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SADRŽAJ / CONTENT

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UVOD / INTRODUCTION

U Uvodnom delu se navode reference radova prethodnika sa kratkim komentarom. Takođe u tom delu treba pomenuti tematski povezane radove autora i koautora predmetnog rada. U Uvodu autori označavaju cilj rada i metododе naučnih istraživanja. Osim diskriptivnih metoda treba navesti metode komparativne analize, a takođe klasične dialektičke metode. U slučaju istraživanja u oblasti prirodnih i tehničkih nauka se primenjuju specijalne instrumentalne metode, gde je neophodna laboratorijska oprema. Statističke metode obrade podataka služe u svim oblastima naučnih istraživanja.

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U ovom delu se navodi opis uzoraka koji su uzeti na analizu sa naznakom lokaliteta. Neophodno je navesti oznake opreme, kao i tehnike i metode kojima su obavljene analize. U slučaju originalnih metoda autora treba priložiti opis metoda i opreme.U oblasti društvenih nauka neophodno je napomenuti, šta je predmet istraživanja.

2. REZULTATI I DISKUSIJA / RESULTS AND DISCUSSION

Tabele, slike, grafikoni i dr. mogu da budu u jednoj ili dve kolone. Iznad tabele treba da stoji naziv, npr.

Tabela 1 - Rezultati eksperimentalnih merenja

Ispod ilustracije treba da stoji objašnjenje, npr.: *Slika 1 - Rezultati simulacije procesa*

Nazive tabela i grafikona takođe dati na srpskom i engleskom jeziku.

Formule numerisati rednim brojevima u malim zagradama. Pozivanje na formule u tekstu vrši se navođenjem odgovarajućeg rednog broja u malim (okruglim) zagradama:

$$\overline{R_u} = L_4 + L_3 F_x \left(\frac{\overline{U_{pm}} - \overline{U_{gm}}}{\overline{U_{pm}^2}} \right) \tag{1}$$

U ovom odeljku se takođe vrši upoređenje rezultata koje su dobili autori s podacima iz radova navedenih u spisku referenci, što predstavlja osnovu diskusije.

ZAKLJUČAK / CONCLUSION

U Zaključku se sažeto navode rezultati istraživanja autora predmetnog rada.

Zahvalnica / Acknowledgements

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LITERATURA / REFERENCES

Literatura (skorijeg datuma: 2010. i novija) se u tekstu navodi prezimenom autora i godinom publikovanja: (Petrović, 2019), (Janković, Marković, 2020). U slučaju kad postoji više autora u tekstu se navodi samo prezime prvog autora: (Jovanović i dr., 2020) ili (Johnson et al., 2021). Reference u spisku literature se navode azbučnim (abecednim) redom:

Petrović, S. (2019). *Zaštita vodnih resursa*, Naučna knjiga, Beograd, 403 str.

Smith, G. (2020). Title of the article, *Chem. Phys.*, 65 (4), pp. 19-35.

Svi radovi podležu recenziji, a za originalnost, kvalitet i verodostojnost rezultata odgovorni su isključivo autori.

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U sve radove neophodno je uvoditi elemente istraživanja. U radove iz društvenog polja neophodno je uključivati komparativne metode, a takođe analize Studija slučajeva (Case Study).

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Digital transformation, smart innovation and sustainable development

Digitalna transformacija, pametne inovacije i koncept održivog razvoja

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Abstract: The contemporary economy is undergoing fundamental changes driven by digital transformation, a process that is altering lifestyles and redefining business principles across virtually all sectors of production without exception. Digital transformation implies a paradigm shift in business management, supporting and promoting increasingly sophisticated business models designed and driven by digital technologies. The goal of digital transformation at the macro level is sustainable economic growth, which takes into account the principles of the circular economy, emphasizes the significance of smart innovations as an appropriate response to the challenges posed by radical and disruptive changes in overcoming growth barriers in modern economies, recognizes the importance of economic resilience in countries, and raises awareness among people about their collective responsibility for preserving the stocks and flows of natural capital. Digital transformation must be viewed in a systemic context. It represents one of the components of a set of structural transformations, and therefore, it cannot be considered in isolation but must be understood in conjunction with numerous other structural changes in the economy and society.

Keywords: Digital transformation, Sustainable growth, Growth barriers, Smart innovation, Economic resilience.

Sažetak: Savremena privreda nalazi se usred suštinskih promena vođenih digitalnom transformacijom, procesa koji menja životni stil ljudi i redefiniše principe poslovanja kompanija gotovo u svim sektorima proizvodnje bez izuzetaka. Digitalna transformacija podrazumeva promenu paradigme u vođenju poslovanja podržavajući i afirmišući sve sofisticiranije poslovne modele dizajnirane i vođene digitalnim tehnologijama. Cilj digitalne transformacije na makro nivou je održivi ekonomski rast koji uvažava principe cirkularne ekonomije, akcentira značaj smart inovacija kao adekvatnom odgovoru na izazove radikalnih i disruptivnih promena u otklanjanju barijera rasta savremenih privreda, percipira važnost ekonomske otpornosti zemalja i podiže svest ljudi o njihovoj sveopštoj odgovornosti za očuvanje fondova i tokova prirodnog kapitala. Digitalna transformacija se mora sagledavati u sistemskom kontekstu. Dakle, ona predstavlja jednu od komponenti skupa strukturnih transformacija usled čega se ona ne može posmatrati izolovano, već isključivo u sadejstvu sa mnogim drugim strukturnim transformacijama privrede i društva.

Ključne reči: Digitalna transformacija, Sustainable growth, Barijere rasta, Smart innovation, Ekonomska otpornost.

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INTRODUCTION

Digitalization is the process of using digital technology to collect data from organizational processes and to perform activities using digital technologies to improve the business performance of economic entities in terms of productivity growth, quality, traceability, responsiveness, as well as better visualization and understanding of the logic of various processes and their position in the value chain of the organization (Goble, 2018). A good example of digitalization is the Industry 4.0 paradigm (Lasi, 2014).

Digital transformation signifies the widespread introduction of digital technologies into all areas of public and economic life that are important for the economic and social development of countries (Tabrizi et al., 2019; Vasyltsiv et al., 2022). It represents a new developmental paradigm that explains a series of economic, social, and cultural changes brought about by digital technologies, with the leading role of the Internet. Given the speed of development and the scope of digitalization's spread worldwide, many researchers consider it one of the most important phenomena of the twenty-first century (Zaki, 2019).

The strength of digital transformation lies in the creation and efficient transfer of knowledge as a key developmental resource, with a focus on demand and the establishment of new quality business models. To stay on top of the possibilities offered by digital transformation, enterprises and the economy as a whole must simultaneously pay close attention to the imperative of sustainable development (Reis et al., 2018). There is a prevailing view that the phenomenon of digital transformation marks the central occurrence of socio-technological changes in the present time (Legner et al., 2017; Schallmo et al., 2017).

The subject of the research in this paper is an attempt to illuminate the physiology of the impact of digital transformation on the emergence of smart innovations that function to overcome development barriers in most countries, caused by excessive consumption of natural capital and increasing climate changes. The process of digital transformation is viewed as a component of structural transformations necessary for achieving sustainable development goals and strengthening the economic resilience of national economies (Copestake et al., 2024).

Smart innovations are innovative solutions that incorporate certain intellectual properties (Waris, 2018). In this paper, they are primarily considered in the context of their role in eliminating growth barriers caused by the limitations of certain types of natural resources and the increasingly evident climate changes (Brad, 2022).

The concept of sustainable development began to be widely used at the end of the last century when a consensus was reached that economic growth, although still crucial, must be achieved in a different way, taking into account both human and environmental needs (Stojkov Pavlović & Jovanović, 2024). It is a complex and multidimensional phenomenon that combines efficiency, generational and intergenerational equality based on economic, social, and ecological aspects. It is the central concept of our time and represents a way to understand the world and a method for solving global problems (Saks, 2014).

Given that the character of the research is primarily socio-economic, the paper utilizes standard analytical tools of macroeconomic analysis, such as description, analysis, and synthesis methods. Additionally, in order to enhance the understanding of the interconnections of the phenomena being studied, graphical illustrations were also used.

The following hypotheses have been proposed:

H1: The limitations of certain natural resources and climate changes have become barriers to economic development in this century, even in innovation-driven countries.

H2: Through its stimulating impact on the creation and widespread application of smart innovations in value creation, the process of digital transformation has contributed to the realization of the vision of sustainable development.

RESEARCH RESULTS

Digital Transformation from a Systemic Perspective

Digital transformation implies a paradigm shift in business operations. It involves more sophisticated business models where value propositions, key processes, monetization, partnerships, market channels, and customer relationships are designed and driven by digital technologies. From this perspective, digital transformation can be seen as an action aimed at supporting production sectors where current business models have become obsolete and are unable to respond to the growing number of challenges. Digital transformation is applicable to any sector of the economy, ranging from education, healthcare, administration, entertainment, and sports, to energy, agriculture, food production, construction, finance, consulting, etc., and even the IT sector.

Digital transformation is just one part of broader structural changes and is simultaneously influenced by a set of numerous other modifications, as shown in Figure 1. Structural changes must lead to increased production activities. However, it is an indisputable fact that sustainable economic growth occurs

under the condition that global productivity increases through the improvement of the competitiveness of microeconomic entities (Cvetanović & Andrejević Panić, 2024). Positive interventions at the macro level that make the economic environment more stimulating for business development are important, but they do not guarantee the achievement of competitive superiority.

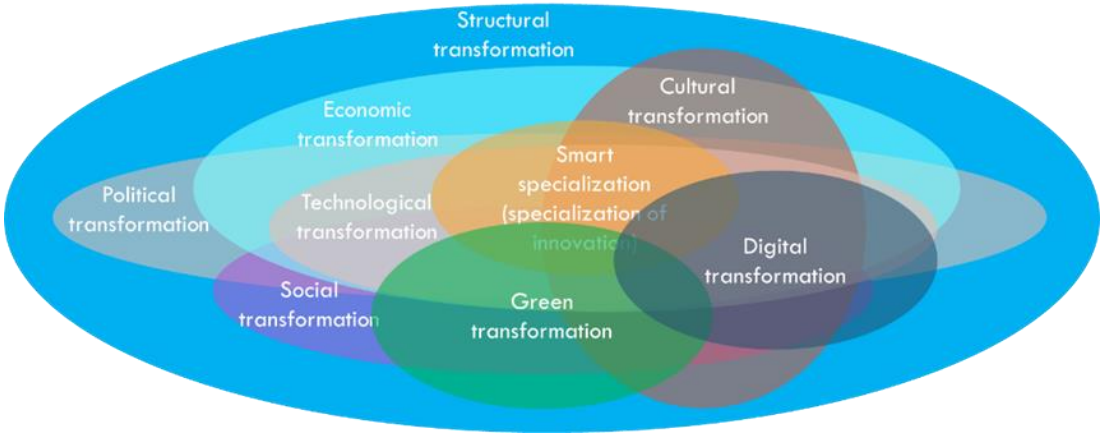

Figure 1. Key Forms of Structural Transformations
Source: Brad, 2022

Digital transformation implies a paradigm shift in business management. This change is reflected in increasingly sophisticated business models in which all key processes, market channels, and customer relationships are designed and driven by digital technologies. From this perspective, it can be said that digital transformation supports the functioning of areas where business models, due to obsolescence, cannot effectively respond to new challenges.

Answering the posed question requires first identifying areas where the need for structural transformations arises. The ultimate goal of digital transformation must be sustainable economic growth (Stahel, 2016), smart specialization of jobs (Hassink & Gong, 2019), and increasing the economic resilience of the country to various crisis disruptions (Simmie & Martin, 2010), while achieving prosperity at the social level (Cieplinski, 2021) and a collective human responsibility for the preservation of natural capital (Brad, 2019). This leads to intelligent management of all development factors (natural, financial, human, technological), which implies the ability of all actors (policy makers, managers, employers, citizens) to reconcile numerous contradictions regarding the use of limited resources, on the one hand, and achieving maximum results in an ethical, responsible, and ecologically sustainable manner, on the other (Raworth, 2017; Andrejević Panić et al., 2024).

Trends in Digital Transformation

Digital transformation is a process with an encompassing character, affecting nearly all areas of the economy and society. Table 1 presents an overview of the presence of various technological solutions in significant trends in digital transformation, highlighting both the positive effects and the potential negative consequences of their increasingly widespread use.

All the technologies mentioned have the potential to increase business productivity, whether the technological solutions listed in Table 1 are used separately or in combination. The exclusive challenge is deciding on a specific technological solution. In short, digital technologies can stimulate innovation growth and improve the performance of businesses and countries, provided their application is appropriate.

Table 1. Trends in digital transformation

Technologies	Description	Positive Impacts	Negative Implications
Implantable Technologies	Devices implanted into the human body	Health monitoring, tracking children	Privacy threats, data security issues
Wearable Internet	Technologies integrated into clothing and accessories, connected to mobile phones	Rational decision-making, better management of daily activities	Privacy threats, data security issues, addiction

Internet of Things (IoT)	Connecting devices to the internet through sensors and corresponding applications	Increased productivity, improved quality of life, better security, new business creation	Privacy concerns, job losses, security threats
Smart Cities	Using sensors and platforms to manage energy, material flows, logistics, and traffic	Increased productivity, improved quality of life, lower crime rate, better mobility, improved access to education	Privacy concerns, system collapse risks, cyber attacks
Big Data	Managing and using large amounts of data for automated decision-making and customization	Faster decision-making, cost savings, new job categories	Job losses, privacy concerns, questionable data trust and ownership
Driverless Cars	Vehicles using technology for autonomous driving	Improved traffic safety, reduced environmental impact, better mobility for elderly and disabled people	Job losses, cyber attacks, reduced public transport revenue
Robotics	Use of robots in design, construction, and other operations	Increased efficiency and precision, reduced human error in industrial processes	Job losses, cyber attacks, reduced public transport revenue
Blockchain	Distributed trust mechanism designed to track transactions	Increased transparency, financial disintermediation	Lack of trust, fear of unregulated markets, potential financial risks
Sharing Economy	Exchange of physical goods, assets, or services	Expanded access to resources, better use of assets	Abuse of trust, increase in precarious employment contracts, growth of the informal economy
3D Printing	Creating physical objects by printing layer by layer from digital designs	Accelerated product development, growing demand for personalized products, design innovations	Piracy, potential for producing illegal body parts or weapons, safety threats

Source: Pihir et al, 2018

Limitations of natural resources and climate change as barriers to growth in conventionally innovation-driven economies

The question arises as to how digital transformation can contribute to intensifying economic growth amidst the manifestation of many developmental barriers, especially those related to the limitation of natural resources and the increasingly evident climate changes. At the same time, one must never lose sight of the fact that the ultimate goal must be sustainable development (Stahel, 2016). Sustainable development should result in the opening of new jobs, better-paid positions, economic diversification, business expansion, improved quality of life, and increased government revenue.

There are economies where most business models are driven by basic factors (e.g., primary agriculture, outsourcing business processes, contract labor in the textile industry, software outsourcing, mining, forest exploitation, etc.). In other economies, business models in manufacturing sectors are driven by productivity factors. In a third group, growth and development in businesses are predominantly driven by innovation. Every national economy is a mix of these three models, but with differences in their size and intensity. In some economies, there is dominance of one of the three sectors or models of creating economic value. Various events over time undermine the sustainability of the dominant production model. This phenomenon forces some manufacturing sectors to transform and adopt advanced business models to ensure survival in the market. In principle, in these production models, the significance of solutions based on knowledge and smart innovations increases compared to production models based on basic factors, productivity-driven models, and even innovation models promoted in the last third of the 20th century.

