares (ha), has significant agricultural potential and is one of the largest agricultural producers in the European Union, mainly for cereals, sunflower seeds, honey and plums. Romania's agriculture is characterized by a very large number of small individual holdings and several thousands of large agricultural companies. By implementing the EU's common agricultural policy (CAP), Romania has access to several financial instruments which support agriculture and rural development and create new opportunities.

Sustainability is a very important issue for the development of society. In order to meet the environmental requirements CAP post 2020 must define coherent and clear objectives in accordance with the Sustainable Development Goals (SDGs) [9]. The large-scale implementation of sustainable farming practices, requires financial, logistic and political support [1].

Member states of EU were defined in the national strategic plans a set of sustainable practices at farm level, which qualify for eco-scheme payments and which are funding through CAP.

The European Union dedicates a significant financial support to the agricultural sector every year, accounting for more than 30% of total EU budget in the period of 2023 - 2027. The European Union's Common Agricultural Policy (CAP) is an essential source of funding for environmentally friendly agricultural practices in farms. However, its financial instruments have variable success and uptake across member states and regions in EU [11]. The financial instruments represented by direct payments promoted through CAP, overall had a positive impact on the economic resilience of agriculture across EU-27 [13]. Direct decoupled payments from CAP play an important role in supporting the income of numerous European farmers. The amount of financial support from agricultural European funds received increases with the economic dimension of the agricultural holding [2].

This paper aims to provide a documentation and analyses related to the financial instruments that are promoted through common agricultural policy to increase competitiveness and sustainability of agricultural systems.

MATERIALS AND METHODS

The case study was carried out with the aim of emphasizing the importance of access to financial instruments promoted through Common Agricultural Policy to increase competitiveness and sustainability of agricultural systems in Romania. The work methodology was based on scientific documentation of specialized literature, collection and analysis of data from European Commission [4], [5] and the main public institutions that implement agricultural policy in Romania:

- Ministry of Agriculture and Rural Development (MADR);
- Agency for Financing Rural Investments;
- Payments and Intervention Agency for Agriculture.

APIA mainly manages European funds for the implementation of the support measures financed from the European Agricultural Guarantee Fund (FEGA) and other commercial market mechanisms according to the Common Agricultural Policy (CAP). Subsidies are granted in the form of direct payments per hectare and these are managed by the Integrated Administration and Control System of APIA. In this case study, mainly data related to the main direct interventions at the hectare level for crops promoted by the CAP Strategic Plans of Romania were included. Strategic Plan of Romania, approved in December 2022, started to implement the financial opportunities for agricultural systems in 2023 - 2027 period. Agency for Financing Rural Investments mainly manages European Agricultural Fund for Rural Development (EAFRD), the CAP's "second pillar". EAFRD bring a significant contribution to sustainable

development of rural areas providing investment support for rural enterprises, authorities and rural communities.

RESULTS and DISCUSSION

EU's common agricultural policy (CAP) 2023 - 2027 is the most important European policy that provides financial instruments to support farmers, rural communities and rural areas. Several studies have examined the role of financial instruments from common agricultural policy for agricultural sector [3], [6], [12], [13]. A study from France emphasized that the cost of eco-schemes implementation in farms is lower than the eco-scheme payment and in this regards farmers are not encourage to adopt more environmental friendly practices [7]. Thus, the non-financial advantages that the implementation of sustainable practices can bring must be explained much better.

The Common Agricultural Policy is currently the main instrument of the member states for the development of the agricultural sector and rural areas. CAP is focused on ten key objectives related to social, environmental and economic goals. The Strategic Plan for the Common Agricultural Policy (CAP) of Romania for the period 2023-2027 have been approved by the European Commission in 7 December 2022 and then the plan The Commission approved Romania's first amendment in 11 December 2023 and second amendment in 22 May 2024.

The strategic objectives of Romania's Plan for the implementation of the CAP 2023-27 include includes a series of objectives and interventions that are in agreement with the EU's environmental and climate ambitions, promoted through European Green Deal, related to mitigating and adapting to climate change, sustainable development, efficient management of natural resources and conservation of biodiversity (Figure 1).

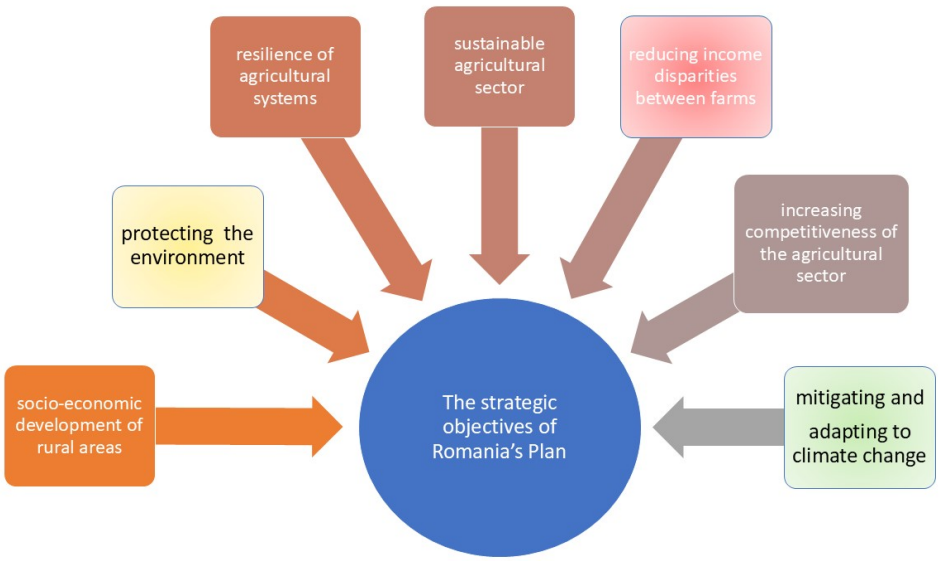


Figure 1. The strategic objectives of Romania's Plan for the implementation of the CAP 2023-27.

The Romanian Strategic Plan is most important instrument for financial support of agriculture and rural development. The strategic plan is substantiated by the financial resources provided by European funds, the European Agricultural Fund for Rural Development and European Agricultural Guarantee Fund, and funds from the state

budget. In addition to these financial sources, there are other relevant sources for supporting the agricultural sector (figure 2).

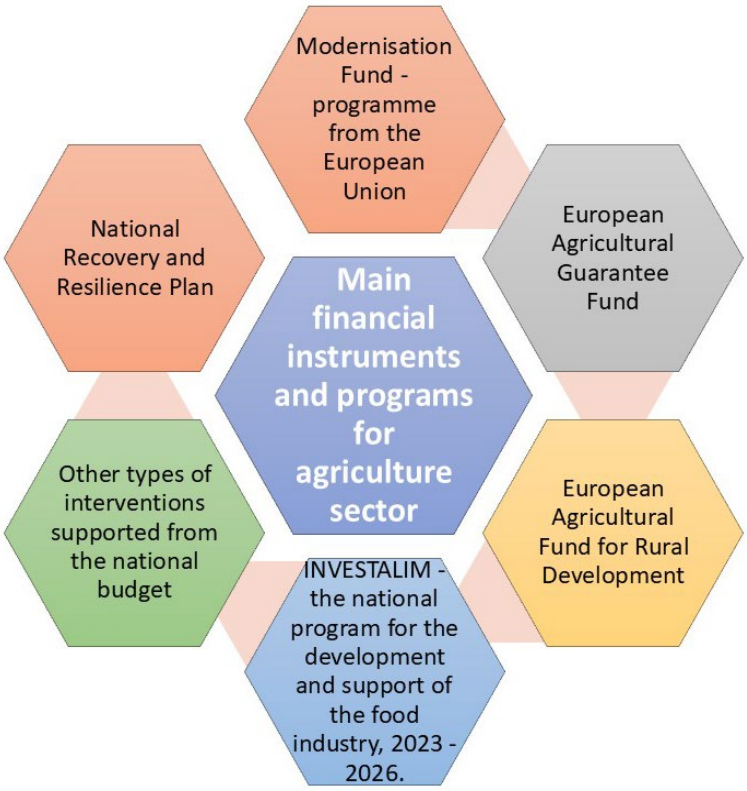


Figure 2. Main financial instruments and programs for agriculture sector.

The Strategic Plan for 2023 - 2024 with a total allocation of 15.83 billions € (14,96 billions € from EU budget and 0,86 billion € national funding) represent the most important instrument for financial support of agriculture and rural development (Table 1). Direct payments represent 61,77% from the total allocation in the Romania Strategic Plan 2023 – 2024, while interventions for rural development have a weight of 37.07% of the total budget. Pillar II of CAP regarding rural development has an allocation from the EAFRD and the national budget of 5.87 billion Euros.

Table 1. Romania CAP Strategic Plan (2023 – 2024) - EU budget and national funding.

Interventions	EU budget	National funding (€)	EU budget and National funding (€) 0
Direct payments	9 783 148 797	n/a	9 783 148 797 (61,77%)
Sectoral support	151 684 802	30 408 150	182 092 952 (1,15%)
Rural development	5 034 728 288	835 990 453	5 870 718 741 (37,07%)
Total	**14 969 561 887**	**866 398 603**	**15 835 960 490**

Source: Romanian Strategic Plan 2023 – 2027 (first version) [8].

CAP includes a series of objectives and actions that contribute to the achievement of the environmental targets of the European Green Deal promoted through Farm to Fork strategy and EU Biodiversity Strategy for 2030. Agricultural systems play an essential role to reach the targets of European Green Deal. Sustaining these objectives for

environmental protection in agriculture need proper interventions and financial resources. The sustainability and resilience of agricultural systems are essential features to ensure environmental standards in agriculture and food security [10].

European Union regulations impose minimum financial allocations from European funds for support for young farmers, eco-schemes or direct payments. Romania allocates around 25% of the direct payment's envelope to eco-schemes, which represent incentives to farmers who adopt or maintain farming practices that contribute to EU environmental and climate goals (table 2). Also, Romania CAP Strategic Plan allocate a significant support (41% of the rural development budget) to encourage farmers to apply environmentally friendly practices. Such practices can be applied by farmers on areas with high natural value or on areas that are important for the life of birds and butterflies.

Table 2. Romania CAP Strategic Plan (2023 – 2024) – allocation for EU environmental objectives and young farmers.

EU FUNDING RESERVED FOR	EUR	%
Environmental and climate objectives under rural development	2 080 266 316	41%
Eco-schemes under direct payments	2 447 372 825	25%
LEADER	424 750 000	8%
Complementary redistributive income support	978 688 816	10%
Young farmers (generational renewal)	309 621 824	n/a

Source: Romanian Strategic Plan 2023 – 2027 (first version) [8].

The Romanian Strategic Plan 2023-2027 includes 89 support instruments financed both from the European Agricultural Guarantee Fund (51 interventions: direct payments and sectoral interventions - measures to support the market), and from the European Fund for Agriculture and Rural Development (38 interventions: financing for rural development).

Financial instruments of EU promoted by Romanian Strategic Plan that support farmers through different types of interventions are: basic income support for sustainability, complementary redistributive income support for sustainability, complementary income support for young farmers, environmentally friendly practices applicable to arable land, practicing environmentally friendly agriculture in small farms (Table 3).

These direct payments decoupled from agricultural production have amounts per hectare between 51.13 euros and 102.60 euros.

Table 3. Direct Payment per hectare (2023).

Direct Payment Type	EUR/ha
Basic income support for sustainability – BISS	97.57
Complementary redistributive income support for sustainability – CRISS	51.13
Complementary income support for young farmers – CIS-YF	60.29
Environmentally friendly practices applicable to arable land	73
Practicing environmentally friendly agriculture in small farms, traditional households	98.80
Grassing the interval between the rows in orchards, vineyards, nurseries and orchards.	102.60

Source: Romanian Strategic Plan 2023 – 2027 [8].

According to the Romanian Payments and Intervention Agency for Agriculture, for the 2023 campaign, a number of 759,976 payment requests were submitted for an area of over 9.98 million hectares (figure 4). For the 2024 campaign in Romania, 42 counties submitted payment requests for direct payments. In total, 730,395 payment requests were registered for an area of 9,962,885 million hectares. The most requests were submitted by farmers from Suceava, Maramures, Bihor or Dolj, each with over 30,000 requests, covering an area of over 1.09 million hectares. The counties with the largest areas requested for payment were represented by Timis, Teleorman, Constanta, Dolj, each with areas of over 400,000 hectares.