During the first decade of this century, numerous limiting growth determinants became more pronounced, even in innovatively driven economies worldwide. The limitation of certain natural and energy resources became an increasingly significant problem for uninterrupted economic activity, while the consequences of increasingly evident climate issues seriously shook development models based on innovations in products, processes, organization, and marketing, understood in their conventional meanings. This is some-

what dialectically understandable, as over time, a period emerged in which knowledge became the key resource for the emergence of new technological solutions, and logically, also for the economic and social progress of countries. The commercialization of knowledge into innovations - knowledge as a unique, unlimited resource that cannot be replaced by other production factors - has made innovations increasingly embody the attributes of smart innovation.

In the economy of innovation, it is well-known that the development of every technological paradigm follows the S-curve trajectory. In the initial period, the application and development of new technology face numerous barriers. By eliminating these barriers, its widespread application grows over a longer period. After the saturation point, there is a change in the dominant technological pattern (Figure 2).

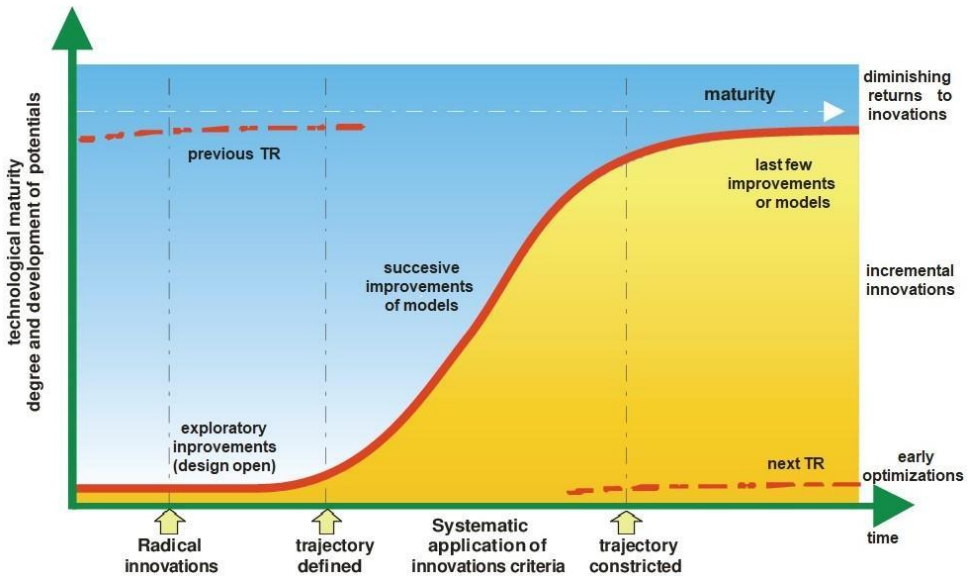

Figure 2. Technological S-curve. Technological Revolution (TR)
Source: Cvetanović et al., 2012: 154

Innovations that predominantly shape the design of the existing technological paradigm acquire the status of a key developmental factor. Sectors playing a leading role in their application and commercial valorization represent the most dynamic production sectors in the observed economy. Therefore, the phenomenon of innovation in the knowledge economy and the imperative of sustainable development must be examined from the perspective of their contribution to enhancing the economy's resilience against the growing number of challenges threatening its functional stability.

This transformation is inextricably linked to the increasing application of “smart innovation” (Figure 3). Unlike previous production models shaped by numerous incremental and radical innovations, smart innovations respond to changes arising from barriers that have proven resistant to prior “non-intelligent” innovative solutions. As shown in Figure 3, these barriers include the scarcity of certain natural resources, climate change, planetary sustainability, and similar global challenges. Mitigating the negative consequences of these crises necessitates a comprehensive process of digital transformation (Brad, 2022).

Even though economic growth is the engine of the economy, it should not be an end in itself but rather a means of creating social welfare, taking into account its implications for natural ecosystems. Simply put, the consumption of natural capital exceeds all socially acceptable norms, and the emission of pollutants into the natural environment is more than unacceptable.

In this context, digital transformation makes sense only if it is directly correlated with the ecological, economic, and social dimensions of sustainable development. Furthermore, the process of digital transformation must be viewed as part of a broader set of structural transformations necessary to support this goal, rather than in isolation. In essence, digital transformation must contribute to the economic resilience of individual national economies.

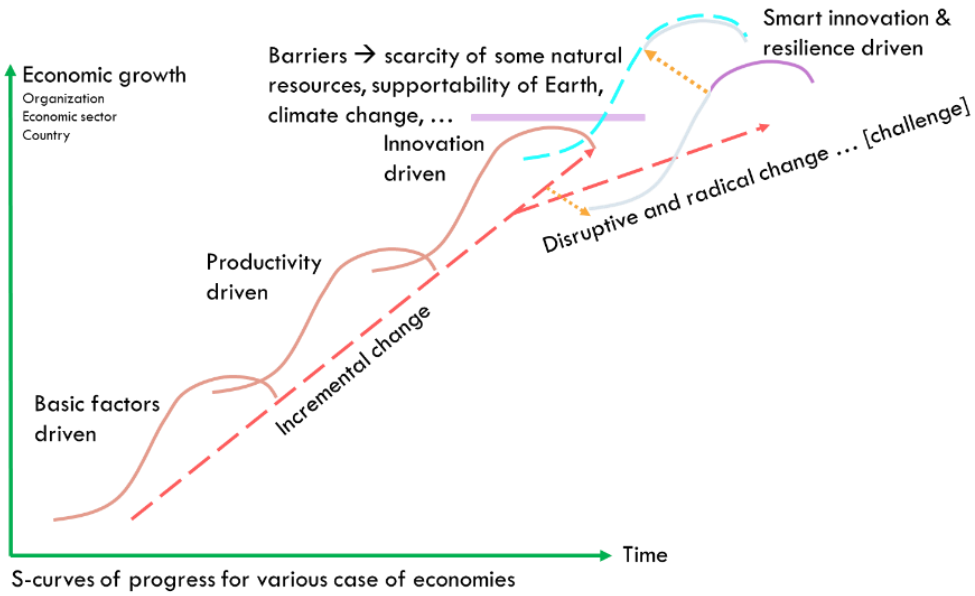

Figure 3. Equilibrium trajectory of economic progress of countries depending on dominant technological solutions (Source: Brad, 2022)

Smart ecological innovation – a key driver of sustainable growth in the digitalized economy

Some national economies are facing the challenge of transitioning from an innovation-driven economic growth model to a growth model based on smart innovation. This is primarily because high total costs make business operations in innovation-driven economies unprofitable across many industrial sectors. In short, due to high capital intensity, the use of many earlier and current innovations is associated with the emission of negative extern-alities from the systems in which they are implemented.

For example, fossil-fuel-powered cars and airplanes are radical innovations, but their widespread use is accompanied by the emission of numerous air pollutants. Nuclear power plants have contributed to the reliable supply of electricity to consumers but at significant environmental protection costs and with catastrophic consequences in cases of technical failures. Similarly, the widespread use of the internet has revolutionized information dissemination but has also introduced harmful side effects, such as threats to privacy, manipulative mass influence, and the spread of low-quality information (Brad, 2022).

These observations suggest that, under current economic conditions, innovations must increasingly be evaluated through the lens of sustainability and economic resilience. This shift represents the emergence and affirmation of so-called soft innovations. A growing number of innovative products, services, and processes are becoming increasingly “intelligent”, enabling some national economies to transition to a developmental phase no longer solely based on innovations but rather on soft innovations (Figure 2).

A special category of smart innovations is smart ecological innovations, which provide new ways to address contemporary environmental protection challenges. These innovations involve the application of eco-efficient smart technologies. Eco-efficient technology directly or indirectly improves environmental quality. This includes technologies that reduce pollution, create more environmentally friendly products and production processes, ensure more efficient resource management, and implement technological systems that are less harmful to the environment (Kasztelan et al., 2020).

Compared to S-curves of progress, which typically follow incremental evolution, smart innovations involve more disruptive shifts and radical changes, as they must provide adequate responses to challenges such as resource scarcity, climate change, and global sustainability. Additionally, addressing the increasing frequency of economic disruptions necessitates comprehensive digital transformation across economies.

Digital transformation is meaningful only when aligned with sustainable economic growth and social inclusion. This process must be viewed as an integral part of broader structural transformations required to meet sustainable development goals and should never be addressed in isolation. Moreover, digital transformation must function as a component of a resilient economy, contributing to the enhancement of national economic resilience.

The development of economic digitalization fundamentally reshapes the economic structure. The

intensity of digital transformation exhibits a “snowball effect”, altering consumer preferences and behaviors on one hand and simultaneously improving productivity and operational efficiency on the other (Singgalen et al., 2019; Lincaru et al., 2018). Digital transformation redefines the competitive environment for today’s enterprises. Strategic management must recognize and leverage the opportunities presented by digital transformation to quickly translate them into competitive advantages (Bonnet, Vesterman, 2021).

Digital transformation is one of the primary drivers of contemporary economic and social development (Vlasov et al., 2019). By intensifying their digital transformation efforts, countries can create significantly more attractive environments for business establishment and operations (Liu, 2022). Digital technology forms the core of economic activity and value creation. Nearly all economic interactions can be driven by digital technologies, which serve as a catalyst for global economic development and an engine for economic growth (Feng et al., 2019).

Sustainable economic development is critical for national economies as it fosters job creation, expands well-paid employment opportunities, diversifies industries, promotes business growth, enhances competitiveness, and improves overall quality of life (Barbier, 2007; Hammer & Pivo, 2017).

Furthermore, the digitalization of economies and societies supports the implementation of circular economy principles and enhances overall resilience to economic shocks. The core idea of the circular economy concept is to replace the unsustainable linear economy model due to natural resource constraints, waste accumulation, inadequate waste management, and environmental damage caused by this model. The key aspects of the circular economy concept include: (1) resource recycling, (2) a multidimensional approach, (3) achieving sustainable development, and (4) close interconnection with societal innovation (Prieto-Sandoval et al., 2017).

CONCLUSION

Digital transformation is one of the primary drivers of contemporary economic and social development. By intensifying their digital transformation efforts, countries can create significantly more attractive environments for establishing and sustaining business operations.

Highlighting the importance of smart innovations in overcoming development barriers, even for countries whose economic growth relies on traditional notions of innovation, digital transformation offers practical solutions for policymakers at local, regional, and national levels, aligned with the knowledge economy framework.

When viewed in this context, digital transformation is meaningful only if it enhances smart innovativeness, which directly and indirectly impacts not only the economic but also the environmental and social dimensions of sustainable development. Moreover, this process must be understood as part of the broader structural transformations essential for supporting sustainable development goals and improving the economic resilience of individual national economies.

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Peculiarities of heavy metals accumulation by *Cladochaeta candidissima* under conditions of the polymetallic biogeochemical provinces in the territory of the North Ossetia

Osobenosti akumulacije teških metala kod *Cladochaeta candidissima* u uslovima polimetalnih biogeohemijskih provincija na teritoriji Severne Osetije

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Abstract: The content of heavy metals (Pb and Cd) in *Cladochaeta candidissima* plants in North Ossetia is variable and, as a rule, depends on their content in soils. The studied plants are not Pb accumulators, although they contain relatively high concentrations of this element in places of lead anomalies. But, naturally, they reflect its content in the soil and can help identify the dispersion halos of this element. We have established for the first time that *Cladochaeta candidissima* accumulates cadmium and has a high phytoremediation potential. It can be used in environmental monitoring of soils and phytoremediation of anthropogenic landscapes of North Ossetia contaminated with both Cd and Pb.

Keywords: accumulation, lead, cadmium, heavy metals, trace elements, plants, phytoremediation.

Sažetak: Sadržaj teških metala (Pb i Cd) u biljkama *Cladochaeta candidissima* u Severnoj Osetiji je promenljiv i po pravilu zavisi od njihovog sadržaja u zemljištu. Ispitivane biljke nisu Pb akumulatori, iako sadrže relativno visoke koncentracije ovog elementa na mestima anomalija olova. Ali, prirodno, one odražavaju njegov sadržaj u tlu i mogu pomoći u identifikaciji oreola disperzije ovog elementa. Po prvi put smo utvrdili da *Cladochaeta candidissima* akumulira kadmijum i ima visok fitoremedijacioni potencijal. Može se koristiti u ekološkom monitoringu zemljišta i fitoremedijaciji antropogenih predela Severne Osetije kontaminiranih sa Cd i Pb.

Ključne reči: akumulacija, olovo, kadmijum, teški metali, elementi u tragovima, biljke, fitoremedijacija..

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INTRODUCTION

In North Ossetia, in the Ardon River basin, the Sadon group of lead-zinc polymetallic deposits is concentrated. Long-term mining in this area has had a negative impact on the environment. The consequences of the activities of the Mizur Mining and Processing Plant and the storage of waste in the Unal tailings dump, located near the village of Nizhny Unal, have led to significant pollution of the environment with heavy metals. In this regard, there is an urgent need for phytoremediation of contaminated areas. The main task is to search for plants - accumulators and indicators of soil pollution in order to identify the dispersion halos of such toxicants as lead and cadmium. We have found that *Cladochaeta candidissima* plants growing in those places contain high concentrations of lead and cadmium (Ermakov et al., 2018, 2018a) Therefore, in connection with the issues of phytoindication and phytoremediation of polluted landscapes, we studied the ability of this plant to accumulate heavy metals in areas with different levels anthropogenic pollution.

1. MATERIALS AND METHODS

The object of the study was *Cladochaeta candidissima*, a perennial herbaceous plant of the Asteraceae family, common in the Northern and Eastern Caucasus, as well as in Transcaucasia (Golubev, 2021). The plant is densely white-tomentose. The stems are straight, 10-40 cm high. The leaves are alternate, entire, lanceolate or oblong-lanceolate, sessile. The baskets are yellowish, collected in a dense corymbose inflorescence. The fruit is an achene. The distribution of *Cladochaeta candidissima* plants was studied using the route method in the Ardon River basin in the Alagir District of North Ossetia. The total length of the sampling area was more than 50 km, including the section from the village of Nizhniy Zaramag to the city of Alagir. In the surveyed area, samples of the above-ground part of *Cladochaeta candidissima* plants and soils from the root part were collected in natural and man-made landscapes with varying levels of lead and cadmium pollution. For each sampling point, the coordinates were noted: latitude and longitude (Tables 1, 2). The elements in the above-ground organs of plants collected during the vegetation phase and dried at room temperature were analyzed. The dried plants were ground in an A11 basic IKA electric mill with a tungsten knife. The soils were ground in an agate mortar to a powder state (grain size ≤ 200 mesh).

The trace elements in plants and soils were determined through atomic absorption spectrometry (AAS) using KORTEK LLC devices both in the flame and flameless versions of the assay folloving standard methods (GOST, 2013; M-MVI-80-2008). The spectrometer was calibrated using RF standard plant composition samples including SP-1,SP-2 and SP-3.The accumulation of elements in the objects of study was also judged by the value of the coefficient of biological accumulation (CBN), which was calculated using the formula: C = element content in dry biomass plants (mg/kg) / element content in soil (mg/kg). With a C value of ≥1, plants were considered as accumulators (concentrators) of chemical elements.

2. RESULTS AND DISCUSSION

Cladochaeta candidissima is found scattered in North Ossetia from the foothill plains to the mid-mountain belt. It grows in the arid Unal basin, along dry stream beds and rubble areas, as well as in the Ardon River basin on coastal pebbles and sands (Golubev, 2021). Of the surveyed territory (from the village of Nizhniy Zaramag to the outskirts of the city of Alagir), in the Ardon River basin we found only in the area from the village of Nizhniy Unal to the city of Alagir. The plants are found sporadically, but in places of growth, as a rule, they form extensive thickets.