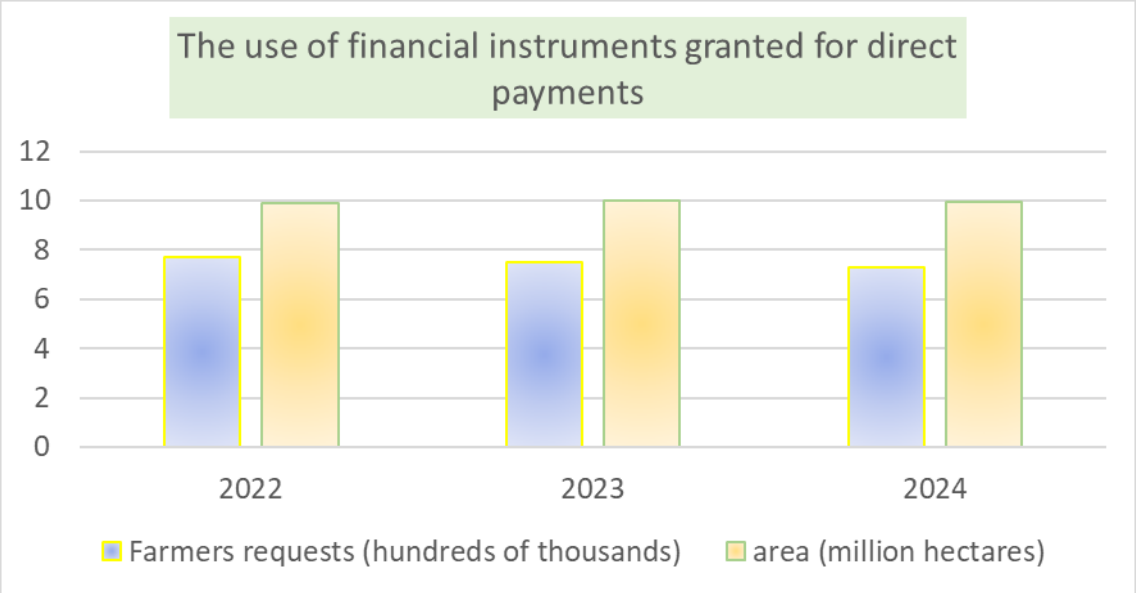


Figure 4. The use of financial instruments granted for direct payments.

Financial resources, agricultural subsidies and other financial instruments promoted in Europe provide income support, but also multiple other benefits for the agricultural sector (figure 5).

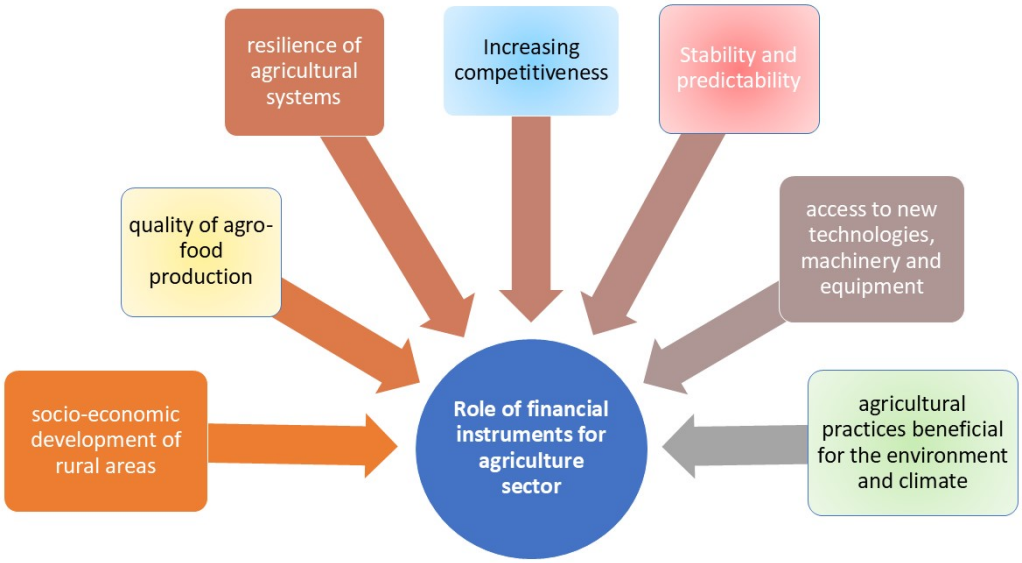


Figure 5. Role of financial instruments for agriculture sector.

CONCLUSION

The EU Common Agricultural Policy provides income support for farmers, agricultural holdings and multiple benefits for rural areas and rural communities. Agricultural subsidies play a significant role for competitiveness, stability, predictability and the application of environmental standards at the farm level. However, there is still no balance in the efficient distribution of EU funds at the level of small, medium and large farms. In the same time, farmers must be aware of the importance of land consolidation in order to increase productivity and competitiveness on the market. CAP Strategic Plans are largely responsible for the structuring of various payment schemes and interventions, as well as the allocation of amounts for various targets and objectives of interest at the national and European level. In recent years, over 730,000 farmers from Romania have accessed the facilities granted through the direct payments instrument, and the eligible area was over 9.9 million hectares annually. It can be concluded the agricultural subsidies play an essential role for agribusiness. Environmental and climate ambitious targets of EU will remain a great challenge in the coming years.

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SOCIAL AND ECONOMIC INEQUALITY AS A BRAKE ON EFFECTIVE ENVIRONMENTAL POLICY

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ABSTRACT

Social and economic inequality in different countries or regions can be a significant obstacle to the implementation of an effective environmental policy. In general, people who are economically disadvantaged are often the most vulnerable to the negative impacts of environmental degradation and climate change. They may also lack the political power and resources to advocate for policies that protect their interests. For example, low-income communities are disproportionately affected by pollution and environmental hazards, such as toxic waste landfills and air pollution from factories and highways. Typically, these communities do not have the financial resources or political clout to demand that their government take action to address these issues. Economic inequality can create a political climate that is less favorable to environmental regulation. Wealthy societies or corporations generally have the resources to lobby against environmental protection or fund political campaigns of candidates who oppose environmental regulation. Social and economic inequality can lead to a lack of public trust in state institutions and skepticism regarding the effectiveness of environmental policies. If people do not feel that their government is working for them or that policies are against them, they may be less likely to support environmental initiatives, even if they benefit from them. For this reason, it is important to address social and economic inequality as part of any comprehensive approach to environmental policy. Typically, these measures include increasing access to education and job opportunities, investing in public transport and renewable energy infrastructure, and ensuring that vulnerable communities have a seat at the table in policy discussions. By tackling inequality and poverty, we can build a fairer and more sustainable society that is better equipped to deal with the environmental challenges we face.

Keywords: social and economic inequality, environmental policy, climate change

INTRODUCTION

The purpose of the research is to justify the need for active policies regarding social and economic inequality. The aim is to achieve a normal level of socio-economic inequality within countries, leading to effective implementation of environmental policies, as marginalized communities resist or are unable to comply with these policies. In urban areas, marginalized communities tend to be located in more polluted and hazardous zones, while in rural contexts, the poor are more susceptible to the impacts of droughts, floods, and other climate-related events [1].

The object of the study is the impact of socio-economic inequality on the implementation of environmental protection policies.

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The subject of the study is the impact of income tax rates on the level of economic inequality in society.

The research methodology is based on the use of general scientific (scientific abstraction, unity of historical and logical, analysis and synthesis, induction and deduction, methods of comparison and analogy) and special methods of knowledge (indicative method, method of expert assessments). The work uses a systematic and integrated approach. The information base of the research was the official statistics, the works of leading researchers dedicated to the problems of socio-economic inequality and environmental policies.

Social and economic inequality differs in economic well-being between individuals in one group, between groups from the population, or between citizens. The problem with economic inequality is related to the concept of justice, equality of outcome, and equality of opportunity. Inequality exacerbates environmental degradation through various mechanisms, including the disproportionate consumption patterns of the wealthy, the undue influence of elites in obstructing climate mitigation efforts, and the erosion of social cohesion needed for collective action [2].

The problem of socio-economic inequality is typical for many countries of the world, among which there are mainly countries of "catching up development". In a period of deep economic recession and political stagnation, this phenomenon exacerbates the unresolved problems of the level and quality of life, access to social benefits and the opportunity to work. Experience shows that the most successful in smoothing out socio-economic inequality are those countries that pursue an active social and redistributive policy.

Social and economic inequality in different countries or regions can be a significant obstacle to the implementation of an effective environmental policy. In general, people who are economically disadvantaged are often the most vulnerable to the negative impacts of environmental degradation and climate change. They may also lack the political power and resources to advocate for policies that protect their interests. For example, low-income communities are disproportionately affected by pollution and environmental hazards, such as toxic waste landfills and air pollution from factories and highways. Disadvantaged groups are more vulnerable to the adverse effects of climate change, as they often have higher exposure and lower resilience to environmental shocks [3].

Income inequality affects consumer behavior and manufacturing, and environmental regulations affect corporate profits and production costs. Therefore, income inequality and environmental regulations can affect environmental quality. Considering the inequality of environmental quality between regions, the heterogeneity of the effect of income distribution and environmental regulations on environmental quality can be revealed under different environmental quality distributions [4].

The problems of social and economic inequality and the possibilities of achieving an effective environmental policy lead to the question - was there environmental justice and what does it represent? Environmental justice is the principle that all people, regardless of race, disability, age, or socioeconomic status, have the right to live, work, and play in communities that are safe, healthy, and free from environmental harm. Environmental justice means the fair treatment and meaningful participation of all persons, regardless of race, colour, national origin, or income, in the development, implementation, and enforcement of environmental laws, regulations, policies, and

activities, and in relation to the distribution of benefits to environment. On the one hand, rich societies talk about environmental problems and make policies to protect it, but on the other hand, they do not help the poor enough to fight inequality. Poor societies, on the other hand, receive aid to deal with pollution, for example, but cannot or do not want to comply with environmental policies. There is also a reverse process, poorer societies are willing to join environmental protection policies but do not receive sufficient support from richer ones.

The poor people alone cannot be blamed as the key contributors of environmental degradation. In many areas the poor people are more aware about the proper use of natural resources like land, forests and water resources, as they get their livelihood from these resources [5].

Climate justice is the recognition that it is these historically overburdened communities that are most vulnerable to a rapidly changing climate. The inequalities that persist in our society, ranging from social to economic and health inequalities, may be exacerbated by the effects of climate change, such as extreme heat, floods and catastrophic weather events. The pursuit of climate justice also means holding those most responsible for the climate crisis accountable. By taking action to combat climate change, we have the opportunity to address the social, economic and health inequalities in our communities that are exacerbated by the effects of climate change.

Severe droughts caused by climate change raise the question of water inequality in the world.

Besides impacts on human health, it is emphasized that droughts can exacerbate economic inequality due to rising water bills, constituting significantly different challenges for different segments of the population [6].

Typically, these communities do not have the financial resources or political clout to demand that their government take action to address these issues. Economic inequality can create a political climate that is less favorable to environmental regulation. Wealthy societies or corporations generally have the resources to lobby against environmental protection or fund political campaigns of candidates who oppose environmental regulation. Social and economic inequality can lead to a lack of public trust in state institutions and skepticism regarding the effectiveness of environmental policies. If people do not feel that their government is working for them or that policies are against them, they may be less likely to support environmental initiatives, even if they benefit from them. For this reason, it is important to address social and economic inequality as part of any comprehensive approach to environmental policy. Inequality can obstruct the implementation of environmental regulations, as powerful economic interests leverage their influence to block or weaken policies that threaten their profits [7]. The wealthy and influential are often able to avoid the costs of environmental protection, while the burdens fall disproportionately on the poor and marginalized [8].

The exposure of certain communities to environmental risks is largely shaped by unequal resource distribution and different vulnerabilities. According to the Centre for Climate Change Economics and Policy, environmental degradation triggered by climate change has asymmetric effects, impacting the poor more than the rich, and uncover, as well as reinforce existing patterns of socio-economic inequality [9].

Air pollution remains the biggest environmental threat to health in Europe, with more than 400,000 premature deaths due to air pollution each year in the EU. Noise

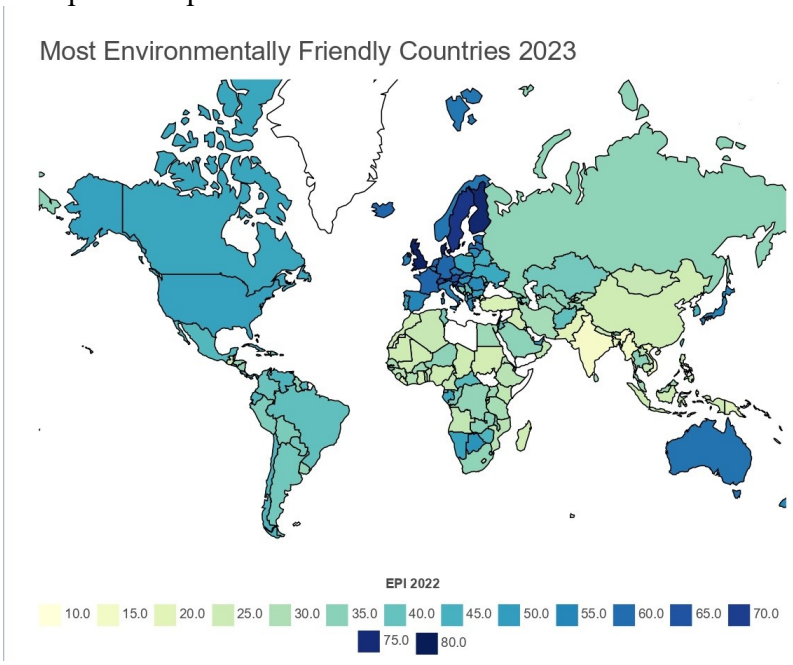
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pollution is in second place, causing 12,000 premature deaths, followed by the effects of climate change, especially heat [10].