Lead content in plants and soils

It was found that lead and cadmium predominate in the soils of almost all sites in the upper horizons. Soil analysis showed a very high content of heavy metals in the urban soils of the vicinity of the village of Nizhny Unal (Table 1,2).

As a result of soil sampling at experimental sites in the area of the Unal tailing dump, the oscillation limits for lead ranged from 255 to 2202 mg/kg (Table 1).

Based on the fact that the maximum permissible concentrations of lead for soils in Russia are 32 mg/kg (Hygienic standards, 2006), the soils of man-made sites have very high values of lead content, orders of magnitude higher than the maximum permissible concentrations (Table 1). Soil contamination with lead was reflected in the level of its accumulation by *Cladochaeta candidissima* (Table 1). At the same time, the lead content in plants varied from 4.5 to 41.7 micrograms/g. Considering that the permissible values of lead in plants vary from 0.1 – 6 mg/kg according to different sources, it is easy to see that the level of lead reached high

values and exceeded the maximum permissible concentrations by 1.5-7.5 times in man-made sites (№ 3,4,5,8,11).

The concentrations of this element in the studied plants in relatively background areas ranged from 2.4-6.9 mg/kg, and in some areas corresponded to the norm (Table.1). It is noted that the maximum values for the content of this element relate to plants growing near the main source of pollution – a tailings dump. As a result of comprehensive studies conducted over a large area and on a large amount of factual material, we have established that *Cladochaeta candidissima* does not belong to plants accumulating lead (The coefficient of biological accumulation = 0.013 – 0.384), but only "reflects" its content in soils.

*Table 1 – Lead content in soils and plants of Cladochaeta candidissima**

№	Sampling location	Coordinates GPS	Pb, mg/kg	CBN
1.	Nizhny Unal village. The first terrace of the left bank of the Ardon River.	N42º51.456´ E 44º08.223´	5,4 / 417,6	0,013
2.	The Unal depression, above the Unal tailings pond. On the pebbles of the right bank of the Ardon River.	N42º51.473´ E 44º08.438´	4,5 / 255	0,017
3.	The Unal depression, above the Unal tailings pond. The pebbles of the left bank of the Ardon River.	N42º51.590´ E 44º08.607	21 / 478,8	0,044
4.	The Unal depression basin, above the Unal tailings pond. Above-floodplain terrace on the left bank of the Ardon River.	N42º51.614´ E 44º08.621´	10,5 / 448,2	0.023
5.	The Unal depression basin, above the Unal tailings pond. On the pebbles of the right bank of the Ardon River, 5 meters from the water's edge.	N42º51.776´ E44º08.811´	41,7 / 2202	0,019
6.	Surroundings of Nizhny Unal village. Next to the tailings dump. Alluvial soils of the right bank of the Ardon River.	N42º52.294´ E 44º09.353´	0,9 / 61,80	0,014
7.	On the banks of the Ardon River (between the village of Zintsar and the village of Biz).	N42º 54.219´ E 44º10.370´	3,6 / 63,60	0,056
8.	Surroundings of Biz village. The bank of the Ardon River.	N42º54.955´ E 44º10.871´	45 / 117	0,384
9.	Between the village of Biz and the village of Tamisk	N42º55.856´ E 44º11.698'	2,7 / 107,40	0,025
10.	Tamisk. The bank of the Ardon River.	N42º57.303´ E 44º12.784´	3,6 / 171,6	0,021
11.	Between the village of Tsementny and the city of Alagir. Industrial area. Stony areas.	N43º 00.373´ E 44º13.515´	6,9 / 64,8	0,106
12.	Coastal sands and pebbles in the floodplain of the Ardon River near the town of Alagir	N43º 01.505´ E 44º13.940´	2,4 / 58,2	0,041
13.	The city of Alagir. Alluvial soils of the Ardon River.	N43º01.930´ E 44º14.128´	2,4 / 58,2	0,041

*Note: the numerator is the lead content in *Cladochaeta candidissima* plants, the denominator is the lead content in soils; CBN is the coefficient of biological accumulation.

Cadmium content in plants and soils

As a result of soil sampling and analysis in the area of Unal tailing dump it was shown that the limits of variation for cadmium ranged from 1.80 to 66.0 mg/kg (Table 2).

*Table 2 – Cadmium content in soils and plants of Cladochaeta candidissima**

№	Sampling location	Coordinates GPS	Cd, mg/kg	CBN
1.	Nizhny Unal village. The first floodplain terrace of the Ardon River.	N42º 51.456´ E 44º08.223´	2,79 / 1,80	1,55
2.	Unal depression, above the Unal tailing pond. Pebbles of the right bank of the Ardon River.	N42º51.473´ E 44º08.438´	2,80 / 1,85	1,51
3.	Unal depression, above the Unal tailing pond. Pebbles of the left bank of the Ardon River.	N42º51.590´ E 44º08.607´	2,97 / 3,72	0,79
4.	Unal depression, above the Unal tailing pond. Upland terrace of the left bank of the Ardon River.	N42º51.614´ E 44º08.621´	6,00 / 5,22	1,15
5.	Unal depression, above the Unal tailing pond. On pebbles on the right bank of the Ardon River, five meters from the water's edge.	N42º51.776´ E 44º08.811´	5,90 / 14,22	0,41
6.	The vicinity of Nizhny Unal village. Near the tailing dump. Alluvial soils of the right bank of the Ardon River.	N42º52.294´ E 44º09.353´	2,58 / 66,0	0,04
7.	The bank of the Ardon River. Between the village of Zintsar and the village of Biz.	N42º 54.219´ E 44º10.370´	3,30 / 1,50	2,20
8.	The outskirts of Biz village. On the bank of the Ardon River.	N42º54.955´ E 44º10.871´	1,14 / 0,36	3,17
9.	Between of Biz villages and Tamisk	N42º55.856´ E 44º11.698´	4,95 / 0,72	6,87
10.	Tamisk. The bank of the Ardon River.	N42º57.303´ E 44º12.784´	2,97 / 0,32	9,28
11.	Between the village of Tsementny and the city of Alagir. Industrial area. Stony areas.	N43º 00.373´ E 44º13.515´	2,70 / 0,36	7,50
12.	Coastal sands and pebbles in the floodplain of the Ardon River near the Alagir town.	N43º 01.505´ E 44º13.940´	2,34 / 0,24	9,75
13.	Ardon River floodplain. Alluvial soils. Near the Alagir town.	N43º 01.930´ E 44º14.128´	1,68 / 0,23	7,30
14.	Alluvial soils of the Ardon River outside the Alagir city.	N43º 03.889´ E 44º 14.603´	2,22 / 0,54	4,11

*Note: the numerator is the cadmium content in *Cladochaeta candidissima* plants; the denominator is the cadmium content in soils; CBN is the biological accumulation coefficient.

Based on the fact that the approximate permissible concentrations of cadmium for soils of populated areas in Russia is 0.5 mg/kg (Hygienic standards, 2009), the soils of technogenic areas have very high values for cadmium content, which are orders of magnitude higher than the approximate permissible concentrations (Table 2, №1-6). As the distance from the mining industry area increases, a decrease in cadmium content to approximate permissible concentrations and below is observed in the upper soil horizons (Table 2, № 7-14).

Soil contamination with cadmium was reflected in the level of its accumulation by *Cladochaeta candidissima* plants (Table 2). The cadmium content in plants varied from 1.14 to 6.0 mg/kg. Considering that the permissible values of cadmium content both in plants and in preparations produced on their basis vary from 0.03 to 1 mg/kg (Galenko et al., 2021; Hygienic requirements, 2002), it is easy to see that the level of cadmium content in *Cladochaeta candidissima* in the study area reached very high values and exceeded the maximum permissible concentrations by 6 to 38 times. Concentrations of this element in the studied plants in relatively background areas varied within the range of 1.14 to 4.95 mg/kg. These data differ relatively insignificantly from similar data on cadmium concentration in plants taken from heavily polluted man-made areas near the Unal tailings dump (2.58–6.0 mg/kg), which indicates a high adaptive potential and cadmium-accumulating capacity of *Cladochaeta candidissima* plants. The high efficiency of cadmium

accumulation by plants is indicated by the biological accumulation coefficient, which decreased with an increase in cadmium concentration in soils (Table 2).

High concentrations of the element were also observed in plants growing on soils with relatively low cadmium content (CBN = 2.20 – 9.75). The highest accumulating capacity of plants was demonstrated in soils with a low content (0.24-0.72 mg/kg), the biological accumulation coefficient was 9.75 and 6.87, respectively, which indicates a high phytoremediation potential of plants. The lowest accumulative capacity of *Cladochaeta candidissima* was observed at higher soil concentrations of this element from 0.54 to 1.85 mg/kg. The values of the biological accumulation coefficient were 4.11 and 1.51, respectively (Table 2). At very high values of cadmium content in soils 3.72 to 66.0 mg/kg, the accumulative capacity of plants was not pronounced (corresponding CBN values = 0.79 and 0.04). This is due to the fact that plants of this species can withstand cadmium stress enhancement up to certain values due to an increase in the content of antioxidant defence components (Sanita di Toppi, Gabrielli, 1999). When the study objects were exposed to very high concentrations of cadmium, presumably, the ability of plants to photosynthetic assimilation of CO_2 decreased, oxidative stress developed as a result of increased formation of reactive oxygen species and changes in the function of a number of antioxidant enzymes, i.e. imbalance of antioxidant defence components was observed.

CONCLUSION

In conditions of polymetallic biogeochemical provinces in North Ossetia, high content of lead and cadmium in soils and plants of *Cladochaeta candidissima* was observed in comparison with conditionally background areas. The highest concentrations of lead were found in plants growing near the main source of pollution - the Unal tailing dump. On conditionally background areas the concentrations of this element in plants are orders of magnitude lower. The content of lead in plants of *Cladochaeta candidissima* is variable and, as a rule, depends on its content in soil. Despite the fact that in places of lead anomalies *Cladochaeta candidissima* contains relatively high concentrations of this element, it is not a concentrator of lead. But, it naturally reflects its content in the soil. Using a large amount of factual material, we have established for the first time that *Cladochaeta candidissima* accumulates cadmium, has a high phytoremediation potential, and can be used in ecological monitoring of landscapes polluted with both cadmium and lead.

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Organizational culture as the foundation for responsible business: a path to sustainability

Organizaciona kultura kao temelj odgovornog poslovanja: put ka održivosti

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Abstract: In the contemporary business environment, companies face increasing demands to establish practices that support sustainability and social responsibility. Organizational culture plays a crucial role in this process, as it shapes values, norms, and behaviors within the company, directly influencing its ability to respond to ecological, social, and ethical challenges. This paper explores the relationship between organizational culture and sustainability principles, highlighting how a culture focused on responsible business practices can enhance company performance in areas such as environmental protection, ethics, and social responsibility. Additionally, the impact of organizational culture on sustainability assessments is analyzed, using EcoVadis as an example of an evaluation framework. The investigation shows that a culture that values sustainable practices can serve as the foundation for long-term success, strengthening the company's ability to create value for all stakeholders.

Keywords: sustainability, responsible business, organizational culture, corporate social responsibility, EcoVadis..

Sažetak: U savremenom poslovnom okruženju, kompanije se suočavaju s rastućim zahtjevima za uspostavljanjem praksi koje podržavaju održivost i društvenu odgovornost. Organizaciona kultura ima ključnu ulogu u ovom procesu, jer oblikuje vrijednosti, norme i ponašanje unutar kompanije, direktno utičući na njenu sposobnost da odgovori na ekološke, socijalne i etičke izazove. Ovaj rad analizira povezanost između organizacione kulture i principa održivosti, primjenom Cameron-Quinnovog modela organizacione kulture, sa posebnim naglaskom na način na koji kultura usmjerena ka odgovornom poslovanju može unaprijediti performanse preduzeća u oblastima zaštite životne sredine, etike i društvene odgovornosti. Takođe, analiziran je uticaj organizacione kulture na ocjenjivanje održivosti preduzeća, koristeći EcoVadis kao primer evaluacionog okvira. Ispitivanje pokazuje da kultura koja vrednuje održive prakse može biti temelj dugoročnog uspeha, jačajući sposobnost kompanije da stvori vrijednost za sve zainteresovane strane.

Ključne riječi: održivost, odgovorno poslovanje, organizaciona kultura, društvena odgovornost, Eco Vadis.

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INTRODUCTION

In contemporary markets, constant changes and uncertainties occur, positioning companies in situations where they must continually face new challenges and seek solutions that ensure responsible and sustainable business operations. Under such circumstances, companies are increasingly expected to meet stakeholder demands across all aspects of their business activities.

Particular attention is directed toward sustainable development and socially responsible business practices. Beyond achieving profitability, companies are expected to manage responsibly, adhere to the highest ethical standards, maintain transparency, and foster fair relations with both internal and external stakeholders. In this context, organizational culture plays a crucial role as it shapes the values, attitudes, and behaviors within the company, thereby directly influencing the organization's capacity to respond to environmental, social, and ethical challenges.

Additionally, companies are expected to minimize their negative environmental impact and contribute to societal welfare. Environmental, social, and ethical performance - or sustainability - has become a key factor for successful business in the present context. Companies face increasing pressure to enhance transparency and adopt sustainable development practices.

1. APPROACH TO SUSTAINABLE DEVELOPMENT AND RESPONSIBLE MANAGEMENT

The concept of sustainability within policy was first introduced in the Brundtland Report in 1987, which addressed the tensions between humanity's aspirations for improved quality of life and the limitations imposed by nature. Over time, this concept has expanded to encompass three key dimensions: social, economic, and environmental.

In recent years, major corporations have joined development agencies and organizations that promote sustainable development. The growing commitment of senior managers to concepts such as corporate citizenship and social responsibility indicates that the business sector is increasingly redefining its relationship with the environment and its stakeholders. This shift in approach marks a significant departure from earlier perceptions, where large corporations were often viewed as contributors to serious environmental degradation.

Business sustainability, as part of this transformation, can be observed through responsible management in areas such as finance, quality, human resources, environmental protection, ethics, and contributions to the local community. All these dimensions can be measured through relevant indicators, allowing for progress tracking and affirmation of responsible business practices (Zlatanović et al., 2022).

1.1. Sustainable business practices

Sustainable business practices encompass the implementation of new technical solutions, reporting on activities that contribute to sustainability, employee training, and the adoption of new knowledge that promotes sustainability. Employees need to be convinced that ethical and responsible business practices can benefit both them and society. Sustainable business enhances organizational profitability and improves the quality of life for employees and their families (Kitsios et al., 2020).

Organizations do not operate in isolation; their activities impact society just as society influences them. Only responsible and sustainable organizations can contribute to community prosperity. Sustainable business necessitates collaboration between the public, private, and civil sectors.

The main reasons for implementing sustainable business practices include government regulations, community interpersonal relationships, moral and social obligations, and financial incentives. Compliance with laws and regulations is mandatory for organizations, as violations can lead to significant financial losses, reduced productivity, and even business prohibitions. Additionally, non-compliance can harm an organization's reputation.

Non-governmental organizations and the general public demand that companies reduce their negative impacts on the environment and society. Understanding the importance of social and environmental issues is essential for stakeholder relations and business continuity (Upward & Jones, 2016; Joyce & Paquin, 2016).

Integrating environmental and social issues into business operations improves a company's competitiveness and revenue. Innovations and technologies that protect the environment mitigate the negative consequences of production, increase revenue, and enhance market reputation. Sustainable business practices also reduce operational costs and the risk of fines for non-compliance, achieving the economic aspect of sustainability. Thus, sustainable business is always a sound choice, and managers should integrate environmental and social issues into their strategies, aligning them with the organization's mission and values while also meeting consumer and community needs.