The burden of pollution and climate change varies across Europe, with a clear difference between countries in Eastern and Western Europe. The highest share of national deaths (27%) related to the environment is in Bosnia and Herzegovina, and the lowest in Iceland and Norway, where this value is 9%. In Western Europe, environmental policies are developing at a faster pace than in Eastern Europe. Data clearly show that in economically and socially developed countries we also have a better environmental policy. Socially weak and economically poor communities typically struggle with the triple burden of poverty, poor environmental quality, and poor health. In Eastern Europe, environmental policies are generally difficult to implement. Often, poorer communities are exposed to higher levels of pollution and noise and to high temperatures, and pre-existing health problems increase vulnerability to environmental risks. This is a brake on the support of these communities for policies related to environmental protection. In order to improve the environmental conditions for the most vulnerable citizens in Europe, targeted measures related to the support of these citizens are needed.

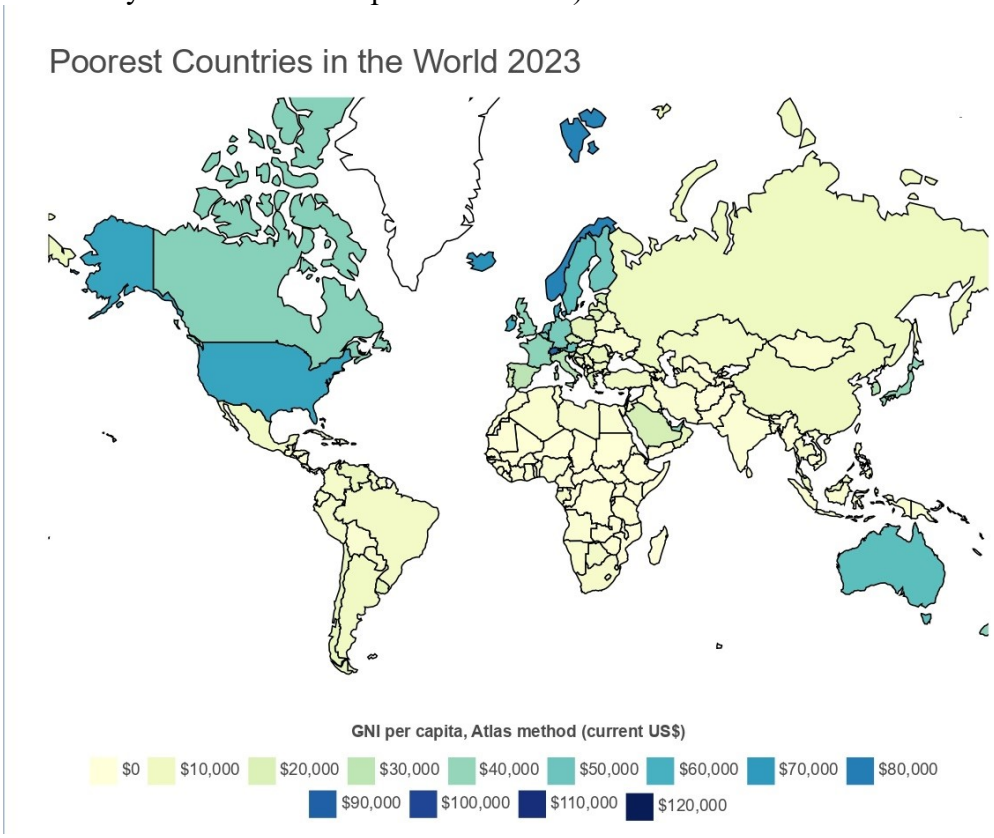
The environment is an essential source of livelihood on which the continued existence for poor people depends. However, denial of primary requirements results to poverty. The evaluation suggests that higher population and fertility rates were associated with higher deforestation in the tropical evergreen forest. Poverty reduction and environmental protection are two international obligations for sustainable development. The relationship between population, poverty and environmental degradation is regionally unique or has regional uniqueness [11].

Globally, we can argue that social and economic inequality is bad for the environment. As can be seen in the two maps, economic inequality (expressed by income) contributes to the development or lack of development of environmental policies. Economic and social inequality can worsen the quality of the environment by increasing the ecological intensity of society's consumption or reducing social cohesion and the willingness to cooperate to protect common resources.



https://worldpopulationreview.com/

Admittedly, in Northern and Western European countries, the level of environmental concern rose before the financial crisis of 2008 and fell sharply after it (it took about ten years to recover to pre-crisis levels).



https://worldpopulationreview.com/

The growth of economic dependence between nations leads to increasing ecological dependence, which increases the relationship between the economy and the environment and affects the process of environmental management. With the increase in the number of humanity against the background of limited natural resources, the relationship between economic development and the environment is becoming one of the main and complex problems of modern society [12].

However, this does not mean that concern for the environment is the lot of the rich and the middle class. According to the same researchers, in low-income countries where water, air and soil are sometimes critically polluted, residents take environmental problems extremely seriously - they simply cannot ignore them. Concern is also growing when people are directly confronted with extreme weather events: droughts, floods, hurricanes, and so on.

The enumeration of the challenges to environmental management and the impact of socio-economic development is very often associated with the identification of the most important environmental issues. Climate change, increasing waste, and air and water pollution are identified as such. In the current 21st century, existing environmental problems have a direct impact on people daily lives and health and determine the challenges facing environmental management [13].

And yet we have to answer the question - What influences "environmental awareness"?

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The global environment is our common home, but not everyone lives in the same room. Clearly, many crucial dimensions of environmental quality are not private goods, exchanged in markets where the rich can buy more than the poor. But neither are they pure public goods, that when available to one person are equally available to all. Rather, many aspects of environmental quality lie in the intermediate terrain between the public and the private, a terrain where, in George Orwell's haunting phrase, some are "more equal than others [14]".

When it comes to "environmental awareness", the most popular thesis is that a person begins to worry about the state of the environment when his basic needs are closed - when he does not experience hunger, he has a steady income and he feels safe. If a person does not have a permanent job, if he lives below the poverty line, all his thoughts are focused only on how to feed himself and his family. Roughly speaking, he has no time for sorting waste - he has enough other worries, and in the store he chooses not an eco-friendly product with a label, but one that he can afford.

The demographic factor is interesting. Regions with relatively young and well-educated populations are more concerned about environmental issues. Researchers attribute this to a better level of scientific literacy, abstract thinking skills, and social norms accepted in this environment.

CONCLUSION

Social and economic inequality have emerged as significant barriers to the implementation of effective environmental policies [15]. The current situation regarding the environment and climate change highlights the acuteness of the problem of socio-economic inequality in different societies, indicating the need to solve it. The examples show that the most relaxed situation regarding inequality and environmental policies has developed in countries where the population has high personal incomes.

Of course, there are many measures in relation to dealing with inequality and opportunities to adopt policies related to environmental protection by society.

Typically, these measures include increasing access to education and job opportunities, investing in public transport and renewable energy infrastructure, and ensuring that vulnerable communities have a seat at the table in policy discussions. By tackling inequality and poverty, we can build a fairer and more sustainable society that is better equipped to deal with the environmental challenges we face.

Environmental justice recognizes the intersection of economic and social injustice with climate change and environmental policies. To promote environmental justice in our society, we must promote a variety of initiatives to ensure that everyone can benefit from a climate-adapted future, that all urban projects and programs help slow climate change and environmental justice and create prepared for the new realities inhabitants of the world. All this helps create good green jobs and move away from the fossil fuel economy.

It is necessary to establish a Ministry for Adaptation to Climate and Environmental Changes and Overcoming Inequalities in Society in governance in every country. It will help implement policies that eliminate environmental and health inequalities, support action to increase access and involve people at all levels of planning and decision-making, ensure equitable protection for the environment and reduce environmental hazards. attitude of good health.

A possible way out is the introduction of a stimulating regional policy to guarantee the development of targeted economic zones, clusters, cities of economic growth. In the formation of zones with a special socio-ecological regime for nature management, it will be possible to ensure accelerated development of the economy in conditions of ecological safety.

DISCUSSION

A growing body of research has examined the complex linkages between inequality and environmental issues. Climate change is likely to exacerbate existing inequalities, as the damages disproportionately impact low-income and minority communities. These communities often have higher exposure to environmental risks, greater susceptibility to climate-related damages, and less capacity to recover in the aftermath of environmental crises. Equitable policy responses are therefore crucial, as poorly designed climate mitigation and adaptation programs may inadvertently widen societal divides.

Beyond the distributional impacts of environmental degradation, inequality can also constrain the political and economic conditions needed for effective environmental governance. Highly unequal societies tend to have weaker social cohesion, less trust in institutions, and greater barriers to collective action - all of which hinder the development and implementation of far-reaching environmental policies. Addressing underlying inequities is therefore essential for fostering the inclusive, participatory approaches required for durable environmental solutions.

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FUTURE CHALLENGES AND CONDITIONS OF THE SUSTAINABLE AGRICULTURAL PRODUCTION IN THE EUROPEAN UNION

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ABSTRACT

The sustainability, the digitalization and the generation renewal of the agricultural sector are the most important aims of the Common Agricultural Policy after 2020. Among the horizontal goals of the European Agricultural Policy are the widespread of digitalization technology in the agricultural production, as well as, the education and the innovation. The key conditions are the widespread application of digitalization technologies in the agricultural production and food industry, the implementation of the investments for the new sustainable technologies, the education and training of the sustainability and the digitalization technologies in adequate level and the innovation. The fair income level of the farmers from their agricultural production activity is the most important determination factors for the generation renewal in the agricultural sector. The most interesting issues of our research project the motivating and hindering factors of the sustainability and the spreading of the digitalization, as well as the generation renewal in the European Union's agriculture.

Keywords: sustainability, digitalization in the agriculture, generation renewal

INTRODUCTION

The research carried out on this topic examined the factors affecting sustainability and generational renewal in agriculture, the factors that contribute to the sustainability of the farm transfer, and the attitudes of current and future generation farmers and professionals towards smart tools in agriculture, their benefits, drawbacks, opportunities and challenges. In our research project we examined the factors affecting sustainability and generational renewal in agriculture, the factors that contribute to the sustainability of the farm transfer, and the attitudes of current and future generation farmers and professionals towards smart tools in agriculture, their advantages and disadvantages, opportunities and challenges.

The problems of generational change should first be discussed in the context of the drastic reduction in the number of farms, which unfortunately is a serious problem today. Nevertheless, the age distribution of the heads of the farms is indicated, that it is time for a generational change.

According the above facts it can be concluded, that the issue of generational change is a current priority for EU agriculture and is one of the current objectives of the Common Agricultural Policy. The other current objectives are illustrated in the Figure 1 below.

The objectives of Common Agricultural Policy after 2020

For the period 2023-27, the common agricultural policy (CAP) is built around ten key objectives. Focused on social, environmental and economic goals, these objectives are the basis upon which EU countries designed their CAP Strategic Plans. [1]

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Figure 1: The objectives of Common Agricultural Policy after 2020 [1]

According to the European Green Deal the European Commission will work together with the European Parliament and the European Council to ensure that the objectives set out in strategic plans drawn up by the European Union and its Member States, such as the "From farm to fork" strategy or Biodiversity Strategic Plan are implemented. These objectives set out in the above-mentioned documents should lead to use of sustainable practices such as precision farming. They should reward higher environmental and climate performance of farmers, including carbon management and sequestration in soils, and better nutrient management to improve water quality and reduce emissions. [2]

Green Deal

Climate change and environmental degradation are an existential threat to Europe and the world. To overcome these challenges, the European Green Deal will transform the EU into a modern, resource-efficient and competitive economy, ensuring:

- no net emissions of greenhouse gases by 2050
- economic growth decoupled from resource use
- no person and no place left behind. [2]

The European Commission has adopted a set of proposals to make the EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels. [2]

Farm to Fork Strategy

The European Green Deal sets out how to make Europe the first climate-neutral continent by 2050. It maps a new, sustainable and inclusive growth strategy to boost the economy, improve people's health and quality of life, care for nature, and leave no one behind. The Farm to Fork

Strategy is at the heart of the Green Deal. It addresses comprehensively the challenges of sustainable food systems and recognizes the inextricable links between healthy people, healthy societies and a healthy planet. [3]

Biodiversity Strategy for 2030

The EU's biodiversity strategy for 2030 is a comprehensive, ambitious and long-term plan to protect nature and reverse the degradation of ecosystems. The strategy aims to put Europe's biodiversity on a path to recovery by 2030, and contains specific actions and commitments. A core part of the European Green Deal. [4]

Digitalization widespread

The widespread dissemination and application of digitalization will be a priority task in the field of European agriculture, as it is expected to solve emerging problems and achieve future objectives. Future professionals will have to work towards post-2020 achieving the objectives of the Common Agricultural Policy and solving the future challenges described below with the widespread using of digitalization tools, that help them to reach these destinations.