2. ECOVADIS: MEASURING SUSTAINABILITY AND CORPORATE SOCIAL RESPONSIBILITY

EcoVadis is a global platform focused on assessing the sustainability and corporate social responsibility (CSR) of enterprises. This platform provides companies with analyses and ratings of their environmental, social, and ethical performance, allowing them to identify strengths and weaknesses in their business practices (Grdinić et al., 2023).

EcoVadis is distinguished by its comprehensive approach to sustainability assessment, encompassing the analysis of policies, activities, and achievements in areas such as environmental protection. The sustainability evaluation involves a detailed review of a company's policies, actions, and results concerning environmental issues, labor rights, ethical practices, and sustainable supply chain management. The assessment is conducted in four main areas: Environmental, Social, Ethical, and Sustainable Procurement. EcoVadis boasts an extensive network of users and assessors worldwide, enabling companies to benchmark their performance against peers.

Following the evaluation, companies receive reports containing recommendations for improvement. Additionally, successful companies may obtain certification that attests to their level of sustainability. This information assists companies in enhancing their processes, meeting stakeholder expectations, and contributing to more sustainable business operations.

EcoVadis has become a popular tool for companies seeking to bolster their reputation in CSR and sustainability and to meet the expectations of clients and investors who demand high standards in these areas (Vuohijoki, 2023; Varzandeh et al., 2023; Cash, 2020; Schwarzkopf et al., 2021).

3. ORGANIZATIONAL CULTURE AND ITS IMPLICATIONS FOR MODERN BUSINESS

Organizational culture represents how tasks are performed within an organization (Quinn & Rohrbaugh, 1983). It encompasses the mindset and behavior of employees, directly influencing organizational performance. Hofstede (2001) defines organizational culture as the collective programming of the mind that distinguishes the members of one organization from those of another. It includes values, beliefs, and norms developed through shared experiences, guiding thought and behavior. Organizational culture is the sum of values and rituals that serve as the "glue" for integrating organizational members (Mukhopadhyay & Mukhopadhyay, 2020). It also involves socio-cultural activities, recurring patterns, work methods, as well as sets of myths, symbols, and shared behaviors (Chatman & Choi, 2022; Scott & Allen, 2023). Despite varied definitions, they share the common understanding that organizational culture arises from acquired knowledge and experience, contributing to the creation of a distinct organizational environment.

Organizational culture is often studied and linked to various aspects of business activities, with particular emphasis on analyzing its impact on these segments. When considering innovation, organizations with cultures that foster innovation achieve significant improvements in product development and business processes, directly enhancing their competitiveness (Aparisi-Torrijo et al., 2023; Cherian et al., 2020). From the perspective of organizational agility, cultural dimensions such as knowledge sharing and coordination significantly contribute to increased organizational agility, enabling rapid responses to change and improved business outcomes (Budur et al., 2024; Syifa & Ahman, 2022). A positive organizational culture also improves employee satisfaction, reduces burnout, and enhances the work environment, contributing to greater efficiency and employee well-being (Inegbedion et al., 2020; Chan et al., 2022). Regarding leadership, it can be concluded that leadership aligned with a positive organizational culture enhances overall organizational performance and contributes to gender balance in management structures (Nguyen et al., 2023; Daher-Moreno & Arnold, 2024). The impact of organizational culture on sustainability is reflected in aligning the organization with the goals of sustainable development, including environmental, economic, social, and cultural aspects (Assoratgoon & Kantabutra, 2023; Trifunović, Lalić & Tankosić, 2023; Ali et al., 2024).

Organizational culture can be classified in various ways depending on the aspects being considered. Deal and Kennedy's (1982) classification based on the degree of risk and feedback time identifies: The Tough-Guy, Macho Culture; Work Hard, Play Hard Culture; Bet-Your-Company Culture; and Process Culture. According to the Competing Values Framework (Cameron & Quinn, 2011), organizations can be classified based on their orientation towards stability and control or flexibility and innovation, leading to four main types: Hierarchical Culture, Market Culture, Clan Culture and Adhocracy Culture. Handy's (1995) classification by power distribution and orientation towards people/tasks differentiates: Power Culture, Role Culture, Task Culture, and Support Culture. These classifications help better understand the various types of organizational cultures and their impact on employee behavior and organizational success.

4. ORGANIZATIONAL CULTURE IN THE CONTEXT OF SUSTAINABLE BUSINESS

4.1. Dimensions of organizational culture and their impact on sustainable business

Organizational culture and sustainability represent two critical factors shaping the long-term success of enterprises in the contemporary business environment. Sustainability is increasingly recognized as an integral component of business strategies, while organizational culture serves as the foundation for implementing these strategies in the organization's day-to-day operations. The connection between organizational culture and sustainability is becoming more significant, given that cultural factors can greatly influence how an organization approaches environmental, social, and economic challenges.

Effective sustainable business practices result from strategic and carefully planned management, involving a complex process tailored to the requirements of sustainability. Managerial knowledge, expertise, and skills are essential for selecting relevant information and making optimal decisions that enable an organization to achieve economic growth and sustainable development. Such decisions encompass responsible resource management, environmental protection, active contribution to community development, and the building of healthy and productive interpersonal relationships within the organization.

Business operations and management are subject to numerous external and internal factors. External factors are challenging to influence and require management to understand them thoroughly and align their actions accordingly. National culture is a notable external factor. Internal factors originate within the organization itself, over which management has control and can direct them toward achieving organizational goals.

National culture, with its underlying values, affects all elements of an organization. Leadership styles, employee motivation, organizational structure, and the culture of the organization are influenced by national cultural characteristics. Sustainable business practices and management involve decentralization of decision-making, flexible organizational structures, and a forward-thinking culture. Leadership styles vary across cultures. According to Hofstede (2001), cultures can be categorized based on four fundamental dimensions: Power Distance, Individualism versus Collectivism, Uncertainty Avoidance, and Masculine versus Feminine Values. Among these dimensions, Power Distance has the most substantial impact on leadership style, and consequently, on sustainable business. In high power distance cultures, an authoritarian leadership style prevails, whereas in low power distance cultures, a democratic leadership style is more common. In high power distance cultures, leaders often retain control and centralize decision-making, which can lead to power misuse and neglect of employees' opinions and contributions. This centralization can limit transparency and open communication, negatively affecting sustainable practices as broader community and environmental interests are often overlooked. Conversely, in societies with low power distance, democratic leadership encourages openness and employee participation. Employees have greater freedom to express their ideas and engage in decision-making processes, fostering innovative and responsible practices. This collective approach enables decisions to be made considering diverse perspectives and long-term goals, directly contributing to sustainable business. Transparency and collaboration in such environments enhance the likelihood that organizations will adopt practices supporting ecological, social, and economic sustainability aspects.

In individualistic cultures, emphasis is placed on achieving personal goals and independent work, often leading to rational and calculative relationships between employees and the organization. Leaders are task- and result-oriented, with less focus on building interpersonal relationships. This approach can result in neglecting employee well-being and reduced loyalty, potentially hindering sustainability. When employee needs are overlooked, motivation and engagement decline, adversely affecting long-term sustainable development goals, such as talent retention and collective responsibility for social and environmental aspects.

On the other hand, collectivist cultures emphasize harmonious relationships and team spirit. In these cultures, the relationship between individuals and the organization is often based on ethical and emotional values, where leaders focus on the well-being of the group. Such leadership promotes collaboration, support, and shared responsibility, contributing to sustainable business practices. Employees are motivated to act in the collective's interest, enhancing engagement and contribution to socially responsible initiatives. In such an environment, sustainability becomes not just an objective but part of the organizational culture and values, positively impacting long-term success and stability.

Cultures characterized by "masculine" values, according to Hofstede's cultural dimensions theory, prioritize competition, material success, and individual achievement. In such settings, priorities often shift towards profit maximization and productivity,

potentially at the expense of social and environmental business aspects. This orientation can impede sustainable business practices, as short-term goals and competitive advantage are prioritized over long-term employee well-being and environmental protection.

Conversely, "feminine" cultures emphasize interpersonal relationships, community care, harmony, and overall quality of life. In this context, leaders and organizations value cooperation, empathy, and work-life balance. This orientation encourages sustainable business practices by supporting policies that address social responsibility, environmental issues, and employee well-being. In "feminine" cultures, business strategies focus more on long-term objectives that consider the needs of all stakeholders, contributing to organizational stability and sustainable development.

The dimension of uncertainty avoidance reflects how comfortable a society feels in uncertain or unfamiliar situations. In cultures with low uncertainty avoidance, people and organizations are more open to change, innovation, and experimentation. These cultures exhibit greater tolerance for risks and unknown circumstances, allowing them to adapt quickly to new trends, technologies, and sustainable business practices. Changes are seen as growth opportunities, aiding organizations in adopting sustainable practices that involve new ideas and approaches.

In contrast, high uncertainty avoidance cultures tend to prefer stability, rules, and predictability. These cultures often perceive changes as potential threats, leading to resistance toward new initiatives and innovations. Organizations operating in such environments may face challenges when attempting to implement changes that support sustainable business, as rigidity and fear of the unknown can restrict flexibility and adaptability. This reluctance to change may result in conflicts with the environment, reduced responsiveness to ecological or social challenges, and ultimately threaten long-term sustainable business operations.

Sustainable business requires changes in the way organizations operate and individuals behave (Geissdoerfer et al., 2016). In conclusion, sustainable business depends on various factors, among which national culture plays a crucial role. National culture shapes the organizational structure and its ability to implement sustainable strategies, as evidenced by research. Understanding cultural dimensions, such as uncertainty avoidance, enables organizations to tailor their approaches, overcome barriers, and establish sustainable practices aligned with the specific context in which they operate.

4.2. The role of organizational culture in developing sustainable business strategies through the competing values framework of Cameron and Quinn

As previously mentioned, organizational culture consists of shared values, norms, beliefs, and behaviors among organizational members. When an organization fosters a culture emphasizing the importance of sustainability, it can profoundly influence its daily operations, strategies, and long-term development. In such organizations, employees are motivated and encouraged to participate in initiatives that reduce negative environmental impacts, promote social responsibility, and enhance the economic aspects of business. During the 1990s, organizational culture began to play a pivotal role in researching sustainability within a corporate context. For a seamless transition, organizations must cultivate a culture that supports sustainability and actively work to improve their sustainability practices. Evidence suggests that identifying cultural elements that facilitate or hinder organizational sustainability is essential for achieving corporate sustainability (Pennington & More, 2016).

A sustainable organizational culture, though variably defined (Ketprapakorn & Kantabutra, 2022), consistently highlights the balance between social, environmental, and economic objectives as a crucial factor in fostering organizational awareness. Kantabutra (2021) argues that such a culture is particularly effective in achieving sustainable outcomes. According to the definition presented in this study, a sustainability-oriented organizational culture is characterized by shared basic assumptions, values, and beliefs that shape the organization's behavior through corporate decision-making and practices (Ketprapakorn & Kantabutra, 2022). The ultimate goal of sustainable development is to cultivate a culture that contributes to the long-term sustainability of the enterprise.

By analyzing Cameron and Quinn’s (2011) Competing Values Framework in the context of sustainability, we can observe how different types of organizational cultures shape approaches to sustainable business practices. This model classifies organizations into four fundamental cultural types: hierarchical, market, clan, and adhocracy. Each of these cultures has a specific impact on the implementation of sustainability principles, as they focus on different aspects of the organization - from control and stability, characteristic of the hierarchical culture, to flexibility and innovation, encouraged in the adhocratic culture. Understanding these cultural dimensions helps identify how organizations align their strategies toward sustainability based on their cultural values and organizational goals.

Hierarchical Culture: This culture emphasizes stability, control, and efficiency. In the context of sustainability, organizations operating within a hierarchical culture may focus on compliance with regulatory frameworks, resource optimization, and waste reduction through standardized processes and procedures. The sustainable practices of these organizations typically concentrate on operational efficiency and controlled processes that minimize environmental impact.

Market Culture: Organizations with a market culture are oriented toward efficiency, competition, and goal achievement. Regarding sustainability, these organizations may seek to reduce costs through energy savings, green technology, and innovations in production processes. Although sustainability here is often viewed as a competitive advantage, market-driven organizations may adopt sustainable practices to enhance their market position and reputation.

Clan Culture: Clan organizations value teamwork, community, and mutual support. When it comes to sustainability, organizations functioning within a clan culture often encourage employees to work collaboratively on initiatives that have a positive social and environmental impact. These organizations may develop sustainable business models that include social responsibility, investment in the local community, and the promotion of a green culture among employees.

Adhocracy Culture: Adhocratic organizations prioritize innovation, flexibility, and creativity. These organizations often enhance sustainability by developing new technologies, products, and services that address environmental issues and respond to market demands for sustainable solutions. Sustainable approaches in adhocratic cultures frequently involve research and development of innovative solutions that reduce environmental impact while simultaneously creating new markets and business opportunities.

By analyzing this model, we can conclude that organizations seeking to integrate sustainability into their business processes must develop a culture that aligns with their goals, values, and strategies. Each of these cultures offers specific advantages in implementing sustainable practices, and their successful application depends on the organization's ability to create synergy between its values and sustainable objectives.

5. THE CONNECTION BETWEEN ORGANIZATIONAL CULTURE AND ECOVADIS SUSTAINABILITY RATINGS

Linking organizational culture with EcoVadis principles (or environmental responsibility) can be highly beneficial in the context of modern business, as both areas aim for sustainability and responsible operations, albeit with different focal points. An organization that cultivates a culture emphasizing environmental and social responsibility shapes its strategies and operations to reflect ecological, social, and ethical business aspects, which are fundamental for achieving high ratings on the EcoVadis platform.

An organizational culture that prioritizes values such as transparency, ethics, respect for human rights, and anti-corruption enables sustainability principles to be integrated not just into daily business practices but also to be recognized by external partners and suppliers. For instance, an organization that promotes eco-friendly initiatives, efficient resource use, recycling, and the use of environmentally sustainable products establishes a strong foundation for enhancing its market image and achieving favorable evaluations on the EcoVadis platform.

Employees play a pivotal role in upholding environmental and social responsibility. When an organization fosters a culture that motivates employees to actively participate in sustainable practices - through initiatives like volunteerism, improving production processes to reduce environmental impact, or sustainability-focused innovation - it directly influences the organization’s overall rating. Such employee engagement not only benefits society and the environment but is also reflected in improved EcoVadis scores, enhancing the organization’s competitive standing.

Sustainable innovation, significantly shaped by organizational culture, is also essential for achieving high ratings. Organizations that continuously develop new products, services, or business models that minimize environmental impact and advance social responsibility recognize the value of these initiatives, not just internally, but also through external evaluations like EcoVadis. EcoVadis acknowledges such innovations as indicators of commitment to sustainability, leading to better outcomes and a stronger competitive advantage.

Finally, an organizational culture embedded with the core principles of responsible business permeates all aspects of an organization's daily operations, from high-level decision-making to employee

behavior. These values are reflected in EcoVadis ratings, which provide external partners, investors, and stakeholders with a clear view of the organization's approach to sustainability. Organizations that successfully integrate a culture of sustainability not only enhance their business practices and relationships with partners but also create long-term sustainable models that positively impact the broader social and environmental community.

CONCLUSION

Sustainable business today is a fundamental concept for ensuring the long-term viability of organizations in the modern business landscape. Understanding and integrating the environmental, economic, and social dimensions into business strategies are essential for an organization's success and survival. This approach requires active participation from all sectors of society, including public, private, and civil sectors, to maintain a balance between economic profit, environmental protection, and social well-being.

Organizational cultures that promote values of sustainability, ethics, and responsibility enable enterprises to adapt to the demands of sustainability and contribute to the development of positive practices. Managers play a crucial role in implementing strategic decisions that encompass these principles and facilitate economic growth through responsible business conduct. Research findings indicate that organizations with a well-developed culture of sustainability achieve higher efficiency and competitiveness, while also reducing costs and risks associated with non-compliance.

National culture, with its value system, influences the formation of organizational structures and leadership styles, which can be critical factors in the adoption of sustainable practices. Organizations in societies with low power distance and a flexible approach to change have greater potential for integrating sustainable strategies. Therefore, fostering an organizational culture that encourages participation, transparency, and environmental awareness supports long-term sustainable development.

In conclusion, the implementation of sustainable business practices is not only economically justified but also ethically and socially necessary. Managers and leaders must possess the knowledge and skills needed to recognize opportunities for integrating sustainability into business and to engage in strategic planning that meets the needs of employees, consumers, and the community.

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Standarding the action of microelements based on the methodology of the integration system of soil-plant operational diagnostics of plant nutrition ("ISPROD")

Standardizacija delovanja mikroelemenata na osnovu metodologije integracionog sistema zemljište-biljka operativne dijagnostike ishrane biljaka („ISPROD")

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Abstract: Based on the principles of Integration of the soil-plant system operational diagnostics of plant nutrition set standards for the content of microelements in soil and plants, taking into account the specific natural conditions and the magnitudes of yield formation. Based on conducted years of research developed the formula for calculating the optimal doses of micronutrients for optimal macro background. As a result of the research generated a mathematical model based on the content of microelements in soil from the applied doses of micronutrients in these soils. Contains the optimal ratio of microelements in soil, plants, characterizing a harmonious mineral nutrition culture. In the field of optimal dosages of micronutrients established factors of intensity of the action of trace elements contained in the plant ("b", mg/kg), on the formation of the magnitude of the yield of green mass of fodder crops during the making of Cd, Ni, Zn, Se.

Keywords: soil, plant mineral nutrition, trace elements.

Sažetak: Na osnovu principa Integracije sistema zemljište-biljka operativna dijagnostika ishrane biljaka postavlja standarde za sadržaj mikroelemenata u zemljištu i biljkama, uzimajući u obzir specifične prirodne uslove i veličine formiranja prinosa. Na osnovu sprovedenih višegodišnjih istraživanja razvijena je formula za izračunavanje optimalnih doza mikronutrijenata za optimalnu makro pozadinu. Kao rezultat istraživanja generisan je matematički model zasnovan na sadržaju mikroelemenata u zemljištu iz primenjenih doza mikroelemenata u ovim zemljištima. Sadrži optimalan odnos mikroelemenata u zemljištu i biljkama, karakterišući harmoničnu kulturu mineralne ishrane. U oblasti optimalnih doza mikroelemenata utvrđeni su faktori intenziteta delovanja elemenata u tragovima sadržanih u biljci („b", mg/kg), na formiranje veličine prinosa zelene mase krmnih useva pri izradi Cd, Ni, Zn, Se.

Ključne reči: zemljište, mineralna ishrana biljaka, elementi u tragovima.

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INTRODUCTION

Analyzing the currently available data on the standardization of the content of microelements in environmental objects, most researchers come to the conclusion that microbiologists, soil scientists, agrochemists, veterinarians, hygienists, and doctors should jointly develop MPCs (Ilyin, 1991).

Determining the mathematical patterns of the action of microelements in trophic chains, taking into account geochemical, agroecological conditions, and the specific influence of a certain chemical element on living organisms, is of particular importance in environmental regulation. The standards for the action of chemical elements in trophic chains obtained as a result of modeling make it possible to "manage" the process of mineral nutrition of plants and animals, as well as to diagnose and prevent negative processes caused by an excess, deficiency or imbalance of microelements in environmental objects (Ćupić et al., 2024).

1. METHODS

Taking into account the analyzed theoretical material on the issues of rationing of chemical elements, we developed a dynamic scheme for the interaction of microelements in the soil – fertilizers – plants – animals system based on the principles of ISPROD (Fig. 1) (Ermokhin, Sindireva, 2011).

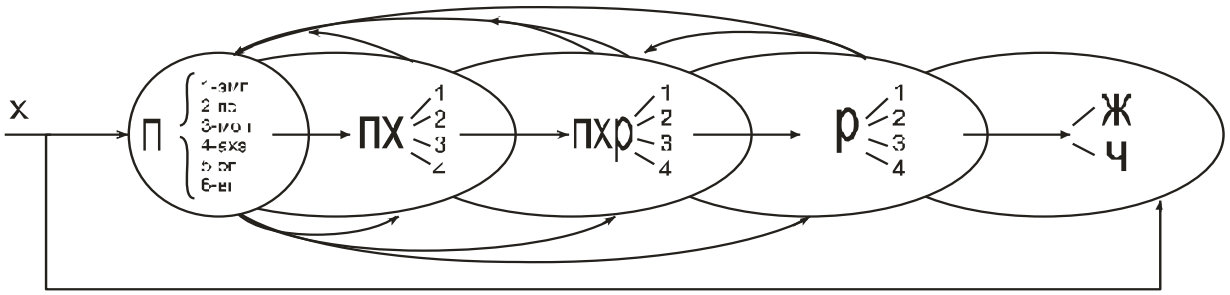

Figure 1 - Dynamic scheme of interaction of chemical elements in the system soil – fertilizers – plants – animals

Legend

	Chemical element
Р (П) The soil. Initial state	1 - mobile elements of mineral nutrition (EMP) 2 - gross content of chemical elements (CE) 3 - soil microorganisms (SOM) 4 - accumulation of chemical elements along horizons (AH) 5 - soil organic matter (SO) 6 - soil moisture (SM)
РН (ПХ) Interaction of elements with soil	1 - dissolution and transformation of chemical elements (X) 2 - "b" intensity of action of element "X" on the soil 3 - accumulation of chemical elements along horizons (AChE) 4 - change in microorganisms in quantitative and species ratio (MOP)
РНR (ПХР) Interaction of chemical elements with a plant	1 - chemical composition of plants (leaves) in ontogenesis (CR) 2 - biometric plant diagnostics (BD) 3 - plant (leaf) diagnostics (RD) 4 - interaction "X" in the "soil-fertilizer-plant" system (SFUR)
R (Р) Result	1 - optimal levels (ratios) of "X" in soil and plants 2 - planned harvest (increase) 3 - increasing soil fertility (SFP) 4 - harvest quality (QU)
F H (Ж Ч) Animal - Human	MDH - modeling of the action of a chemical element in the "PROD" system - soil-plant operational diagnostics on animal and human health

Yu. I. Ermokhin, students of his scientific and pedagogical school "Integrated system of soil-plant operational diagnostics of plant nutrition" ("ISPROD"), developed mathematical models for diagnosing mineral nutrition, the efficiency of using fertilizers, the size and quality of the crop based on the following principles (Ermokhin, 1983):

1) the ability of soils to satisfy the need of plants for nutrients (nitrate nitrogen, mobile phosphorus, exchangeable potassium, mobile microelements,

quantitative characteristics of soil enrichment with biological nitrogen);

2) the needs of plants for nutrients and their ability to assimilate these substances in specific conditions of agricultural production (CIS, CIU, PES, removal of nutrients);

3) nutritional state of plants and calculation of doses of fertilizers during the period of growth and development (optimal levels and harmonious (balanced ratio of macro- and microelements in plants according to phases of growth and development, Kp - coefficient of nutrient requirement, "b" - coefficients of intensity of action of the introduced (or incoming) element on the chemical composition of plants).

2. RESULTS

When assessing the effect of microelements in ecosystems, one of the most important parameters is the productivity and yield of cultivated plants. The main way to assess the need of plants for fertilizer is field experience, which makes it possible to establish the role of individual nutrients in increasing crop yields, to establish patterns between the content of nutrients in the soil, plants, and the size and quality of the crop (Afendulov, Lantukhova, 1973).

In order to create optimal conditions for the formation of the yield of cultivated crops, the method of soil diagnostics is widely used, both here and in foreign countries (Ermokhin, 1983). Using soil chemical analysis data, it is possible to predict the effectiveness of the use of mineral fertilizers.

In connection with the above, there is a need to solve the problem of regulating the content of chemical elements in soil and plants, taking into account specific natural conditions and yield formation values (Ermokhin et al., 2002; Sindireva, 2012). This will allow you to control the process of mineral nutrition of plants and the formation of the size and quality of the crop.

Therefore, our task was to bring the content of the studied elements in the soil to the optimal level for balanced nutrition of crops. To calculate the required doses of fertilizers, formula (1) was used:

$$Д = \frac{Э_0 - Э_ф}{"b"}, \quad (1)$$

where $Э_0$, $Э_ф$ – optimal and actual content of the element in the soil, mg/kg;

"b" – intensity coefficients of action of 1 kg of cadmium (0.011), nickel (0.005), zinc (0.011), selenium (0.0012), mg/kg in a soil layer of 0-30 cm.

It has been established that the relationship between the dose of fertilizers and nutrients in the soil is inversely proportional; therefore, the higher the content of the studied microelements in the soil, the lower the dose of fertilizer (Ermokhin, 1983). Mathematically, this can be expressed by the following formula:

$$Д_o \cdot X_o = Д_n \cdot X_n \quad (2)$$

where $Д_0$ is the established optimal dose of fertilizer nutrients in kg a.i./ha with the corresponding content of elements in the soil before sowing, mg/kg (X_0);

$Д_n$ – dose of fertilizers in kg a.i./ha, predicted depending on the content of nutrients in the soil of a particular field, mg/kg (X_n).

From here:

$$Д_n = \frac{Д_o \cdot X_o}{X_n}. \quad (3)$$

This calculation method allows us to specify the dose of fertilizers depending on the chemical composition of the soil, increase their effectiveness for various plants and obtain high yields of good quality. This method should also be used for microelements that have a narrow line between toxicity and necessity, in particular for Cd, Ni, Zn, Se. The presented approach may also be used to determine environmentally safe levels of anthropogenic input of these chemical elements into the soil, as well as to predict the accumulation and impact of these elements on the yield and quality of crops. Taking into account many years of research, formulas have been developed for calculating optimal doses of microfertilizers on an optimal macronutrient background using spring rape as an example (Table 1).

Table 1. Calculated doses of microelements obtained on the basis of many years of field experiments with fertilizers and chemical analysis of soil

Element	Optimal dose of microelements in the experiment (*Before*), kg/ha	Initial microelement content in soil (X_0), mg/kg	Calculated dose of microfertilizers ($Д_n$), kg/ha
Ni	3,6	0,51	$Д_n = \frac{1{,}84}{Ni_{мг/кг}}$
Zn	26,2	0,66	$Д_n = \frac{17{,}3}{Zn_{мг/кг}}$
Se	11,7	0,052	$Д_n = \frac{0{,}61}{Se_{мг/кг}}$

The proposed formulas for determining the approximate doses of microfertilizers for the crops under study allow us to move away from simple empiricism with the use of fertilizers and focus on specific doses taking into account the content of the available element in the soil.

As a result of the research, mathematical models of the dependence of the content of microelements in the soil on the doses of incoming microfertilizers were obtained. The established coefficients "b" made it possible to calculate the amount of microelements (kg/ha) required to increase the content of mobile forms of Cd, Ni, Zn in the soil by 1 mg/kg:

Cadmium $\frac{1мг/кг}{0{,}011мг/кг} = 90$ kg/ha;

Nickel $\frac{1мг/кг}{0{,}005мг/кг} = 200$ kg/ha;

Zinc $\frac{1мг/кг}{0{,}011мг/кг} = 90$ kg/ha;

Selenium $\frac{1мг/кг}{0{,}0012мг/кг} = 835$ kg/ha.

Using data on the optimal ($Э_0$) and actual ($Э_ф$) levels of microelements in the soil for a given crop, the dose of Cd, Ni, Zn, Se (kg/ha) per plant can be calculated using formulas (4-7):

$$ДCd = (Э_o - Э_ф) \cdot 90 \quad (4)$$

$$ДNi = (Э_o - Э_ф) \cdot 200 \quad (5)$$

$$ДZn = (Э_o - Э_ф) \cdot 90 \quad (6)$$

$$ДSe = (Э_o - Э_ф) \cdot 835 \quad (7)$$

Taking into account the best doses of microelements (for example, Ni, Zn, Se) with an optimal macronutrient background, taking into account the experimental data obtained, we can conclude about the optimal content of microelements in the soil for crop nutrition (C_0, mg/kg), for example, for spring rape, according to formulas (8-10):

Nickel:

$C_0 = C_1 + Д \cdot$"b" = 0,51 + 3,6·0,005 = 0,53 (8)

Zinc:

$C_0 = C_1 + Д \cdot$"b" = 0,66 + 26,2·0,011 = 0,95 (9)

Selenium:

$C_0 = C_1 + Д \cdot$"b" = 0,52 + 11,7·0,0012 = 0,066 (10)

To form a high yield in quantitative and qualitative terms, it is necessary to know, in addition to the optimal levels of microelements in the soil, their balanced combination when feeding the crop plant.

Table 2 shows the optimal ratio of microelements in the soil, which characterizes the harmonious mineral nutrition of spring rapeseed, which allows determining the element action coefficient (Kd) using the formula:

$$Кд \frac{Zn : Ni : Cd : Se : Cu : Pb(оптим)}{Zn : Ni : Cd : Se : Cu : Pb(фактич)} \quad (11)$$

Table 2. Optimal ratio of elements in meadow-chernozem soil

Before sowing rapeseed	Microelements	Zn ≈ 6,3 · Cd ≈ 1,8 · Ni ≈ 14,4 Se
	Macroelements	P_2O_5 ≈ 10 · N - NO_3 ≈ K_2O

Thus, the obtained mathematical models make it possible to predict and adjust the optimal content and ratio of microelements in the soil as a result of their anthropogenic input; doses of microfertilizers, taking into account the content of chemical elements in the soil and the need for these nutrients to form the predicted yield and quality of crop products.

Optimal levels of nutrients in plants depend on the crop, the phase of its development, the level of yield and methods for determining chemical elements (Ermokhin, 1983; Ermokhin, Sindireva, 2011; Sindireva, 2011; Tserling, 1990).

In the area of optimal dosages of microfertilizers, the intensity coefficients of the action of microelements contained in the plant ("b", mg/kg) on the formation of the yield of green mass of forage crops (t/ha) have been established with the main application of Cd , Ni , Zn , Se (Table 3) (Ermokhin et al., 2002; Ermokhin, Sindireva, 2011; Sindireva, 2011; Tserling, 1990).

Based on many years of data from field experiments with microfertilizers, the obtained yield values and the chemical composition of plants, and the identified mathematical dependencies, we established the optimal levels of macro- and microelements in plants corresponding to maximum yield (Table 4).