The goals, that were described by the Hungarian Digital Agricultural Strategy 2019-2022 can be achieved in the near future, which can be facilitated by the widespread application of digitalization. The aims, that can be reach with the widespread application of the digitalization tools are increasing the efficiency of agricultural production, efficient use of natural resources, reducing harmful emissions, improving food chain safety, reducing the amount of waste, processing by-products of agricultural and food production. [5]

The post-2020 objectives of the Common Agricultural Policy, which described in the European Green Deal, the Farm to Fork Strategy and the Biodiversity Strategy. These aims are achieving the circular farming, the agricultural by-product processing, clean energy producing from agricultural by-product, soil fertilizing with organic materials and increasing the organic material content of soils, thereby improving water and nutrient management of soils, improving topsoil thickness, reducing the use of pesticides, and the phasing out dangerous pesticides active substances, reducing the use of antibiotics in the animal products production, converting a quarter of farms to organic farming, preserving biodiversity and improving food chain safety.

The rural development is paramount importance in order to prevent the depopulation of rural areas, because the agricultural products are produced in the rural areas, where must be farmers and agricultural workers to maintain and increase the volume of the agricultural production.

The priorities identified by the European Union's and national strategies and the main target areas promoted by the legal regulations concerning this area are precision agricultural and food production, investments and developments, and – in the area of ensuring the resources needed to achieve these – a more efficient agricultural production, the improvement of sustainability and food safety by means of a more efficient use of natural resources. Achieving these objectives, the European Union has identified the widespread introduction of precision technologies using digitization technology in the agricultural economy. [9]

Hungary is far from fully exploiting its currently available food production potential. This could be significantly improved by a more efficient organization of processes, the improvement of processing, a better serving of domestic and foreign consumer needs and a targeted response to solution demand in the world. "Hungarian food economy provides a 60%

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higher production potential than is currently the case", declares the strategic plan titled Food Economic Concept of Hungary (2017-2050) adopted by the Government for the period until 2050. [10]

According Horváth (2018) the three main objectives of the Common Agricultural Policy are structured around the concepts of food, environment and rural areas, which means that farmers and agricultural workers want to receive a fair income for producing sufficient quantity, quality and affordable agricultural products, adequate raw materials for food production in order to ensure a decent standard of living for their families. In addition, the rural development is particularly important, because the rural areas are the place, where agricultural products are produced as raw materials for food products. Generational renewal in agriculture can only occur, if the rural areas are not depopulated, and the services are provided, that necessary for everyday life, there are jobs for everybody, who would like to work. [6]

The various services become available with the spreading of digitalization, for example the personal and business relationships development is ensured continuously and the availability and application of modern technological and digitalization tools in the field of agriculture. The digitalization technology makes the agricultural career more attractive for young people, which also promotes generational renewal.

METHOD AND MATERIAL

The sustainability, the generation renewal can be achieved by the spreading and application of digitalization, so first of all we examined the factors and advantages of the spreading of digitalization by processing the professional literature sources related in this topic.

Secondly objects of this research study were the examination of the facilitating and hindering factors of the spreading the digitalization technologies in the agricultural sector, which we compared with the results of an international survey conducted by the Hungarian Agricultural Research Institute as part of the LivestockSense research project. [7] For this examination it was prepared a special questionnaire survey. The number of the respondents were 155 in Wenner's Thesis. [8] The results of examination were compared with the similar international research project, called LivestockSense, that were lectured in the PREGA 2023 Conference in Budapest by Ildiko Tikasz, who works in the Hungarian Agricultural Economics Institute and leads this research project. The compared results were shown in the below tables (Table 1 and Table 2). In the LivestockSense project were collected data from the 7 listed different countries, Austria, Denmark, Sweden, Poland, Estonia, Hungary, Israel. The number of the respondents were 269 in the LivestockSense research project. [7] [8]

RESULTS AND DISCUSS

The widespread of digitalization in agricultural sector

The widespread of the digitalization tools is maybe the most important among another goals, because it is a horizontal aim of the Common Agricultural Policy after 2020. As we know the horizontal aims can help to fulfill another 9 main aims of the Common Agricultural Policy. The horizontal aim is among all the ten is the „Knowledge and innovation". In the innovation means the applied industrial research and the technological investments, but in addition the education and the attitude are also extremely important. The attitude formation for the older

age group is more important and for the younger age group is the digital education is the more important education form. Therefore the members of the older age group must „prepare the ground" for digital technologies investments and their operation, young people must acquire the necessary skills and knowledge for the operation.

The tender sources and bank loans, that supporting the financing of new technological investments will be paramount importance in the future. The sustainability will be one of the main aspects of resource allocation. These include combating climate change, reducing greenhouse gases and reducing air polluting emissions from agricultural production such as ammonia, furthermore the efficient management of natural resources and biodiversity conservation.

In addition to the above listed aims are the increasing the efficiency of agricultural production and food processing, reduction waste, process as much agricultural and food by-products as possible and improving food chain safety. The Hungarian Digital Agricultural Strategy 2019-2022 identified the widespread dissemination of digitalization as a means of achieving these goals.

The increasing the digitalization level of agricultural and food production plants and sustainability have been included among the most important criteria for judging tender funds intended for investment purposes and bank loans.

In examining the spread of digitalization, we seek to answer the question of what are the motivating and hindering factors, future problems and challenges regarding the widespread introduction of digital technology. The advantages, possible disadvantages, motivating and hindering factors of spreading digitalization in the agricultural and food industry sector can be learned through a questionnaire survey.

The facilitating and hindering factors of the digitalization technological spreading in agriculture

Wenner (2024) published the facilities and hindering factors of digitalization technological spreading in the Hungarian agricultural production in his Thesis. The results were presented in the below table (Table 1, Table 2).

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Table 1: Comparsion Wenner (2024) and Tikasz (2023) results about the facilitating and hindening factors of the spreading of digitalization technology in agricultural sector according the University of Szeged's students and professions of 7 different countries answers

	Results of LivestockSense project according Tikasz (2023)		Results the University of Szeged's students in Wenner's Thesis (2024)	
Statements about the digitalization technologies	Proportion of those who agree in the group of digitalization technology users	Proportion of those who agree in the group of digitalization technology non-users	Proportion of those who agree in the group of digitalization technology users	Proportion of those who agree in the group of digitalization technology non-users
The digitalization tools provide real-time information.	*89%	*67%	100%	100%
The using of digitalization technology increase the efficiency of production.	*88%	*56%	100%	100%
The digitalization tools can be easily purchased.	*69%	*19%	85%	80%
The digitalization tools work reliably.	*61%	*22%	90%	80%
The digitalization tools operation is simple.	*59%	*31%	47%	50%
The digitalization tools maintenance costs are acceptable.	*47%	*8%	51%	45%
The service facilities for digitalization tools are easily acessable.	*47%	*8%	47%	50%
The digitalization tools can make ensure the transparency.	*47%	*8%	90%	100%

Forrás: Tikasz (2023); Wenner (2024) [7] [8]

The based on the results of the questionnaire survey, most people agreed with the following statements.

- The most respondent person, who filled the questionnaire agreed with the following statements:
- The digitalization tools provide real-time information.

The using of digitalization technology increase the efficiency of production. [8]

According the digitalization tools users respondent person's opinion the during the comparison Wenner (2024) get a similar results like the LivestockSense projects results in the following statements.

- The digitalization tools maintenance costs are acceptable.
- The service facilities for digitalization tools are easily acessable. [8]

Table 2: Comparsion Wenner (2024) and Tikasz (2023) results about the facilitating and hindening factors of the spreading of digitalization technology in agricultural sector according the Hungarian and 6 different countries profession's answers

	Results of LivestockSense project according Tikasz (2023)		Results the Hungarian profession's answer in Wenner's Thesis (2024)	
Statements about the digitalization technologies	Proportion of those who agree in the group of digitalization technology users	Proportion of those who agree in the group of digitalization technology non-users	Proportion of those who agree in the group of digitalization technology users	Proportion of those who agree in the group of digitalization technology non-users
The digitalization tools provide real-time information.	*89%	*67%	97%	98%
The using of digitalization technology increase the efficiency of production.	*88%	*56%	97%	98%
The digitalization tools can be easily purchased.	*69%	*19%	25%	30%
The digitalization tools work reliably.	*61%	*22%	75%	70%
The digitalization tools operation is simple.	*59%	*31%	47%	55%
The digitalization tools maintenance costs are acceptable.	*47%	*8%	42%	45%
The service facilities for digitalization tools are easily acessable.	*47%	*8%	47%	47%
The digitalization tools can make ensure the transparency.	*47%	*8%	93%	95%

Forrás: Tikasz (2023); Wenner (2024) [7] [8]

However the digitalization technology users and the students of University of Szeged is more optimistic like other professionals who asked in this research project. According Wenner (2024) the „The management of digital devices requires a high level of expertise, so it is worth while to start company training. [8]

CONCLUSION

In order to achieve the set goals, the European Union has previously supported and will continue to support environmentally friendly technology investments within agriculture, but especially in the livestock sector, which has the highest greenhouse gas and ammonia emissions. The main objectives in this regard have been recorded in the relevant strategic documents. It can be concluded that precision digitalization investments supporting sustainability are expected to come to the fore in the future, as the Hungarian Digital Agricultural Strategy 2019-2022 identifies this as a means of solving sustainability problems.

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For this reason, the spreading and applying of these technologies in agriculture, especially in the field of livestock farming is expected in the future, because the sustainability will become crucial from both an environmental and an economic perspective in the next period.

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EU JOINT AGRICULTURAL POLICY AS A FACTOR OF SUSTAINABLE DEVELOPMENT IN THE CONTEXT OF DIGITALISATION

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ABSTRACT

In the context of modern globalisation and the rapid development of digital technologies, the agricultural sector faces new challenges and opportunities. The Common Agricultural Policy (CAP) of the European Union (EU) plays a key role in ensuring a sustainable economy by promoting the introduction of innovative solutions and technologies in agriculture. The purpose is to study the impact of digitalisation on the EU agricultural sector in the context of the Common Agricultural Policy, to determine the theoretical and practical significance of these processes for sustainable economic development. Research results. The key concepts, theories, models and paradigms of sustainable development of EU agricultural policy are analysed and the impact of digital technologies on the agricultural sector is shown. New directions and features of the Common Agricultural Policy (CAP) of the EU countries, innovative solutions for sustainable agricultural development, and the cost-effectiveness of digital technologies and social aspects of the digitalisation of the agricultural sector are developed. Digitalisation helps to reduce costs and increase productivity. The introduction of automated farm management systems allows to reduce labour-intensive processes through digital technologies.

Keywords: Common Agricultural Policy (CAP), digitalisation, EU countries, agricultural sector, sustainable development

INTRODUCTION

The EU's Common Agricultural Policy (CAP) plays a key role in ensuring a sustainable economy in the context of digitalisation. This policy not only promotes agricultural development, but also actively integrates digital technologies to improve the efficiency and sustainability of the agricultural sector. Digitalisation includes the introduction of technologies such as precision farming, drones, sensors, big data and artificial intelligence. They allow collecting and analysing data on soils, plants, and climatic conditions, which helps to optimise resource use, reduce costs, and increase yields. big data analysis helps to make informed decisions about crops, harvesting, and inventory management. The aim is to study the impact of digitalisation on the EU agricultural sector in the context of the Common Agricultural Policy, to determine the theoretical and practical significance of these processes for sustainable development in the context of digitalisation [1].