Table 3. Action intensity factors ("b") units Cd, Ni, Zn, Se contained in plants (in mg/kg) on the formation crop yield (in t/ha)

Culture	Action intensity coefficients (“*b*”)			
	Cd	Ni	Zn	Se
Roots				
Beet	78	36	1,8	**
Carrot	n*	18,2	4,64	-
green mass				
Rape	8,15	6,42	0,34	1,1
Astragalus	-	-	-	0,75

Note: *n – no increase in yield, ** – no data

Table 4. Optimal content of chemical elements in spring rape and Astragalus galegidae plants

Plant	Optimal content								
	macroelements, %			microelements, mg/kg					
	N	P	K	Se	Cd	Ni	Zn	Cu	Pb
Above ground mass									
Rape	3,7	0,6	3,3	1,2	0,9	5,1	44,0	3,6	3,5
Astragalus	3,6	0,7	2,0	1,9	0,04	1,4	7,0	2,6	1,0
Beet	1,8	0,5	2,5	*	0,6	3,2	26,9	6,9	3,8
Carrot	1,9	0,4	2,6	-	0,4	2,0	17,3	4,4	3,6
Root vegetable									
Beet	1,4	0,5	1,9	-	0,3	1,1	17,3	5,6	2,6
Carrot	1,0	0,6	2,4	-	0,2	1,0	22,5	3,7	1,3

Note –* no data available

Our research has shown that with the additional intake of a chemical element into the environment, the entire chemical composition of the plant organism changes due to the manifestation of antagonism-synergism between ions both in the environment surrounding the plant (soil) and inside the plant organism (Ermokhin, Sindireva, 2011). As a consequence, it seems necessary to establish the relationship between macroelements and microelements in the plant organism on the most favorable macro- and microelement backgrounds with the elements being studied. The resulting ratios make it possible to normalize the chemical composition of plants in order to create crop products that are optimal in terms of productivity and quality. Table 5 shows the optimal ratios of macro- and microelements in vegetable and forage plants.

Table 5. Optimal ratio of chemical elements

Culture	Optimal ratio	
	macronutrients	microelements
Beet		
Above ground mass	N ≈ 3,4 · P ≈ 0,7 · K	Zn≈45 · Cd≈8,3 · Ni≈3,9 · Cu≈7 · Pb
Root vegetable	N ≈ 2,9 · P ≈ 0,7 · K	Zn≈56 · Cd≈8,3 · Ni≈3,4 · Cu≈7 · Pb
Carrot		
Above ground mass	N ≈ 4,2 · P ≈ 0,7 · K	Zn≈42 · Cd≈8,1 · Ni≈4,4 · Cu≈5 · Pb
Root vegetable	N ≈ 1,9 . P ≈ 0,4 · K	Zn≈52 · Cd≈8,3 · Ni≈2,7 · Cu≈6 · Pb
Spring rape		
Above ground mass	N ≈ 6,2 · P ≈ 1,1 · K	Zn≈48 · Cd≈8,6 · Ni≈12 · Cu≈12,6 · Pb≈36,7 · Se
Astragalus galegidae		
Above ground mass	N ≈ 5,1 · P ≈ 1,8 · K	Zn ≈3,7 · Se ≈ 175 · Cd ≈5,4 · Ni ≈2,7 · Cu ≈7 · Pb

The established optimal levels of supply of nutrients to crops make it possible to correctly interpret the actual results of chemical analysis of plants in a natural environment. K.P. Magnitsky (1964) noted that when diagnosing plant nutrition, it is important to determine in the soil and plants (leaves) not only

the element for which the need must be established, but also others that influence the level of plant nutrition with this element (Magnitsky, 1972).

Vegetable and forage plants suffer from a deficiency or excess of macro- and microelements in plants of two types: absolute and relative. If there is an absolute deficiency of any microelement in the plant, it is enough to bring its content to the optimal level, taking into account the requirement coefficient (K_n) according to formula (11):

$$Kn = \frac{оптимальныйуровеньэлементаврастении, мг/кг}{фактическийуровеньэлементаврастении, мг/кг} \quad (12)$$

If there is a relative lack of nutrients in the soil, that is, an imbalance in the ratio, it is necessary to determine the missing element for a balanced balance and restore the balance by applying fertilizers. In this case, K_n for microelements is determined by formula:

$$Kn = \frac{Zn : Ni : Cd : Se : Cu : Pb(оптим)}{Zn : Ni : Cd : Se : Cu : Pb(фактич)} \quad (13)$$

where the numerator is the optimal ratio, and the denominator is the actual ratio of microelements in plants.

The requirement coefficient (K_n) shows how much the content of the missing element or elements in the plant should be increased or decreased for harmonious nutrition and, accordingly, normal growth and development of plants.

Thus, strict regulation of the content and ratio of basic macroelements (N, P, K) and microelements (Cd, Ni, Zn, Se, Cu, Pb) in plants will make it possible to predict the effectiveness of microfertilizers, the amount of crop yield, as well as the environmental situation associated with chemical load in the soil-plant system..

CONCLUSION

The methodology for regulating the action of microelements in the soil-plant system, which was based on the principles of the ISPROD system, was developed taking into account the provisions on the presence of a close relationship between external nutritional conditions and internal metabolic processes in plants, on the close dependence of the size, quality of the harvest and the supply of elements nutrition in plants depends not only on the absolute content, but also on the ratio of these elements to each other.

The identified patterns make it possible to optimize the supply of microelements to plants using the developed regulatory parameters of the ISPROD system, and thereby manage the process of formation of the size and quality of the yield of cultivated crops, as well as establish gradations and ratios of chemical elements in the soil and plants, taking into account agronomic and sanitary-hygienic aspects.

The obtained research results must be taken into account when cultivating crops. At the same time, it is necessary to take into account the sanitary and hygienic aspect of rationing when further consuming plants for human and animal food. Identifying the characteristics of the behavior of microelements in the soil – plant – animal system is necessary for the prevention and treatment of diseases caused by excess, deficiency or imbalance of microelements.

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Ecological sustainability in agritourism development: navigating opportunities and challenges for a balanced future

Ekološka održivost u razvoju agriturizma: upravljanje mogućnostima i izazovima za uravnoteženu budućnost

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Abstract: This study examines the ecological impacts of rural tourism development in four eco-ethno villages in Western Serbia: Koštunići, Vraneša, Sunčana Reka, and Sirogojno. The research focused on ten ecological indicators, including ecosystem degradation, water and land pollution, disturbance of wildlife, and loss of aesthetic values, as perceived by 468 residents. Using an ordinal Likert scale, respondents assessed the extent of these impacts, with demographic factors such as gender included to explore variations in perception. The findings confirm that rural tourism significantly affects ecological systems, with a majority of respondents reporting negative impacts on key indicators. Gender differences emerged as a significant factor, with women generally perceiving more severe ecological consequences, particularly regarding water consumption and ecosystem degradation. These results underscore the importance of considering gendered roles and responsibilities in understanding how tourism affects local environments. While many respondents noted no change for some indicators, such as air pollution, others highlighted localized issues tied to tourism activities, including increased infrastructure demands and inadequate waste management.

Keywords: rural tourism, quality of life, environmental impacts, Western Serbia.

Sažetak: Ova studija ispituje ekološke uticaje razvoja ruralnog turizma u četiri eko-etno sela u zapadnoj Srbiji: Koštunići, Vraneša, Sunčana Reka i Sirogojno. Istraživanje se fokusiralo na deset ekoloških indikatora, uključujući degradaciju ekosistema, zagađenje vode i zemljišta, uznemiravanje divljih životinja i gubitak estetskih vrednosti, kako ih percipira 468 stanovnika. Koristeći ordinalnu Likertovu skalu, ispitanici su procenili obim ovih uticaja, sa uključenim demografskim faktorima kao što je pol da bi se istražile varijacije u percepciji. Nalazi potvrđuju da ruralni turizam značajno utiče na ekološke sisteme, pri čemu je većina ispitanika prijavila negativne uticaje na ključne indikatore. Rodne razlike su se pojavile kao značajan faktor, pri čemu su žene generalno uočavale teže ekološke posledice, posebno u pogledu potrošnje vode i degradacije ekosistema. Ovi rezultati naglašavaju važnost razmatranja rodnih uloga i odgovornosti u razumevanju kako turizam utiče na lokalnu sredinu. Dok su mnogi ispitanici primetili da nema promena za neke indikatore, kao što je zagađenje vazduha, drugi su istakli lokalizovana pitanja u vezi sa turističkim aktivnostima, uključujući povećane zahteve za infrastrukturom i neadekvatno upravljanje otpadom.

Ključne reči: seoski turizam, kvalitet života, uticaji na životnu sredinu, Zapadna Srbija.

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INTRODUCTION

Rural tourism, as explored by Gao and Wu (2017), represents a dynamic and diverse niche within the tourism sector, focusing on authentic experiences rooted in rural communities. Rural tourism's key aspects include location, sustainable development, community-based features, and experiences, with challenges mainly affecting internal resources in both developed and developing contexts (Rosalina et al., 2021). This type of tourism product encourages interactions that focus on the natural environment and traditional ways of life, highlighting the importance of sustainable practices. It supports efforts to maintain rural landscapes and ecosystems, often emphasizing environmentally responsible tourism activities. Agritourism, as a subcategory of rural tourism, combines agricultural practices with visitor participation, providing a practical way to promote ecological awareness. By offering an alternative to intensive agricultural use, agritourism can help reduce the strain on farmland, contributing to more sustainable land use and conservation (Ciolac et al., 2020; Ćirić et al., 2021). Agritourism is often aligned with sustainable tourism principles, promoting the conservation of rural landscapes and biodiversity. It encourages the use of local resources and traditional practices, which can help maintain ecological balance (Belliggiano et al., 2020; Ammirato et al., 2020; Adamov et al., 2020).

Tourists are drawn to this form of tourism to engage in activities such as agricultural participation, cultural exploration, or enjoying natural landscapes (Nelson et al., 2021). Unlike urban or coastal tourism, rural tourism emphasizes a connection to traditional lifestyles and natural environments, offering experiences such as farm stays, local festivals, outdoor recreation, and wildlife observation. Panić et al. (2024) highlight its significant potential to drive economic development in rural regions by supporting local businesses and creating employment opportunities. In addition to its economic benefits, rural tourism holds the potential to foster ecological awareness and sustainable practices within both visitors and host communities. Martínez Álvarez & Cortes-Vazquez (2020) highlight this claiming that the impacts of rural tourism on socio-ecological resilience go beyond economic metrics like overnight stays or income generated. Understanding the implications of tourism initiatives requires considering the moral values that shape these practices. This includes examining the material, symbolic, and experiential transformations brought about by tourism in local communities and their interactions with the environment. By understanding the concept of sustainable development, Guizzardi et al. (2021) emphasize that it can drive tourism development in small rural areas, with cultural heritage conservation and well-protected natural environments being key indicators.

While agritourism can support ecological sustainability, it also has the potential to harm local environments if poorly managed (Popescu et al., 2023; Ammirato et al., 2020). For example, increased visitor traffic can disturb wildlife and lead to soil erosion, while the need for additional infrastructure, such as parking areas or access roads, can result in the loss of natural habitats. Similarly, excessive reliance on certain agricultural activities to attract tourists may lead to overexploitation of resources or disrupt local ecosystems. The ecological impact of agritourism is not uniform and varies between regions. Some areas achieve more positive results due to effective local policies and careful integration of tourism with agricultural practices, while others may struggle with ecological challenges resulting from insufficient planning or regulation (Belliggiano et al., 2020; Bocheńska-Skałecka et al., 2022). Bocheńska-Skałecka et al. (2022) also add that the transformation of traditional agricultural farms into agritourism sites can lead to significant changes in rural landscapes which may include the adaptation of farms to accommodate tourists, which may alter the natural and cultural landscape.

By promoting environmentally conscious tourism activities, such as organic farming or guided eco-trails, it encourages a harmonious relationship between tourism and nature. Moreover, the focus on preserving rural traditions and landscapes can lead to a stronger community commitment to environmental stewardship. Wang et al (2023) claim that rural tourism often thrives in areas with high ecological quality, indicating a strong relationship between ecosystem services and tourism. These services, such as climate regulation and anion supply, significantly support the development of rural tourism, promoting regional green development. Rural tourism encourages the preservation of natural resources by transforming ecological advantages into economic benefits (Li, et al., 2022). Moreover, the integration of agriculture and tourism promotes the sustainable use of ecological and environmental resources. This integration has been shown to improve the quality of the rural ecological environment by fostering better agricultural practices and environmental governance (Sun, et al., 2023; Wang et al., 2022).

This paper focuses on Western Serbia, a region characterized by its varied geography and rural lifestyle, providing a basis for rural tourism devel-

opment. The area includes diverse landscapes such as hills, rivers, agricultural lands, and forested areas, which serve as settings for differet sort of tourism activities. Its proximity to protected areas of nature further contributes to its role as a rural tourism destination. The study examines four tourist villages - Koštunići, Vraneša, Sunčana Reka, and Sirogojno - that have adopted tourism to leverage their cultural and natural resources. Tourists to these villages engage in agricultural activities, participate in traditional practices, explore the natural environment, and experience the local way of life. The aim of this study is to evaluate the ecological effects of rural tourism in these villages, with a focus on changes in land use, environmental conservation, and resource management.

The findings indicate that rural tourism has influenced ecological conditions in the observed areas in both positive and negative ways. On one hand, increased awareness of the region's natural value has led to initiatives aimed at protecting certain habitats and promoting environmentally friendly practices. On the other hand, the rise in tourism activities has contributed to localized environmental pressures, such as habitat disruption and minor degradation of natural areas. These findings underscore the need for balanced tourism development that integrates ecological considerations into planning and management to ensure the long-term sustainability of these rural areas.

1. THE RESEARCH METHODOLOGY

1.1. Study area

This study examines four tourist villages in Western Serbia: Koštunići, Vraneša, Sunčana Reka, and Sirogojno. Each village represents a distinct example of the natural and cultural richness of the region, reflecting the interplay between rural traditions, cultural heritage, natural landscapes, and modern tourism activities. These villages offer diverse environments making them suitable case studies for exploring how rural tourism development impacts ecological systems observed from the perspective of local population. By analyzing these villages, the study provides important insights into the challenges and opportunities associated with balancing tourism growth and environmental sustainability. The focus on these destinations also allows for an evaluation of the extent to which tourism can support the preservation of natural habitats, promote sustainable practices, and influence local communities' perceptions of environmental stewardship.

Koštunići, located 32 kilometers northwest of Gornji Milanovac, is a rural settlement with a dispersed layout, primarily centered around cattle breeding. Positioned on the southern slopes of Suvobor Mountain, which peaks at an elevation of 866 meters (Čulić, 2006), it is the largest rural settlement in the Gornji Milanovac municipality in terms of land area (Pavlović, 2016). The village is traversed by four mountain rivers - Grab, Bukovača, Čemernica, and Šiban - that support diverse aquatic species, including river fish and crabs (Milošević, 2006). Koštunići is recognized for its ecological and scenic values, encompassing diverse ecosystems such as river valleys, agrarian fields, forests, and meadows. These areas are rich in medicinal herbs and forest fruits (Jovanović Tončev, 2016). Due to its preserved natural environment, Koštunići holds the distinction of being Serbia's only ecological village.

Vraneša, located in the Zlatibor region near Nova Varoš, is renowned for its natural beauty. The village, set within a coniferous forest at an elevation of 943 meters, offers views of Zlatar Lake (Svojić, 2015). Its ethno-eco village features traditional Serbian architecture, utilizing sustainable materials such as black pine and stone. The wooden components are treated with natural resin, and handcrafted split shingles are used for roofing. Surrounded by forests, hills, and rivers, Vraneša is a popular destination for outdoor activities such as trekking and exploring local landscapes. The village combines natural beauty with cultural immersion, offering visitors an authentic rural experience (Svojić, 2015).

Sunčana Reka is situated on the banks of the Drina River, near Loznica. Known for its proximity to natural attractions such as the Drina River and Banja Koviljača, as well as the historically significant Gučevo Mountain, the village is a prominent rural tourism site. The tourist complex comprises seven accommodation units with a total of 43 facilities, offering 124 beds. Visitors have access to various recreational activities, including horseback riding, ball games, and water-based activities on the Drina River (Stepanović, 2013). The village serves as a hub for both leisure and nature-based activities, highlighting the ecological potential of rural tourism.