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MATERIALS AND METHODS

The study is based on the analysis of scientific literature, statistical data, EU policy documents, as well as surveys and interviews with farmers and agricultural experts. The EU's Common Agricultural Policy is an important factor in a sustainable economy in the digitalised world. It promotes the implementation of innovative solutions, improves the efficiency and environmental sustainability of the agricultural sector, and provides support and a regulatory framework for the development of digital technologies in agriculture. Research methods. The study of the impact of the EU's common agricultural policy on a sustainable economy in the context of digitalisation involves the use of various methods to obtain comprehensive and reliable results. The main research methods include: Study of scientific articles, monographs and research reports related to the Common Agricultural Policy, digitalisation of the agricultural sector and sustainable development. Review of official EU documents, such as regulations, directives, strategies and support programmes related to the Common Agricultural Policy and digitalisation in agriculture. Use of statistical data from Eurostat, national statistical agencies of EU countries and other sources to analyse productivity, efficiency, environmental sustainability and socio-economic conditions in the agricultural sector.Use of regression models to study the relationships between the introduction of digital technologies and indicators of efficiency and sustainability of the agricultural sector.Research of specific examples of successful implementation of digital technologies in the agricultural sector of EU countries. Analysing best practices and results achieved in different regions and at different types of agricultural enterprises. Development of economic models to assess the impact of digital technologies on productivity, costs and sustainability of the agricultural sector. Include different development scenarios and analyse their implications.Use environmental models to assess the impact of digital technologies on resource use and environmental sustainability of agricultural production.Compare the results of digital technologies and support policies in different EU countries to identify effective strategies and approaches.The use of different research methods allows for a comprehensive understanding of the impact of the EU's common agricultural policy on a sustainable economy in the context of digitalisation. This provides a solid basis for formulating recommendations and further development of the agricultural sector.

RESULTS

1. Key concepts, theories, models and paradigms of sustainable development of EU agricultural policy

The EU CAP provides financial support for the introduction of digital technologies in agriculture, so we need to identify key concepts, theories, models and paradigms of sustainable development of EU agricultural policy.[2] The EU is developing a regulatory framework that promotes the development of digital infrastructure and ensures data protection. The digitalisation of the agricultural sector contributes to the creation of new jobs and the upgrading of employees' skills. The introduction of new technologies requires training and retraining, which creates opportunities for professional development in rural areas.The EU actively supports cooperation between member states in the field of agricultural digitalisation. This includes the exchange of experience, technologies and best practices, which contributes to the overall development of the agricultural sector in Europe. The EU's common agricultural policy

is an important factor in a sustainable economy in the context of digitalisation. It promotes the implementation of innovative solutions, improves the efficiency and environmental sustainability of the agricultural sector, and provides support for.[3]

The analysis of the EU agricultural policy and its impact on agriculture and sustainable development can be carried out in the context of the following key concepts, theories, models and paradigms.

Table 1 - Key concepts, theories, models and paradigms of sustainable development of EU agricultural policy

Concepts, theories, models, paradigms	Content and characteristics
The concept of sustainable development	Incorporates the principles of balanced economic, environmental and social development, and integrates environmental practices, support for rural communities and economic efficiency to achieve sustainable development. It defines sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. CAP actively integrates this approach into its programmes.
Precision agriculture	It includes the use of technology to manage fields with precision, which increases efficiency and reduces environmental impact. Precision agriculture reduces the use of chemical fertilisers and pesticides, which reduces soil and water pollution, and agroecological approaches help to preserve local ecosystems and biodiversity.
Inclusive development	It focuses on ensuring equal access to resources and opportunities for all participants in the agricultural sector, including small farmers and youth.
The theory of innovation diffusion (Everett Rogers)	It describes how, why and at what speed new ideas and technologies spread across cultures. CAP promotes innovation through financial support and training programmes.
Agroecology model	Agricultural approach that takes into account ecological principles to support biodiversity, soil and water conservation. CAP supports agro-ecological practices through eco-schemes and other initiatives.
Farm to Fork model	This model aims to create more sustainable food systems that provide healthy food, protect the environment and ensure fair conditions for producers.
The paradigm of multifunctional agriculture	Recognises that agriculture has not only production functions, but also environmental and social functions. CAP reflects this paradigm by supporting ecosystem services and socio-economic initiatives in rural areas
The green economy paradigm	Aimed at economic growth and development that is consistent with environmental goals and sustainable development principles. CAP integrates green practices and technologies to ensure the economic sustainability of the agricultural sector.
Model of Regional Development of Rural Areas (LEADER)	It is being implemented in many EU countries and is aimed at supporting local initiatives and projects that contribute to the economic and social development of rural areas.
Cooperation and clustering model	This model involves organising farmers into cooperatives and clusters to address economic and social issues together.

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All EU countries are implementing elements of all agricultural policy models to varying degrees, as this is a common trend across EU member states. Each country adapts these models to its national strategic plans, taking into account local specifics and needs. Thus, the LEADER, Farm to Table, agroecology, regional rural development, cooperation and clustering, and green payment schemes are being actively implemented in different EU countries to promote sustainable development of agriculture and rural areas.[4]

2. Main directions and features of the Common Agricultural Policy (CAP) of the EU countries

The new Common Agricultural Policy (CAP) of the European Union has been in force since 2023 and is aimed at ensuring sustainable development and supporting innovation in the agricultural sector. The European Union's Common Agricultural Policy (CAP) applies to all 27 EU member states and is a joint initiative regulated by the European Commission and approved by the European Parliament and the Council of the European Union. The CAP has been approved and signed by various EU institutions, including: 1) The EU Executive, which proposes legislation and enforces it. 2) The European Parliament: Composed of MEPs elected by EU citizens and plays an important role in approving the budget and legislation, including the CAP. 3) The Council of the European Union, which consists of ministers from all EU member states who make decisions on key policy issues, including the CAP. The CAP is developed and adopted at the EU level, but its implementation and adaptation to specific conditions is carried out at the national level of each member state. Each Member State develops its own national strategic plans, which are aligned with the CAP's EU-wide objectives and take into account local specificities and needs. Thus, the Common Agricultural Policy applies throughout the European Union, providing comprehensive support to the agricultural sector with a focus on environmental sustainability, innovation and socio-economic development.[5]

The new CAP also makes Member States more responsible for developing and implementing national strategic plans that take into account local circumstances and needs, allowing for better adaptation of policies to specific conditions. This contributes to the flexibility and efficiency of agricultural policy implementation in different regions of the EU. Blockchain technology will help to improve food traceability and quality. supply chain efficiency, thereby reducing waste and increasing transparency and trust in the value chain; deep learning, machine learning and artificial intelligence help in advanced crop management, disease detection, species identification and water, soil and forest management to ensure food security; improve the accuracy of monitoring, reporting and inspection of farmers

The European Union's Common Agricultural Policy (CAP) is one of the most important EU policies aimed at supporting agriculture and rural areas. It has a significant impact on sustainable agricultural development, as it includes economic, social and environmental aspects. The main objectives of the CAP are: 1) Supporting agricultural production, ensuring food security and reducing dependence on imports. 2) Ensure stable and fair incomes for farmers. 3) Supporting rural communities and promoting economic development in rural areas. 4) Stimulating environmentally sustainable agriculture, protecting natural resources and preserving biodiversity. 5) Support for innovation and modernisation, which contributes to the competitiveness of European

agricultural producers on the global market. 6) Support for small farms and traditional production methods contributes to the preservation of the cultural heritage of rural areas; support for measures aimed at adapting to climate change and reducing the negative impact of agriculture on the climate.[5]

The EU's Common Agricultural Policy has a significant impact on sustainable agricultural development, as it takes into account economic, social and environmental aspects. Through financial support, rural development, and environmental initiatives, the CAP contributes to the creation of a sustainable and competitive agricultural system in the European Union.

The study of the impact of digital technologies on agriculture allows for a deeper understanding of the mechanisms and consequences of the transformation of the agricultural sector in the context of digitalisation. This helps to form the theoretical basis for further research in this area.[6]

Theoretical research allows us to create new models of agricultural enterprise management that take into account the use of digital technologies. This includes process optimisation, efficient use of resources, and sustainable development strategies.The theoretical analysis of the impact of digitalisation on the social structure of rural regions and the economic performance of the agricultural sector contributes to a better understanding of the social impact and economic efficiency of digitalisation.The study of the relationship between digitalisation and environmental sustainability of the agricultural sector helps to formulate new approaches to environmental protection and the rational use of natural resources.

CONCLUSIONS

Practical research allows for the development and implementation of specific digital solutions in the agricultural sector, such as precision farming, process automation, and the use of drones and sensors. This increases the productivity and efficiency of agricultural operations. The results of research can be used to develop policies and programmes to support farmers in adopting digital technologies. This includes funding, training, advice and infrastructure. The use of digital technologies helps to increase the competitiveness of agricultural enterprises in domestic and foreign markets by reducing costs and improving product quality. The practical application of digital technologies contributes to the sustainable development of the agricultural sector, reducing the negative impact on the environment and contributing to the conservation of natural resources.

The theoretical and practical significance of the study of the common agricultural policy of the EU countries in the context of digitalisation is to develop new management models, increase the efficiency and competitiveness of the agricultural sector, ensure sustainable development and create conditions for the socio-economic development of rural regions. Digitalisation of the agricultural sector helps to increase production efficiency, reduce costs and improve product quality. Innovative technologies help to optimise the use of resources, which contributes to sustainable development and environmental protection. The EU's Common Agricultural Policy provides financial and regulatory support for the introduction of digital technologies in agriculture. The introduction of digital solutions creates new jobs and opportunities for professional development of agricultural workers in the digitalised environment.

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SECTION EDUCATION, TRAINING, AND CAPACITY BUILDING IN GEOSCIENCES

IMPORTANCE AND IMPACT OF ENGINEERING AND ENVIRONMENTAL PROTECTION STUDY PROGRAMMES IN HEIS

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ABSTRACT

In today's fast-changing world, the link between engineering and environmental protection is very important for higher education institutions (HEIs). As global issues like climate change, resource loss, and biodiversity decline grow, there is an urgent need for professionals who have both technical skills and environmental awareness. These academic programs help create a skilled workforce that can design solutions focusing on ecological sustainability and promote teamwork, connecting engineering and environmental sciences. Therefore, HEIs should focus on combining engineering with environmental studies, as this approach leads to innovation and social responsibility, which are essential for tackling complicated ecological challenges. This enhances their educational experience and prepares graduates with the viewpoint needed to understand environmental stewardship within engineering. Importantly, these initiatives inspire students to see themselves as positive change-makers who can support sustainable practices in different industries. The value of these study programs goes beyond the classroom; they significantly impact societal perspectives on engineering and environmental ethics. As graduates leave HEIs with a solid grasp of both fields, they can shape policy decisions, lead corporate sustainability efforts, and help communities resist environmental harm. The benefits of this education can create a more informed public ready to tackle environmental challenges, making sure that the push for sustainability continues even after students graduate. Thus, merging engineering and environmental protection disciplines at HEIs is not just an academic task but a crucial commitment to building a sustainable future.

Keywords: education, engineering, environmental protection, students, university

INTRODUCTION

The connection between fields of engineering and caring for the environment is getting more important today due to global issues like climate change and the need for sustainable development. Engineering and Environmental Protection Study Programs aim to give students the skills and knowledge needed to create solutions for environmental problems, while also considering ethical, economic, and social aspects [1]. These programs usually take a multidisciplinary approach, using ideas from natural and applied sciences, social sciences, and engineering principles to build a complete educational system. This mix in the curriculum is key for encouraging creative thinking and flexibility in future engineers who will tackle difficult real-life challenges [2 - 3]. As stated in the ANDROID Disaster Resilience Networks roadmap, including resilience

in engineering education is vital for dealing with disaster risk management challenges, emphasizing the importance of these programs in training responsible professionals in the field. Therefore, a well-organized study program not only boosts technical skills but also encourages a sustainable mindset among graduates—making sure they can contribute positively to society and the environment [4 - 5].

The field of Higher Education Institutions (HEIs) is always changing, reacting to what society needs and global problems, especially in engineering and environmental protection. These schools help drive innovation and develop skills, preparing graduates to tackle urgent challenges like climate change and sustainable development. Research shows that the main research in quality management within HEIs is currently limited in both quantity and methods, reducing their potential effect [6]. Additionally, networks aimed at disaster resilience, such as the ANDROID network, highlight the interdisciplinary issues HEIs face to improve educational systems that include engineering and environmental studies. By focusing on these areas, HEIs are not just meeting market needs; they are also making sure that future workers have the skills needed to deal with social and environmental challenges.

Today, the need to deal with environmental problems has made Engineering and Environmental Protection Study programs at Higher Education Institutions (HEIs) more important [7 - 8]. These programs teach students technical skills for creating sustainable solutions and help them understand the social and ecological systems related to these solutions [9]. For instance, a study on Education for Sustainability (EfS) at Monash and Warwick Universities shows that stakeholders are more aware of sustainability issues and expect academic institutions to lead the way. Additionally, the importance of these programs goes beyond just schools, as seen with law placements in legal education; such programs allow students to connect with real-world situations and actively participate in their communities. Thus, these educational structures are a vital part of the larger movement towards resilience and sustainability, linking professional training to current environmental needs [10] .

Global environmental problems have led to a need to rethink curriculum design in higher education institutions (HEIs), especially in engineering and environmental protection fields [11-12]. As issues like climate change, resource depletion, and loss of biodiversity grow more serious, it is important for curricula to include sustainability skills to prepare future engineers for these difficult challenges. Recent changes in accreditation show this need by focusing on adding sustainable development ideas into engineering education [13-14]. This change not only matches with efforts by professional engineering organizations to promote environmental responsibility but also improves students' understanding of the socio-technical systems they will face in their jobs. Additionally, research shows that focusing on safety behaviours in construction work, based on safety psychology and work environment factors, can greatly help reduce accidents. Therefore, adding safety and sustainability topics into the curriculum is crucial for training professionals who can tackle complex global issues effectively [15-16].

MATERIALS AND METHODS

For this scientific article we used a mixed method, comparative one and analysis too, pointing out the relevance from the geosciences relevance of the topic.

The connection between educational results and skill growth is very important, especially in Engineering and Environmental Protection programs at Higher Education Institutions (HEIs). These programs not only get students ready for jobs right after they graduate but also help them succeed in their careers for a long time by giving them a broader view of their professional environments. The success of graduates should be assessed based on the unique circumstances in their fields, which highlights the importance of being adaptable in skills for effective entry into the job market. Additionally, prediction models—like the Safety Psychometric Model mentioned in show how psychological elements and environmental factors can affect safety behaviours and help shape engineering education. By building a strong educational system that combines theory with hands-on skill training, HEIs can improve graduates' abilities, which can lead to better job prospects and a beneficial effect on their industries.

The study programs in engineering and environmental protection at higher education institutions (HEIs) help develop important core skills that future workers need in a changing job market. With a wide-ranging curriculum that combines technical skills and a focus on sustainability, these programs prepare students with essential problem-solving skills, teamwork abilities, and a solid grasp of safety measures in construction settings, as shown in the Safety Psychometric Model. They also raise awareness about the social aspects of sustainable development, which is often ignored in typical engineering education. Researchers claim that if programs do not move from a technical-only approach to one that considers social issues, the full integration of sustainability ideas will be limited. Together, these skills allow graduates to effectively contribute to engineering and environmental protection fields, showing how vital these programs are in creating responsible and flexible professionals.

Bringing together different fields in engineering and environmental education is very important for tackling the tough problems of sustainability and climate change. These teaching methods combine technical skills with knowledge from social sciences, economics, and policy studies, helping students create comprehensive solutions for complex environmental challenges. As discussed in talks about sustainable governance, the complicated nature of these areas requires new frameworks that go beyond usual limits. Also, collaborative models in Open and Distance Learning (ODL) show how various professional skills can improve educational resources and support creative teaching methods that show how engineering and environmental sciences are linked. By connecting different fields, colleges and universities can prepare students with both technical and critical thinking abilities needed to deal with real-world environmental issues, which can help lead to a more sustainable future.

RESULTS

Moving from school to a job is getting harder but is important for graduates in engineering and environmental protection. A course of study that focuses on hands-on skills and abilities helps these graduates find jobs and be ready for their careers. Recent studies show there are big gaps in regular Science and Engineering programs, meaning graduates often do not have important skills, like applying what they know in the Testing and Certification (T&C) field. This problem shows the need for courses that connect learning with what businesses need. Also, looking at local job markets, especially in rural areas, shows that colleges and universities must adjust their programs

to fit what the community needs, which improves job readiness. So, changing how education is structured to include what industries expect helps not just with getting jobs but also supports long-term career growth in engineering and environmental fields.

The connection between engineering and environmental education is very important for community and nature results. By teaching students the skills and knowledge needed to solve difficult environmental issues, higher education institutions (HEIs) play a big part in creating strong communities and sustainable methods. For example, the ANDROID Disaster Resilience Network shows how important it is to use different fields to reduce disaster risk, showing that education can encourage proactive actions toward environmental dangers. Additionally, recent research on predicting safety behaviors in construction shows that knowing about human factors can greatly enhance workplace safety and lower environmental risk. These studies highlight how focused educational programs can change community health and environmental care. Therefore, it is essential to encourage a complete understanding of engineering and environmental protection for the steady growth of society.

Higher Education Institutions (HEIs) have an important part in supporting Sustainable Development Goals (SDGs) through focused study programs in engineering and environmental protection. These programs teach students about sustainable methods and help include sustainability ideas in many academic areas. For example, the update of the Partnerships for SDGs online platform stresses that working together with many groups is key to reaching these global aims, showing HEIs' crucial role in forming such partnerships ((Division for Sustainable Development United Nations Department of Economic and Social Affairs (DESA). Besides just theory, hands-on outreach projects allow students and faculty to work with local communities, creating a space for shared learning and putting sustainable practices into action. Research shows that while energy sustainability is often part of university operations, its inclusion in teaching and outreach is not fully addressed. Therefore, HEIs need to improve their courses and broaden outreach efforts to ensure they make important contributions to the SDGs, which will ultimately help both academic and local communities.

DISCUSSION

Colleges and universities (HEIs) have an important part in dealing with climate change and environmental damage through their Engineering and Environmental Protection Study programs. These programs give students the cross-disciplinary learning needed to understand the challenges related to sustainable development and gender equality, as shown in discussions about the links between these issues. In particular, women’s access to resources is important for reducing environmental effects. Research shows that when women are empowered, it helps not only communities become stronger but also leads to better environmental practices. Moreover, programs that focus on community adaptability in response to environmental changes are essential. The Colombian Temporary and Circular Labour Migration project, for example, shows how organized migration can ease environmental stress while promoting growth. Therefore, HEIs need to keep changing and updating their courses to meet these serious global issues.

The potential of engineering and environmental protection study programs in higher education institutions (HEIs) is shown through various successful projects that graduates have started. These case studies show creative solutions to important societal issues like climate change and using resources sustainably. For example, in Victoria, a

state dealing with an aging population and regional differences from fast growth, graduates have led projects that use technology to enhance service delivery and infrastructure connections. Such projects often show how the theoretical knowledge learned in school can be applied in real-world scenarios, achieving progress in fields like biotechnology and renewable energy. As graduates solve practical problems, their results not only prove the effectiveness of their education but also highlight the significant influence of these programs on the resilience and sustainability of local communities. This connection between education and real-world application emphasizes the crucial role of HEIs in developing a skilled workforce that is prepared to innovate and lead.

CONCLUSION

In conclusion, the important role of Engineering and Environmental Protection Study programs in higher education institutions (HEIs) is very significant. These programs not only give students key technical skills but also help them to understand safety behaviours and ethical practices that are important for their career growth. For example, the Safety Psychometric Model, which helps predict safety behaviours in construction workers, shows the importance of including psychology in engineering education. Additionally, as noted by the ANDROID Disaster Resilience Network, the increasing focus on disaster resilience education gets students ready to tackle serious environmental issues, which aligns closely with global efforts such as the Sendai Framework for Disaster Risk Reduction. As HEIs keep changing, it is crucial that these programs stay interdisciplinary and responsive to social needs to nurture a generation that can effectively promote both engineering and environmental protection efforts.

The analysis highlights the important role that Engineering and Environmental Protection Study programs have in colleges and universities, not just by tackling present environmental issues but also by training future leaders in sustainability. The detailed review of literature shows that quality management is crucial in these programs and that their success depends on engaging stakeholders effectively, especially students, whose input and experiences are vital for ongoing improvement. Additionally, findings from the ANDROID Disaster Resilience Network stress the need for cross-disciplinary methods in reducing disaster risks and building resilience, providing a model that can be included in engineering courses to improve both theoretical knowledge and practical skills. As a result, these programs not only equip students with technical skills but also develop a broader understanding of environmental responsibility, preparing graduates to face complicated global issues and aid in sustainable development.

Looking at the future of Engineering and Environmental Protection programs, it is essential to focus on changing fields like biotechnology and disaster resilience in the curriculum. The move toward sustainable innovation means that programs should not only prioritize new technology but also pay attention to social and governance issues. This is evident in the research about China’s biotechnology innovation system, which shows the need to connect social sustainability with tech growth. Additionally, the recent challenges in the ANDROID disaster resilience roadmap suggest a strong need for teamwork across different science areas to effectively tackle environmental risks. By building cooperative frameworks and highlighting how engineering connects with environmental and social factors, colleges can better prepare students to deal with

complex global issues, enhancing the importance and effectiveness of these programs in creating sustainable solutions for the future.

In summary, combining Engineering and Environmental Protection Study programs in Higher Education Institutions (HEIs) is not just a trend but an important step toward a sustainable future. These programs give students necessary skills and knowledge to tackle today's major environmental problems. By promoting teamwork across disciplines, these curricula inspire creative thinking and solutions that connect engineering practices with caring for the environment. Additionally, the focus on hands-on learning in these programs helps graduates apply theoretical ideas in real-life situations, which boosts their job readiness and positive impact on society. In the end, supporting and growing these programs in HEIs is key for developing a group of leaders who can make smart choices, drive tech progress, and support sustainability in both local and global settings. This vision not only improves personal career chances but also greatly aids in building societal strength and environmental well-being.

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THE IMPACT OF FOREIGN LANGUAGES ON ENVIRONMENTAL PROTECTION

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ABSTRACT

In modern society, the urgency for environmental protection has emerged as a significant global issue. The increasing recognition of the harmful impacts of climate change and pollution has triggered a heightened emphasis on sustainable practices and conservation efforts. Consequently, the importance of foreign languages in promoting environmental protection initiatives has attracted notice within academic communities. The application of language can affect attitudes towards the environment and induce behavioral changes that support sustainability and conservation. By examining the linguistic subtleties and cultural settings of environmental discourse, scholars can obtain an understanding of the various perspectives and practices that define environmental stewardship in different societies. Furthermore, analyzing the connection between foreign languages and environmental protection can foster a deeper comprehension of the relationship between language diversity and biodiversity. The loss of languages and the extinction of cultures are frequently linked with environmental deterioration, underscoring the necessity of preserving linguistic diversity as a component of comprehensive conservation efforts. By appreciating and advancing linguistic diversity, societies can also aid the preservation of ecosystems and natural habitats. Therefore, investigating the role of foreign languages in environmental protection provides a distinct viewpoint on the intricate relationship between language, culture, and the environment.

Keywords: foreign languages, environment, impact, protection, climate change

INTRODUCTION

The intersection of acquiring foreign languages and environmental stewardship extends past mere communicative obstacles. Investigations have indicated that individuals with proficiency in several languages tend to adopt environmental values and exhibit sustainable conduct more readily. This tendency is linked to their capability to access a broader spectrum of environmental knowledge and diverse viewpoints, consequently nurturing a profound bond with nature and an amplified global accountability. For example, research has demonstrated that polyglots show a higher propensity to engage in environmental activism and endorse conservation and sustainability policies. Further to this, foreign languages are instrumental in promoting international cooperation concerning environmental concerns. Given the interconnected nature of modern environmental issues, which surpass national limitations, proficient communication

becomes instrumental in addressing complications such as climate change, biodiversity depletion, and pollution.

The endeavour of foreign languages has significant bearings for worldwide environmental protection movements. By advancing communication via foreign languages, environmental messages can spread to a more extensive audience, breaking linguistic barriers and promoting international collaboration in addressing environmental issues [1]. Zhang, [2], emphasizes that the cultivation of cultural soft power, inclusive of foreign language expertise, is instrumental in forging a favourable international image and establishing an amicable global milieu for sustainable development. Recognizing how foreign languages impact the communication of environmental hazards, such as plastic pollution, is crucial for effectively engaging varied audiences and sparking collective action toward environmental preservation [2]. Viewing through the prism of foreign language soft power, the spread of environmental information can be enhanced, enabling individuals globally to partake in eco-friendly practices and aid in the planet's conservation. The adoption of foreign languages in environmental protection discourse not only aids knowledge exchange but also fosters cultural understanding and respect for diverse ecological issues [3, 4]. Li [5] points out that the strategic employment of foreign language skills in advancing cultural heritage and tourism initiatives, like coastal tourism, highlights the linkage between language adeptness and sustainable development endeavours [6 - 8]. By exploring how environmental threats are disseminated through foreign languages, insights can be accrued regarding the efficacy of message propagation and stakeholder participation in environmental conservation efforts [9 -10].

MATERIALS AND METHODS

We used for this scientific paper the analysis method, based on the background of all the authors and the research activity undertaken so far, but also comparison methods from different geographical areas.

Language functions as a powerful instrument influencing our perceptions and attitudes regarding the environment. As exemplified by educational undertakings in nations such as India, Brazil, Australia, and various western European states, integrating environmental education into language study programs holds critical importance for nurturing a sense of environmental duty among the youth. Language facilitates students not merely in understanding ecological principles but also in assimilating the significance of sustainability and conservation in their daily routines. This all-encompassing strategy towards environmental literacy signifies a worldwide acknowledgment of the essential role language occupies in instilling environmental attitudes from an early stage [11]. Additionally, the impact of language goes beyond structured education, influencing societal norms and values.