Sirogojno, located on Zlatibor, is best known for its open-air museum, Staro Selo (Old Village), which illustrates the traditional lifestyle of Serbian peasants. The museum spans 5 hectares and includes approximately 50 buildings relocated from surrounding Zlatibor villages (Đenić, 2008). The architecture reflects traditional construction methods and interior designs typical of the hilly and mountainous Dinaric region (Ranko, 1987). Situated near one of Serbia's largest mountaineering centers, Zlatibor, Sirogojno offers both cultural and ecological value, showcasing historical crafts, skills, and sustainable rural practices.

2. SOURCES OF DATA

This study examines the ecological impacts of rural tourism development in four eco-ethno villages in Western Serbia: Koštunići, Vraneša, Sunčana Reka, and Sirogojno. Using data from 468 respondents, the research focused on ten ecological indicators: ecosystem degradation, loss of aesthetic values (particularly during summer), increased risk of landslides, disturbance of wildlife, destruction of plant life, increased water consumption, disproportionate energy use, noise pollution, land pollution, and air pollution. Respondents evaluated these impacts using an ordinal Likert scale ranging from 1 to 5, where 1 represented significant negative impacts, 5 indicated significant positive impacts, and 3 signified no change. The primary objective of the study was to assess the local population's perceptions of tourism's environmental effects, with a specific emphasis on identifying key issues and informing strategies to promote ecological sustainability.

The study builds on and adapts the methodology presented by Monterrubio et al. (2020), which investigated the effects of tourism infrastructure on rural areas and the quality of life of local populations. This research, however, focuses on the perceived impacts of ethnic villages and tourist attractions on the ecological and broader quality of life in their surrounding communities. Conducted from May 2022 to May 2023, the study gathered insights from residents of the selected villages regarding the influence of tourism development on their environment, economy, and social conditions. The research sought to explore how rural tourism impacts the local ecological balance and to identify whether these impacts vary based on demographic factors (Prnjat, 2024).

To evaluate the influence of demographic variables, gender was included as an independent variable, enabling an examination of whether perceptions of ecological impacts differ statistically between male and female respondents. The study applied Chi-Square tests to analyze the relationship between gender and responses, with statistically significant differences identified at $p < 0.05$. The analysis also assumed no significant variation in perceptions based on gender, providing a baseline for comparison.

The study formulates the following hypotheses to guide the analysis of rural tourism's impact on ecological indicators in the observed villages:

H1: Rural tourism development in the observed villages has a statistically significant impact on ecological indicators, as perceived by the local population. This reflects the assumption that residents, as direct witnesses to environmental changes, can offer critical insights into how tourism affects local ecosystems. Supporting this, **H1a** suggests that Rural tourism development contributes to negative ecological outcomes, as identified by the respondents. Further, **H1b** proposes that gender significantly influences perceptions of ecological impacts, with male and female respondents showing differing evaluations of tourism's environmental effects, based on their roles, responsibilities, and interactions within the community. By testing these hypotheses, the study aims to clarify the nature and extent of tourism's ecological effects and identify variations in perception that can inform strategies for sustainable tourism management.

3. RESULT AND DISCUSSION

The study sample included 256 male and 212 female participants, providing insights into gender-based differences in the perception of environmental impacts caused by tourism. The subsequent tables highlight the most significant environmental effects identified by respondents, such as increased risk of landslides, growth in water consumption, and air and land pollution. These impacts are categorized by gender, offering a comparative view of how male and female participants evaluate the ecological consequences of tourism in their communities. This analysis aims to uncover any notable variations in perspectives, contributing to a deeper understanding of gender-specific concerns and priorities regarding environmental sustainability in the context of tourism development.

3.1. Environmental impact of rural tourism

The slightly higher concern among female respondents may reflect their heightened sensitivity to environmental changes, potentially stemming from their closer interaction with household and community spaces where air quality impacts are more immediately noticeable. This gendered disparity, though subtle, could also hint at broader societal roles where women, often caregivers or more engaged in community well-being, are more attuned to shifts in environmental conditions. Meanwhile, men's perceptions may reflect their exposure to outdoor activities or occupations where air quality is less perceptible unless it reaches critical levels.

The overall perception that air pollution remains largely unchanged could suggest that tourism-related impacts, such as vehicle emissions, construction dust, or energy use, are either not yet at a disruptive scale or are localized, affecting specific areas without broader regional visibility. However, the sizable minority noting worsening conditions

indicates that these issues are not universally distributed, potentially concentrated around high-traffic tourist zones or during peak seasons. This finding underscores the dual challenge of balancing tourism's economic benefits with the need to prevent long-term degradation of air quality.

Interpreting these results also invites a deeper reflection on the concept of "perceived" versus "actual" impacts. While visible pollution, such as vehicle exhaust or construction debris, might elicit immediate concern, subtler forms of air quality degradation, like increased particulate matter or reduced oxygenation from vegetation loss, may go unnoticed by the general population. This discrepancy highlights the importance of integrating scientific monitoring into tourism strategies, ensuring that data-driven approaches complement local perceptions to address both visible and invisible environmental challenges.

The rise in visitor numbers can result in increased vehicle traffic and emissions, presenting a dual-edged sword for rural environments (Table 1 and 2). Additionally, the farming activities that underpin agritourism, such as the use of heavy machinery for crop harvesting and land preparation, contribute to air pollution through the emissions of carbon dioxide and volatile organic compounds. Furthermore, waste management practices associated with agritourism - such as the disposal of organic waste and the use of fertilizers - can exacerbate air quality issues. Poorly managed waste can lead to the release of methane, a potent greenhouse gas, into the atmosphere. Thus, while agritourism brings economic benefits, it is imperative to recognize the environmental costs associated with increased activity in these rural areas. Table 1 indicates that there are no problems with pollution, however, for it to remain so, Local authorities must implement mitigation strategies such as promoting public transportation options and encouraging carpooling among visitors. Additionally, some agritourism operators have adopted sustainable farming practices, including the use of electric machinery and organic farming methods, which significantly reduce emissions. by analyzing the data from tables 1 and 2 it it becomes evident that while agritourism can contribute to air pollution, proactive measures can effectively mitigate these effects, creating a more sustainable model for rural tourism.

From a broader perspective, the findings align with global concerns that tourism, particularly in rural areas, risks contributing to cumulative environmental pressures. Increased vehicle usage, the establishment of tourism infrastructure, and energy demands are known contributors to air quality issues. When combined with other ecological challenges such as habitat loss, soil erosion, and the endangerment of biodiversity (Verma et al., 2023), the cumulative impact of tourism calls for proactive intervention. These insights emphasize the critical role of sustainable rural tourism practices, which must harmonize economic opportunities with environmental stewardship. Enhancing public awareness, promoting eco-friendly transportation options, and incentivizing green infrastructure development are essential steps to ensure that air pollution does not compromise the long-term viability of rural tourism destinations.

Table 1. Pollution

		Air pollution		Total
		Worse	No change	
Gender	Male	105	151	256
	Female	93	119	212
Total		198	270	468

Source: Panić, 2024

Since the p-value exceeds the commonly used threshold of 0.05 (Table 2), the results suggest that there is no statistically significant relationship between gender and respondents' perceptions of air pollution. This suggests that male and female respondents evaluate changes in air quality similarly, with no notable gender-based divergence in their assessments. While gender does not appear to influence perceptions in this context, the findings open the door to deeper exploration of other variables that might shape individual views.

The absence of a gender difference could reflect the universal nature of air quality as an environmental concern that affects all residents, regardless of their roles or responsibilities. Unlike resources like water or land, where gendered interactions are more distinct, air quality is pervasive and less tied to specific daily activities. This universality may explain the shared perspective among respondents, as both genders are equally exposed to tourism-related sources of air pollution, such as vehicle emissions, construction activities, or changes in vegetation. This finding points to other factors, such as proximity to tourism hotspots or individual environmental awareness, as likely influences on perceptions of air pollution. Residents closer to heavily trafficked areas or tourism infrastructure may notice impacts more acutely, while broader awareness shaped by education or media exposure may also play a role. The results emphasize the need to combine community insights with scientific monitoring to capture both perceived and actual air quality changes.

Table 2. Pearson Chi-Square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	,387[a]	1	,534

Source: Panić, 2024

The data on perceptions of ecosystem degradation (Table 3) reveals notable differences in how male and female respondents evaluate the impact of tourism activities. Out of 468 participants, 19 individuals (4.1%) rated the ecosystem as "much worse", 237 (50.6%) rated it as "worse", and 212 (45.3%) perceived "no change". Among male respondents (n = 256), 9 individuals (3.5%) indicated that ecosystem conditions were "much worse", 97 (37.9%) reported "worse", and 150 (58.6%) observed "no change". Conversely, among female respondents (n = 212), 10 individuals (4.7%) perceived the ecosystem as "much worse," 140 (66.0%) as "worse", and only 62 (29.2%) noted "no change".

This significant difference may reflect the distinct ways men and women engage with their natural surroundings. Women, often responsible for gathering resources in rural settings, may experience ecosystem degradation more immediately and tangibly. For instance, declining vegetation or polluted water sources could disrupt daily routines, making changes in the environment more evident to them. Their caregiving roles and heightened focus on community well-being may further amplify their sensitivity to ecological shifts. Men, on the other hand, may be more likely to perceive the ecosystem through a utilitarian lens, focusing on its ability to support agricultural productivity or outdoor labor. If these functions remain unaffected, they may be less inclined to notice or prioritize broader ecological deterioration. This divergence could also stem from differences in environmental awareness and values. Women's closer ties to the community and natural resources often foster a greater sense of environmental responsibility. They may also place more emphasis on the aesthetic and biodiversity aspects of the ecosystem, viewing its preservation as integral to cultural and environmental heritage. Men, while not indifferent to these issues, might prioritize immediate, tangible outcomes, such as economic benefits from tourism, over subtle or longer-term ecological impacts.

The findings also raise questions about the visibility and communication of ecosystem changes. Tourism-related degradation may not be evenly distributed across a region. Women's activities may bring them closer to affected areas, while men's routines may limit their exposure to such changes. This spatial and experiential divide underscores the need for targeted efforts to bridge knowledge gaps, ensuring that all community members are equally informed about the environmental effects of tourism.

Table 3. Ecosystem degradation

		Ecosystem degradation			Total
		Much worse	Worse	No change	
Gender	Male	9	97	150	256
	Female	10	140	62	212
Total		19	237	212	468

Source: Panić, 2024

The Pearson Chi-Square test results indicate a significant relationship between gender and perceptions of ecosystem degradation caused by tourism activities (Table 4). The test value is 40.605, with an asymptotic significance (p-value) of 0.000. Since the p-value is below the standard threshold of 0.05, the results demonstrate a statistically significant association between gender and how respondents evaluate the state of ecosystem degradation. This suggests that male and female participants differ in their perceptions of the impact of tourism on the ecosystem, as reflected in the earlier distribution of responses. For example, in many rural communities, women often engage in activities closely tied to natural resources, such as collecting water or doing other important roles in conservation, farming, and food responsibilities (Vercillo et al., 2021). These roles may make women more attuned to subtle changes in the ecosystem, such as a decline in vegetation or increased water scarcity.

Table 4. Pearson Chi-Square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	40,605[a]	2	,000

Source: Panić, 2024

The data on the perceived loss of aesthetic values during the summer, categorized by gender, reveals differences in how male and female respondents evaluate this impact of tourism. Among the 468 total participants, 69 respondents (14.7%) rated the loss of aesthetic values as "much worse", 265 respondents (56.6%) as "worse", and 134 respondents (28.6%) indicated "no change". These results suggest that male respondents were more likely to report severe negative impacts ("much worse" and "worse") on the aesthetic values of the environment, with 81.6% expressing concerns about degradation compared to 59.0% of female respondents. Conversely, female participants were more likely to perceive no change in aesthetic values, with 41.0% providing this response compared to only 18.4% of males.

The higher concern among men regarding the loss of aesthetic values may reflect their greater sensitivity to visible, large-scale changes in the landscape, such as deforestation, construction, or overcrowding. Men may associate these alterations with disruptions to traditional rural landscapes, potentially viewing them as a loss of natural beauty or cultural heritage. Additionally, men's higher involvement in outdoor work or recreational activities might make them more aware of these visual changes, especially in areas frequented by tourists. Conversely, the greater percentage of women perceiving "no change" might be attributed to a different set of priorities and interactions with the environment. Women, who often focus on resource use and functionality in rural settings, may be less influenced by aesthetic changes unless they directly affect daily life. Their engagement with the environment may center more on its utility rather than its visual appeal. This perspective could explain why fewer women express concerns over aesthetic degradation caused by tourism. These differences in perception also highlight varying definitions of what constitutes "aesthetic value". For men, the term might align closely with the preservation of natural landscapes and cultural landmarks, elements that tourism often alters visibly. Women, on the other hand, may integrate a broader view, where aesthetic value encompasses not just visual beauty but also environmental functionality and ecological health, which might not appear as visibly affected by tourism.

The findings emphasize the complexity of managing tourism's impact on aesthetic values in rural areas. Effective strategies must account for these gendered differences in perception, recognizing that visual changes to the environment may provoke stronger reactions in some groups than others. Policies that focus on preserving iconic landscapes, reducing visual pollution, and ensuring careful planning of tourist infrastructure could address men's concerns more directly. Meanwhile, engaging women in conservation efforts that link aesthetic value to broader ecological health could encourage a more balanced approach.

Table 5. Loss of aesthetic values, especially during the summer

		Loss of aesthetic values, esp. during the summer			Total
		Much worse	Worse	No change	
Gender	Male	50	159	47	256
	Female	19	106	87	212
Total		69	265	134	468

Source: Panić, 2024

The Pearson Chi-Square test results (Table 6) indicate a statistically significant relationship between gender and perceptions of the loss of aesthetic values during the summer. The disparity in responses might be attributed to differences in how men and women interact with or perceive the aesthetic aspects of their environment. Men may associate tourism development with visible changes, such as overcrowding or alterations to the landscape, which are more immediately noticeable during the summer. Women, on the other hand, might place greater emphasis on the functionality or use of the environment rather than its visual attributes, leading to less frequent reporting of negative changes in aesthetics.

Table 6. Pearson Chi-Square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	32,619a	2	,000

Source: Panić, 2024

Perceptions of increased landslide risk show some variation between male and female respondents (Table 7). Overall, 9.6% of participants rated the risk as "much worse," 47.6% as "worse", and 42.7% as showing "no change". Among males, 62.5% perceived the risk negatively ("much worse" or "worse"), compared to 51.0% of females. Conversely, a larger proportion of females (49.1%) reported "no change" compared to males (37.5%).

Rural tourism destinations often feature natural landscapes such as mountains and valleys, which are prone to landslides due to factors like high rainfall and seismic activity (De Vilder et al., 2022). García-Chevesich et al. (2022) add that activities such as agricultural irrigation can exacerbate landslide risks by saturating subsurface materials, particularly in regions with dry climates and concentrated rainfall. The expansion of tourism infrastructure, such as roads and facilities, can further destabilize slopes, particularly when construction occurs in ecologically sensitive areas. This is a significant concern in areas with extensive agricultural practices. The level of awareness and preparedness among residents can vary based on socioeconomic factors such as development maturity, economic status, and education (Qasim & Qasim, 2020). In many rural areas, according to Alam (2020) residents may have a low perception of landslide risk, which affects their preparedness and response to potential disasters. This is, same author highlights, evident in regions like Southeast Bangladesh, where despite high-risk conditions, communities perceive low risk and show reluctance to relocate.

Similarly, in rural tourism settings, a lack of awareness about how tourism activities can exacerbate natural vulnerabilities may further hinder effective disaster management and risk reduction.