Foreign language education can be a conduit for students to engage with eclectic environmental perspectives and advocate for worldwide sustainable practices. Assisted by teacher-librarians and the critical scrutiny of multicultural, trans-cultural, and intercultural literature, as mentioned in [12], students can enhance not only their linguistic abilities but also their environmental awareness through exposure to various cultural and ecological narratives. Inclusion of environmental themes in foreign language curricula is imperative for shaping globally conscious individuals who can actively contribute to environmental conservation. As stressed by [1], use of visual

symbolism and rhetoric in media can provoke emotional reactions and elevate public involvement in environmental matters. By integrating environmental concepts into language educational contexts, teachers can enable students to become knowledgeable advocates for sustainability and environmental stewardship. Through a blend of diverse literary materials, critical analysis methods, and intercultural perspectives, foreign language programs can act as a foundation for nurturing a generation of environmentally conscious individuals poised to tackle the challenges of an interconnected globe while fostering a sense of global citizenship.

RESULTS

This research accentuates the value of embedding ecological subjects within language pedagogy to involve students and heighten their grasp of urgent global concerns. Extending this thought to foreign language pedagogy, it becomes discernible that language instruction could act as a medium for fostering eco-awareness and endorsing sustainability principles among learners. The convergence of linguistic education, social equity endeavors, and ecological mindfulness offers an unparalleled chance for universities to cultivate a comprehensive comprehension of world issues among their students. Additionally, as educational bodies endeavor to establish inclusive and fair learning milieus, infusing ecological sustainability themes into foreign language pedagogy resonates with the larger aims of advocating for equity and diversity on campuses. The inclusion of ecological sustainability topics in foreign language teaching not only improves linguistic expertise but also fosters a sense of world citizenship and accountability among learners. Drawing on the principles of agency, mediation, and internalization in SocioCultural Theory, exemplified in [13], teachers can craft language learning scenarios that enable students to interact with ecological issues substantially. This strategy not only provides students with the linguistic capabilities needed to thrive in a polyglot globe but also instills a profound insight into the nexus between language, culture, and environmental care. Through deliberate infusion of ecological awareness into linguistic curricula, academic establishments can significantly contribute to nurturing ecologically alert and socially conscientious global citizens.

To effectively implement global environmental initiatives, the role of cross-cultural communication is pivotal. Differences in culture significantly impact message perception and comprehension, hence making it essential for communication strategies to adhere to various cultural norms and values. For instance, direct communication may be preferred in some cultures, whereas indirect communication may be deemed more respectful in others. Grasping these subtleties is vital for fostering collaboration and cooperation among individuals from disparate cultural backgrounds. Additionally, language barriers can impede effective communication, underscoring the necessity for multilingual methodologies in global environmental efforts. Employing foreign languages enables organizations to reach an extensive audience and convey messages inclusively, ultimately resulting in heightened engagement and support for environmental initiatives. Additionally, in the context of global environmental initiatives, cross-cultural communication can aid in knowledge sharing and the exchange of best practices among different regions. By interacting with diverse perspectives and experiences, organizations stand to learn from successful environmental initiatives applied in other regions. This information exchange can bolster the effectiveness and sustainability of environmental projects, as insights gained

from cross-cultural interactions may ignite innovative solutions to intricate environmental issues. Furthermore, working alongside individuals from various cultural backgrounds encourages a holistic approach to environmental conservation, ensuring initiatives are devised to meet the specific needs and priorities of different communities.

In international environmental cooperation context, multilingual communication assumes a critical function in enabling collaboration and promoting comprehension among varying stakeholders. The importance of effective communication for disseminating information, idea exchange, and negotiating accords on significant environmental concerns is paramount. Capability in multiple languages permits participants to surmount linguistic constraints and better engage with individuals from disparate cultural orientations. Such ability is notably vital in worldwide environmental initiatives where nation-to-nation cooperation proves integral to addressing cross-border environmental challenges like climate change, biodiversity diminution, and contamination. Furthermore, engaging in multilingual communication within the sphere of international environmental cooperation betters transparency and accountability levels, ensuring that involved parties gain access to pertinent information and partake actively in decision-making endeavors. Easy access to information across varied languages enhances the chances of inclusive and representative decision-making. This contributes to fostering stakeholder trust, thereby promoting a sense of ownership and shared responsibility concerning collective environmental objectives. Consequently, multilingual communication not only aids in coordination and collaboration but also fortifies the legitimacy and efficacy of environmental policies and initiatives globally. To summarize, the significance of multilingual communication in the realm of international environmental cooperation is considerable. It serves as a fundamental instrument for encouraging dialogue, relationship-building, and advancing mutual understanding among diverse stakeholders. By dismantling language obstacles and facilitating meaningful interactions, multilingual communication supports cooperation, transparency, and inclusiveness in global environmental decision-making mechanisms. Hence, a forward-looking approach would be to prioritize language education and translation services investment to further international environmental cooperation and secure sustainable environmental results worldwide.

Integrating linguistic diversity into environmental research holds significance for apprehending Indigenous environmental knowledge. Language substantially influences the manner in which individuals perceive and engage with their environment, with Indigenous languages often embodying extensive vocabularies pertinent to describing ecological processes and nature connections. The inclusion of Indigenous languages within environmental investigations grants researchers access to invaluable insights and viewpoints that might otherwise be neglected. For instance, the Inuit language encompasses specific terminology concerning sea ice formations, facilitating a more detailed comprehension of climate change ramifications in the Arctic territory. Moreover, linguistic variety contributes to the preservation of Indigenous environmental knowledge which is essential for sustainable resource management and conservation endeavors. Numerous Indigenous communities maintain oral traditions and languages that convey knowledge pertaining to local ecosystems, flora and fauna, and climatic conditions. This knowledge, transmitted through successive generations, encompasses vital lessons in sustainable environmental practices. Nevertheless, with Indigenous languages facing the threat of extinction, an urgent necessity arises to document and

rejuvenate these languages to ensure the conservation of Indigenous environmental wisdom for forthcoming generations. Hence, the adoption of linguistic diversity within environmental research emerges as a fundamental element of cultural and ecological preservation efforts. Ultimately, recognizing linguistic diversity's role in comprehending Indigenous environmental knowledge is fundamental in fostering sustainable environmental protection methodologies. Acknowledging and integrating Indigenous languages in environmental research bolsters our understanding of native ecosystems, aids in adapting to climate change impacts, and reinforces cultural diversity and robustness. Safeguarding and revitalizing Indigenous languages not only preserves linguistic heritage but also ensures the ongoing transmission of invaluable environmental knowledge critical to effective conservation strategies. As environmental challenges persist, prioritizing linguistic diversity becomes imperative for enhancing collaboration with Indigenous communities and cultivating comprehensive approaches to environmental management.

DISCUSSION

Dissemination of info on environment through translation plays a significant role in making awareness and promoting actions friendly to environment. Risks to environment, like plastic pollution, need effective strategies of communication to engage public [1]. Visual representations in media forms like magazines — example: National Geographic — can evoke emotional reactions and push people towards action. To understand impact of visual rhetoric and image symbols in conveying risks to environment is crucial for communicators and designers to engage public effectively and inspire sustainable behaviors. Furthermore, influence of social, family, and educational environments on children’s acquisition of second language shows that immersive teaching modes for language learning are significant. Immersive language environments for children not only improve their language skills, but also enhance cognitive development and overall learning experience. Interconnections between environmental communication and language acquisition emphasize need for clear and engaging translations to spread info on environment effectively and foster a culture of environmental responsibility.

Concerning the promotion of environmental awareness utilizing social media and internet-based resources in varying languages, grasping the varied linguistic scenario is vital. With more than 6,000 languages worldwide, disseminating information in multiple languages is instrumental for extending reach and nurturing environmental understanding among diverse cultural groups. Through leveraging platforms such as Facebook, Twitter, and Instagram that accommodate multilingual content, environmental entities can adjust their messages to align with different language groups, thereby boosting the efficacy of their outreach undertakings. Also, the interactive characteristic of social media permits live engagement with followers, enabling discussions on notable environmental matters in diverse languages. This bilateral communication not only eases knowledge dissemination but also promotes active involvement and cooperation among persons from varied linguistic backgrounds. Furthermore, the incorporation of visually attractive content such as infographics, videos, and interactive maps can surpass language obstacles and present intricate environmental ideas in a more accessible mode, subsequently heightening audience engagement and comprehension. Moreover, the worldwide extent of social media and

internet-based resources offers a distinct chance to elevate awareness concerning environmental difficulties that surpass national boundaries. By exploiting multilingual platforms, environmental supporters can connect individuals globally in a united endeavor to tackle critical matters such as climate change, biodiversity depletion, and contamination. This interconnection nurtures a sentiment of global citizenship and mutual accountability for environmental management, emphasizing the significance of multilingual communication in advancing sustainable actions and fostering a balanced interaction between humanity and the planet [14].

CONCLUSIONS

In concluding, foreign languages impact on environmental protection exhibits significance and complexity. Through language, individuals advocate for environmental matters globally, encouraging collaboration and shared responsibility sense creation. Furthermore, proficiency in foreign languages provides access to broader resources and research array, aiding knowledge dissemination and best practices in environmental conservation. This underlines language's crucial role in bridging cultural and geographical gaps to address pressing challenges on our planet. Also, foreign language usage can raise awareness and appreciation for diverse ecological systems and conservation efforts worldwide. Engaging with different linguistic communities enables individuals to acquire unique perspectives and approaches to environmental sustainability. Such cross-cultural exchanges not only enrich environmental issue understandings but also promote innovative solutions transcending national borders. Therefore, foreign languages become powerful tools for promoting environmental stewardship and fostering global citizenship among diverse background individuals. In sum, integrating foreign languages into environmental protection initiatives holds vast potential for enhancing international cooperation and sustainability. Breaking communication barriers and fostering mutual understanding, language can trigger collective actions against climate change, biodiversity loss, and other environmental challenges. Policymakers, educators, and environmental advocates must recognize the intrinsic link between language diversity and environmental conservation, leveraging this connection to foster a more inclusive and effective global approach to environmental protection.

In summation, embedding themes of environmental sustainability in foreign language education not only enhances linguistic skill but also nurtures environmental accountability and global citizenship among students. By utilizing the intrinsic links between language, culture, and environmental subjects, educators can motivate learners to become changemakers in promoting ecological preservation and sustainability on a global scale. As foreign language instruction progresses, incorporating environmental subjects empowers individuals to manage intricate environmental issues, bolster cross-cultural comprehension, and champion a more sustainable future.

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ENVIRONMENTAL EDUCATION AS A HOLISTIC CULTURAL PHENOMENON IN THE PROFESSIONAL TRAINING OF FUTURE TEACHERS

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ABSTRACT

This article is dedicated to the topical issue of environmental education as a holistic cultural phenomenon in the context of the professional training of future teachers. Environmental education is considered as a multifaceted process that integrates ecological knowledge with cultural, social, and ethical aspects of the interaction between man and nature. The methodological basis of the study was based on the integration of three scientific approaches to the consideration of environmental education as a holistic cultural phenomenon in the professional training of future teachers, namely: cultural approach, which allowed to consider environmental education as a holistic cultural phenomenon and its impact on the formation of the general pedagogical culture of the future teacher; systemic approach, which provided a comprehensive study of environmental education, taking into account the interrelationships between the various components of the educational process; competency-based approach, which focuses on the formation of professional competencies of future teachers, guaranteeing a practical orientation in training specialists capable of solving environmental problems in their professional activities. The article presents the author's definitions of the concepts of " environmental education as a holistic cultural phenomenon", " environmental culture of the future teacher" and " environmental educational project". Descriptions are provided for the concepts of innovative projects for the development of environmental education and culture, implemented in pedagogical educational institutions of the Kirovograd region: "Green Campus," "Virtual Ecological Laboratory," "Eco-locations of the City of Kropyvnytskyi," "EcoArt," "Mini-farm." Recommendations are formulated for improving environmental education within the framework of the professional training of future teachers, including: compiling an "ecological portfolio of a young teacher", creating a virtual information space of ecological didactics, introducing ecological mentoring and introducing a special course "Ecological Culture". Conclusions have been drawn that hold theoretical and practical significance for the development of environmental education and culture of future teachers in the context of European integration processes in Ukraine.

Keywords: environmental education, future teachers, environmental educational project, culture, nature.

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INTRODUCTION

In the 21st century, society faces unprecedented environmental challenges, such as global warming, pollution of the environment with household waste, a shortage of clean drinking water, and the extinction of certain animal species. These challenges necessitate the cultivation of a respectful attitude towards nature and the formation of a new ecological worldview among young people.

Environmental education, as a pedagogical phenomenon, integrates knowledge from various sciences, including sociology, biology, economics, and ethics, which aligns with the culturological approach to education. Almost all environmental problems are problems of human behavior [8, p. 49]. Environmental research is based on a comprehensive understanding of the diverse environments of a system. This aims to make citizens competent in conducting scientific work and seeking practical knowledge to solve pressing environmental problems [9, p. 8]. Education is a key tool in shaping the environmental consciousness and nature protection culture of society, especially the younger generation. Preparing future teachers with a deep understanding of contemporary environmental problems and ways to solve them is critically important for effective environmental education in the context of Ukraine's European integration processes.

Therefore, considering environmental education as an essential component of modern youth culture allows for incorporating valuable, moral, ethical, and social aspects of human-nature interaction. International treaties, education standards, and national nature conservation documents emphasize the importance of developing environmental education and the need to implement it at all levels. In light of this fact, higher education pedagogy, which is based on the concept of sustainable development, requires the integration of ecological, economic, and social knowledge into the educational process of future teachers.

An analysis of recent research and publications (T. I. Voronenko, B. A. Dey, M. M. Dyachenko-Bogun, D. S. Ilies, O. M. Mandrik, F. Mogensen, L. M. Nevara, V. Voronkova, R. Oleksenko, V. Nikitenko) has shown that the problem of environmental education and the formation of the professional culture of future teachers remains insufficiently studied.

Therefore, this issue is extremely relevant for domestic professional pedagogy, as it necessitates the search for new approaches to ecology that provide an adequate response to contemporary societal and educational challenges, offering a comprehensive approach to preparing teachers capable of fostering a high environmental culture in the younger generation.

MATERIALS AND METHODS

Environmental education as a holistic culturological phenomenon in the professional training of future teachers is a critically important research area in the field of higher education pedagogy. It integrates ecological knowledge, values, and practices into the general cultural paradigm of education, shaping a new type of environmentally conscious teacher capable of not only imparting knowledge but also educating the younger generation to understand the interconnection between humans and nature,

develop strong environmental ethics, and be prepared to actively participate in solving global environmental problems.

The aim of the paper is to define the role of environmental education and develop recommendations for the implementation of educational projects in pedagogical educational institutions to form professional culture in future teachers.

The object of the study is the process of professional training of future teachers in the context of environmental education.

The subject of the study is environmental education as a holistic culturological phenomenon and its impact on the formation of professional competencies of future teachers.

The pedagogical experiment was conducted on the basis of pedagogical educational institutions of the Kirovohrad region: Volodymyr Vynnychenko Central Ukrainian State University, Kirovohrad Regional Institute of Postgraduate Pedagogical Education named after V. Sukhomlynsky, Oleksandriyskiy Pedagogical College named after V.O. Sukhomlynsky. About 150 respondents of the 2nd-4th courses were involved in the study.

The methodological basis of the study was based on the integration of three approaches to the consideration of environmental education as a holistic culturological phenomenon in the professional training of future teachers: cultural approach, which allowed to consider environmental education as a holistic culturological phenomenon and its impact on the formation of the general pedagogical culture of the future teacher; systemic approach, which ensured a comprehensive study of environmental education, taking into account the interconnections between the various components of the educational process; competency-based approach, which focuses on the formation of professional competencies of future teachers, ensuring a practical orientation in the training of specialists capable of solving environmental problems in their professional activities.

During the study, the following scientific methods were used: analogy method (for comparing and contrasting educational processes of forming environmental culture); logical-semantic method (for studying the interrelations between the subject and object of the study, making suggestions, substantiating conclusions); descriptive method (for describing the didactic categories of the study); praxeological method (during the development and implementation of educational projects for the formation of environmental education and culture in future teachers); experimental method - pedagogical experiment (for diagnosing knowledge about environmental education and the level of formation of environmental culture among respondents); mathematical and statistical method (for numerical processing of the results of the experiment, Student's distribution, arithmetic mean, establishing a correlation relationship between phenomena).

The comprehensive application of scientific methods made it possible to comprehensively study the problem of environmental education in the context of the professional training of future teachers, to develop and implement innovative projects, and to evaluate their effectiveness.

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RESULTS

Environmental education should focus on clarifying and developing values within the context of the students' own worldviews, allowing them to freely determine, adhere to, and justify their values [11, p. 13].

1. The Role and Significance of Environmental Education in the Professional Training of Future Educators

The primary aim of environmental education is to cultivate an ecological culture among individuals and society as a whole, fostering skills, ecological knowledge, ecological thinking, and consciousness based on an attitude towards nature as a universal and unique value [5, p. 26]. We propose an original definition of the concept of "environmental education as a holistic cultural phenomenon," which should be understood as a multidimensional educational process integrating environmental knowledge with cultural, social, and ethical aspects of human interaction with nature. Environmental education encompasses the development of environmental awareness, ethics, and aesthetics, the economics of natural resource use, and takes into account the historical, biological, and philosophical contexts of society's interaction with nature. It also promotes the formation of environmentally responsible behavior within the framework of the cultural norms and traditions of different peoples. Environmental education is aimed at raising a disciplined individual, capable of comprehending environmental challenges and making decisions in the context of sustainable development of society, as well as implementing projects with energy-saving technologies and rational use of natural resources.

In our opinion, the environmental culture of a future teacher is a complex characteristic of a pedagogue's worldview that combines deep knowledge of natural sciences, strong environmental values and norms of nature conservation behavior with professional pedagogical skills. A well-developed environmental culture reflects the teacher's ability not only to understand existing environmental problems and ways to solve them, but also to effectively transmit this understanding to their students, forming their environmental awareness and responsible attitude towards living and inanimate nature. Environmental culture manifests itself in the ability to integrate ecological aspects into the educational process of an educational institution, contribute to the development of ecological thinking and responsibility for their actions in future teachers, and implement the principles of sustainable development in pedagogical activity and daily life.

2. Project-based Learning as a Methodology forForming the Ecological Culture of Future Teachers

To integrate interdisciplinary knowledge, innovative methods and learning tools, that are implemented within the framework of educational projects, are used. The project method is a way to achieve a didactic goal through the detailed development of a problem, which should result in a tangible, practical outcome, presented in one form or another.

We shall define the term "environmental educational project" as a detailed plan of actions limited in time, combining teacher-guided theoretical training with the practical activities of their students to solve specific environmental problems or acquire new ecological knowledge and skills. Such a project is primarily aimed at forming ecological awareness, developing environmental competencies, and stimulating environmentally

responsible behavior in all its participants. An environmental educational project integrates interdisciplinary knowledge, utilizes innovative methods and teaching tools, engages participants in active interaction with the natural environment, thereby promoting a deeper understanding of ecological processes, the formation of sustainable development skills, readiness to implement energy-saving technologies, and a humane attitude towards living nature.

Within the framework of a pedagogical experiment conducted in 2022-2024 on the implementation of eco-projects, a survey among students of years 2-4 was conducted, and it showed: 23% of students are ready to participate in eco-projects, 35% of students are interested in a specialized course, 42% of students are unaware of environmental education.

It has been substantiated that the expected results of the formative pedagogical experiment aimed at developing environmental education and eco-culture among future teachers will include the following: raising the general level of environmental education among students; encouraging student initiatives and the generation of eco-projects; and forming a new cultural generation of specialists with a deep understanding of environmental problems and ways to solve them.

The concepts of projects aimed at developing environmental education and culture for future educators, which have been successfully implemented at Volodymyr Vynnychenko Central Ukrainian State University, Kirovohrad Regional Institute of Postgraduate Pedagogical Education named after V. Sukhomlynsky, and Oleksandriya Pedagogical College named after Vasyl Oleksandrovych Sukhomlynsky, include the following:

a) "Green Campus" - an ecological project during which students develop and implement environmental protection technologies to create an environmentally sustainable student campus, including filtration of centralized water supply, installation of energy-saving lamps and solar panels, planting vertical green areas in the corridors of the educational institution, designing an automatic irrigation system for flowerbeds and alleys.

b) "Virtual Environmental Laboratory" involves the creation of an educational computerized online platform for conducting virtual experiments during the study of disciplines "ecology", "biology", "geography", which allows modeling ecosystems, bioprocesses and predicting the consequences of human activity; students of various specialties can unite in circles to develop ecologically oriented startups under the mentorship of teachers, ecologists, and heads of practical training bases.

c) "Eco-locations of the city of Kropyvnytskyi" is a geographical and biologically oriented project for mapping, registering and preserving urban biodiversity. It involves creating an interactive mobile application to familiarize users with and monitor various species of flora, fauna, picturesque corners, cultural monuments, buildings of historical significance, museums, parks, squares, and gardens in the urban environment. This will be useful for ecologists, teachers, historians, tourists who are getting acquainted with the culture of the Kirovograd region.

d) "EcoArt" is a cultural and creative project during which students in the art studio create art installations, herbariums and decorations to raise awareness about the problems of pollution and conservation of wildlife, as well as organize the publication

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of wall newspapers about environmental problems and conduct student clean-up days to clean the green territory of the educational institution, promoting the preservation of flora and fauna of the Kirovograd region.

e) "Mini-farm" is an environmental protection project that involves creating a modular greenhouse with various sections at the educational institution for conducting scientific research on hydroponics, aeroponics and traditional soil cultivation of flowers, vegetables, fruits, introducing automated climate control, irrigation and lighting systems, during which future geography, biology, chemistry, and ecology teachers study modern methods of effective agriculture and develop a culture of respect for wildlife.

The main idea of these projects is to develop environmental education and culture among future teachers to prevent environmental pollution by the younger generation.

3. Methods and Means of Developing Environmental Education as a Holistic Culturological Phenomenon in the Professional Training of Future Teachers

Students vividly highlight environmental issues and the necessity of responsible attitudes towards the environment through discussions, presentations, and self-made films for elementary and middle school children. [2, p. 132]. Adequate and effective promotion of environmental education at the pre-university level necessitates cooperation between schools and local and regional institutions and governing bodies, such as universities [10, p. 131]. Mass media – radio, television, and the press – are utilized to raise environmental awareness [3, p. 73]. The visualization of educational information allows for solving several important pedagogical tasks: ensuring the intensification of learning; activating educational and cognitive activities; developing critical and visual thinking, visual perception; imaginative representation of knowledge and educational actions; knowledge transfer and image recognition; and enhancing visual literacy and culture [6, p. 70].

The results of the conducted pedagogical experiment revealed changes within the experimental group compared to the control group, indicating a positive trend in the development of knowledge regarding environmental education and a rise in the level of ecological culture among future educators. The willingness to participate in environmental projects increased by 17% (from 23% to 40%) among respondents due to the expansion of opportunities for practical participation in environmental programs and initiatives, the information campaign, and the involvement of students in project-based learning. Course attendance in the specialized course "Environmental Culture" grew by 15% (from 35% to 50%) due to the course's promotion, increased general awareness, and the integration of environmental education into the overall educational program for future teacher training. Improving environmental education and fostering ecological culture is a complex and responsible task.

To develop EE within the framework of professional training for future teachers, we propose considering the following recommendations:

- compilation of an "environmental portfolio" for young teachers containing implemented environmental projects and ideas, which would cultivate skills in self-analysis, critical thinking, and ecological reflection;

- creation of a virtual information space for environmental didactics, facilitating the development of innovative teaching methods for ecology and biology, fostering

creativity and ecological knowledge, and shaping methodologies for teaching natural science disciplines;

- implementation of ecological mentoring, based on a system of cooperation with experienced environmental practitioners to cultivate professional identity, practical skills, and communication competencies among teachers;

- introduction of a specialized course "Environmental Culture" into the curriculum, ultimately developing competencies in systemic thinking, strategic planning, and responsible management of natural resources.

Environmental education and upbringing aim to cultivate an internal sense of responsibility and duty towards all living things, as environmental preservation and human health are some of the most important categories within society's value system [1, p. 151]. Recent reforms in the Ukrainian education system bring it closer to the standards of the European Union, due to scientific and technological progress and the growing demands of employers for qualified specialists capable of implementing innovations [7, p. 359].

CONCLUSION

Environmental education as a holistic culturological phenomenon is a key factor in shaping the professional culture of future teachers and plays an integrative role within the education system, by combining environmental knowledge with cultural, social, and ethical aspects. The proposed original definitions of the concepts of "environmental education as a holistic cultural phenomenon," "future teacher's environmental culture," and "environmental educational project" expand the theoretical foundation of the research and contribute to a deeper understanding of the issue. Developed and implemented innovative ecological projects demonstrate the effectiveness of a practice-oriented approach in shaping the ecological culture of future teachers. The proposed recommendations for improving environmental education, including the creation of an "environmental portfolio," a virtual informational space, the introduction of environmental mentorship, and the special course "Environmental Culture," represent promising directions for the further development of professional teacher training. Consequently, integrating environmental education into the professional training of future teachers promotes their environmental awareness, the development of critical thinking, and a readiness to implement the principles of sustainable development in pedagogical practice.

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