Table 7. Increased risk of landslides

		Increased risk of landslides			Total
		Much worse	Worse	No change	
Gender	Male	27	133	96	256
	Female	18	90	104	212
Total		45	223	200	468

Source: Panić, 2024

The Pearson Chi-Square test result indicates a statistically significant relationship between gender and perceptions of increased landslide risk (Table 8). This statistical significance suggests that male and female participants differ in their perceptions of tourism's impact on the likelihood of landslides. These differences could be influenced by the distinct roles and responsibilities typically undertaken by men and women in rural communities. Men may engage more frequently in activities like farming, forestry, or construction, which are directly impacted by land instability, making them more sensitive to the risk of landslides. Women, on the other hand, may interact with the environment in ways less immediately tied to land stability, which could contribute to their more frequent perception of no significant change. Additionally, social and cultural factors, such as gendered awareness of environmental risks or exposure to tourism activities that exacerbate land instability, may shape these perceptions. Understanding these nuances is crucial for developing tailored communication and risk mitigation strategies that address the concerns of all community members effectively. This approach can ensure that both genders are engaged in sustainable tourism development while minimizing the environmental and social risks associated with increased land instability.

Table 8. Pearson Chi-Square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6,331[a]	2	,042

Source: Panić, 2024

The significant proportion of respondents reporting worsening conditions suggests that tourism activities are creating noticeable disturbances to wildlife, likely driven by increased human presence and habitat encroachment. Tourism infrastructure, such as roads, accommodations, and recreational facilities, often cuts into natural habitats, disrupting migration patterns, nesting areas, and feeding grounds. Additionally, the growing number of tourists engaging in activities like wildlife observation or off-trail hiking may inadvertently stress animal populations, altering their behavior or pushing them further from their natural ranges. These disturbances, as highlighted by Cui et al. (2021), emphasize the urgent need for improved management strategies that minimize human-wildlife interactions and mitigate the ecological impacts of tourism.

Conversely, the substantial percentage of participants perceiving no change in wildlife conditions reveals a more complex and uneven dynamic. This could indicate that some wildlife populations are more resilient or that the effects of tourism are geographically localized, concentrated in specific hotspots. For instance, species that are less reliant on habitats affected by tourism infrastructure might not exhibit visible changes, leading some residents to perceive minimal or no impact. Alternatively, this "no change" response might reflect a lack of direct interaction with or awareness of wildlife among certain segments of the population, particularly in areas less frequented by tourists.

This divergence in perceptions underscores the importance of conducting localized assessments to identify areas where wildlife disturbances are most acute. Such assessments can help pinpoint the types of species and habitats most affected by tourism, providing a targeted basis for conservation efforts. As suggested by Tsunoda & Enari (2020), balancing wildlife conservation with the needs of local communities requires innovative strategies such as land-sharing approaches, where tourism activities are designed to coexist with wildlife habitats, or compact planning that minimizes habitat fragmentation. These strategies on one hand reduce human-wildlife conflicts and on the other promote a more harmonious relationship between tourism and conservation. Moreover, tourists must be made aware of how their activities, even seemingly harmless ones, can disrupt wildlife, while locals could benefit from understanding how sustainable tourism practices can support both ecological preservation and economic growth.

Table 9. Increased disturbance of wildlife

		Disturbance of wildlife		Total
		Worse	No change	
Gender	Male	104	152	256
	Female	121	91	212
Total		225	243	468

Source: Panić, 2024

Table 10 shows a statistically significant relationship between the gender of the respondents and perceptions of wildlife disturbance caused by tourism. Those who frequently interact with natural habitats, such as farmers or outdoor workers, may be more attuned to disruptions caused by tourism activities. Banerjee & Sharma (2021) emphasize that gender roles significantly influence human-wildlife interactions. Women's roles and responsibilities, access to spaces, and interactions with wildlife are distinct from men's, indicating that gender can shape perceptions and concerns about wildlife disturbance. Men, often involved in outdoor labor such as farming or forestry, may perceive disturbances through direct interactions with wildlife or habitat changes in their work environment. Women, on the other hand, might notice disruptions more indirectly, such as through changes in biodiversity around their homes or community spaces. Additionally, women may exhibit greater environmental sensitivity due to their caregiving roles or involvement in community activities, leading to heightened concern for ecological stability. Wildlife encounters that are seen as dangerous or disruptive can hinder psychological restoration, while those perceived as fascinating or engaging can enhance it (Johansson et al., 2024). This suggests that both genders may experience wildlife disturbances differently based on their appraisal of the threat or benefit posed by the wildlife.

Table 10. Pearson Chi-Square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12,572[a]	1	,000

Source: Panić, 2024

Table 11 results suggest that a majority of participants did not observe significant impacts on plant life, but a notable minority expressed concerns about worsening conditions. Among the total respondents, the proportions of males and females perceiving worsening conditions are nearly equal, with 87 males (34.0%) and 88 females (41.5%) reporting negative impacts. However, a larger proportion of males (66.0%) indicated no change compared to females (58.5%). This slight variation may indicate that females are slightly more attuned to or concerned about changes in plant life, potentially due to differing interactions with or reliance on local flora.

Motivational factors, such as material benefits and formal institutions, play a leading role in encouraging residents to engage in environmental governance. However, the focus on economic benefits might overshadow concerns about plant life destruction unless these are directly linked to residents' livelihoods (Fan et al., 2024). For instance, residents may prioritize broader environmental goals, like water quality or waste management, if these appear to have a more immediate connection to their economic stability. Hu et al. (2021) state that residents' environmentally responsible behavior positively influences tourists' green consumption, which can indirectly support plant conservation. For example, suppose local communities adopt visible practices such as maintaining green spaces or promoting eco-friendly tourism activities. In that case, tourists may be more likely to follow suit and support initiatives that protect vegetation. However, the primary focus might be on broader environmental issues rather than specific concerns about plant life, unless these are highlighted as part of the tourism experience. Unless the significance of vegetation preservation is explicitly highlighted - for example, by showcasing the role of local plants in biodiversity, traditional practices, or ecosystem services - plant life conservation may receive less attention from both residents and tourists.

Table 11. Destruction of plant life

		Destruction of plant life		Total
		Worse	No change	
Gender	Male	87	169	256
	Female	88	124	212
Total		175	293	293

Source: Panić, 2024

The Pearson Chi-Square test result of 2.805 indicates that there is no statistically significant relationship between the gender of the respondents and perceptions of the destruction of plant life due to tourism. This result suggests that perceptions of plant life destruction are relatively consistent across genders, indicating that factors other than gender - such as proximity to affected areas or awareness of environmental issues - may play a more critical role in shaping these perceptions. Similarly, Kor et al. (2021) observed a widespread concern for plant life sustainability in their research, although their findings did not specifically highlight gender-based differences in these concerns. This aligns with the idea that plant conservation often resonates as a universal issue, transcending demographic categories like gender. However, the level of concern may still depend on personal experiences with environmental changes, exposure to tourism activities, or cultural values tied to vegetation.

Table 12. Pearson Chi-Square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2,805[a]	1	,094

Source: Panić, 2024

The results on perceptions of increased water use due to tourism reveal a nuanced picture. While 59.0% of respondents perceived no change in water use, 40.2% believed it had worsened, and a very small fraction (0.8%) noted improvements (Table 13). The significant minority expressing concerns suggests that tourism-related activities are exerting noticeable pressure on water resources in certain areas. This could include higher water demands from accommodations, recreational facilities, and tourism-related infrastructure, especially during peak seasons. Although the majority perceived no change, this may reflect either effective water management in some regions or a lack of awareness about how tourism indirectly impacts water availability.

The finding aligns with broader observations, such as those by Cao et al. (2023), who identified weak decoupling between tourism economic growth and water consumption. This indicates that while tourism economies grow, the rate of water consumption increases at a slower pace, often due to efficient water use practices or technological advancements. Such decoupling could explain why some respondents did not observe significant changes in water use, as sustainable practices may already be mitigating more severe impacts in certain areas. However, the substantial minority reporting worsening conditions highlights areas where water management may be inadequate or where tourism's demand is particularly acute. For instance, water-intensive facilities like swimming pools, landscaped gardens, or high-capacity accommodations can strain local resources, particularly in rural areas where infrastructure may already be underdeveloped. Additionally, increased competition for water between tourism operators and local communities can exacerbate tensions and affect residents' perception of resource fairness.

These findings underscore the importance of proactive water management strategies in tourism development. Investments in water-efficient infrastructure, such as low-flow fixtures, rainwater harvesting systems, or wastewater recycling technologies, can help minimize tourism's impact on local water supplies. Equally important is raising awareness among tourists and operators about responsible water use, particularly in regions where water resources are already limited. Highlighting water conservation as part of the tourism experience can reinforce the importance of sustainable practices. The data also suggest an opportunity to explore the broader relationship between water resource management and tourism growth. While efficient practices may reduce water consumption, a stronger focus on integrating local knowledge and community participation in water governance could further enhance outcomes. Engaging residents in monitoring water use and decision-making can ensure that tourism development does not come at the expense of local needs, fostering a more equitable and sustainable balance.

Table 13. Increase in water use

		Increase in water use			Total
		Worse	No change	Better	
Gender	Male	87	166	3	256
	Female	101	110	1	212
Total		188	276	4	468

Source: Panić, 2024

The statistical significance between genders on water use increase suggests that men and women perceive tourism-related water use differently, possibly due to varying roles, responsibilities, and interactions with water resources within their communities (Table 14). Women, who are often more directly involved in managing household water supplies, may be more aware of increased competition or shortages caused by tourism demands. This heightened awareness is likely rooted in their daily responsibilities which require consistent and reliable access to water. In contrast, men's interaction with water resources often centers on activities like agriculture or other external uses, making their concerns more focused on operational efficiency rather than immediate availability. They generally exhibit stronger positive attitudes towards water conservation compared to men. This suggests that women may be more inclined to support and engage in water-saving behaviors (Casado-Díaz et al., 2020). This tendency aligns with the observation that women prioritize domestic water use, while men emphasize irrigation systems' efficiency. This distinction reflects broader patterns in environmental attitudes, with women often displaying greater environmental concern and awareness of resource management issues. According to Lafuente et al. (2021), these differences are also influenced by women's relatively higher levels of political knowledge and engagement in water-related governance, which may enhance their understanding of the systemic challenges posed by tourism-driven water demands.

Globally, women are disproportionately affected by poor water access, particularly in regions with high water insecurity. In such areas, women frequently bear the responsibility of water collection, often traveling significant distances to secure this essential resource (Kakinuma & Wada, 2024). This highlights a significant gender-based disparity in water security, where women's livelihoods and well-being are directly impacted by the availability and quality of water resources. In tourism-dependent regions, this disparity becomes even more pronounced, as the competition for water between local communities and the tourism sector can exacerbate existing inequalities.

Table 14. Pearson Chi-Square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9,351[a]	2	,009

Source: Panić, 2024

The relatively high percentage of respondents reporting "no change" in energy use suggests that existing energy infrastructure in some rural areas is adaptable enough to handle increased demand from tourism activities without causing noticeable disruptions (Table 15). This stability may be attributed to either adequate energy capacity in certain regions or effective management practices that balance local and tourism-related energy needs. However, the 43.2% of respondents who observed worsening conditions highlight significant localized challenges. These concerns likely stem from issues such as increased competition for electricity between tourism facilities and local communities or the visible overuse of energy-intensive amenities, such as heating, cooling, and lighting in tourist accommodations or recreational spaces.

Such challenges are often exacerbated in tourism-dependent areas where seasonal demand spikes can strain already limited energy resources. For example, during peak tourist seasons, the demand for electricity in hotels, restaurants, and other facilities can compete with the energy needs of local residents, creating tensions and potential shortages. Additionally, rural regions with underdeveloped energy infrastructure are particularly vulnerable to these pressures. In such areas, even modest increases in energy demand from tourism can expose systemic weaknesses, leaving communities and tourism operations alike struggling to meet their energy needs. Tourism development inherently changes energy use patterns in rural areas. As infrastructure expands to accommodate more visitors, energy consumption grows, requiring greater reliance on local energy systems. This development can improve energy literacy among residents, but it also necessitates more energy consumption to support tourism activities (Sun et al., 2023; Wu et al., 2022). While this growth can bring benefits it also increases the sector's dependency on energy resources. In many cases, this reliance still heavily leans on conventional energy sources, such as fossil fuels, which contribute to environmental degradation and pose a dual challenge of managing resource availability and sustainability.

Despite these concerns, tourism can also act as a catalyst for positive change in energy systems if managed properly. For instance, it can drive investments in renewable energy sources, such as solar or wind power, which not only reduce environmental impacts but also create more resilient and sustainable energy infrastructure. Tourism businesses adopting energy-efficient technologies can further help mitigate the pressure on energy resources. These advancements not only benefit the tourism sector but also improve energy access and reliability for local communities, creating a win-win situation.

Table 15. Disproportionate use of energy

		Disproportionate use of energy			Total
		Much worse	Worse	No change	
Gender	Male	4	89	163	256
	Female	0	113	99	212
Total		4	202	262	468

Source: Panić, 2024

This statistically significant result suggests that perceptions of disproportionate energy use are not evenly distributed and are influenced by the gender of the respondents (Table 16). In the case of gender, this could reflect differing interactions with or awareness of energy-related issues. For instance, women, often responsible for managing household energy consumption, might be more sensitive to the impact of tourism on local energy supplies, especially if it disrupts daily routines. In rural areas, women often bear a dual burden of productive and reproductive work. While men and women may participate equally in productive work, women typically handle most of the reproductive tasks, such as household chores, which limits their leisure time and affects their energy expenditure patterns. (Picchioni et al., 2020). This additional workload can lead to higher energy use by women in non-leisure activities. Due to the additional reproductive work, women have fewer leisure opportunities, which can further impact their energy expenditure patterns

(Picchioni et al., 2020). Conversely, men might focus on broader aspects of energy use, such as infrastructure reliability or efficiency, which could lead to differing evaluations. Pueyo et al. (2020) indicate that men-owned enterprises use electricity more frequently and intensely than women-owned enterprises, despite better business performance, due to factors like poor access to finance, education, and social norms.

Table 16. Pearson Chi-Square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	18,512[a]	2	,000

Source: Panić, 2024

The data on perceptions of noise pollution caused by tourism reveals a complex dynamic between local experiences and environmental changes. Of the 468 respondents, 44.4% reported that noise pollution had worsened, while the majority (54.7%) perceived no change, and only 0.9% described the situation as "much worse" (Table 17). These findings suggest that while a significant minority is concerned about increased noise levels, the majority may not feel that tourism has notably disrupted the acoustic environment. This discrepancy highlights how noise pollution, often considered a less visible form of environmental degradation, can be experienced unevenly within rural communities.

In rural areas, even moderate increases in noise can have an outsized impact due to the typically low baseline noise levels. For local residents accustomed to tranquil environments, the addition of tourism-related sounds can significantly alter the soundscape. This change not only affects their routines and well-being but also challenges the expectations of tourists seeking quiet, restorative getaways. Additionally, noise pollution can have profound ecological effects, disrupting wildlife behavior such as breeding, feeding, and migration patterns. These disruptions can cascade through ecosystems, compounding the broader ecological impacts of tourism development.

The expansion of road networks in rural areas, as noted by Iglesias-Merchán et al. (2021), is a key driver of increased noise pollution. The growth in both the size and extent of roadways facilitates higher traffic volumes, bringing more vehicles into previously quiet and remote areas. This infrastructure development, while essential for improving accessibility and supporting tourism growth, introduces persistent sources of noise that can erode the natural tranquility of rural landscapes. The cumulative effect of these changes may not be immediately visible to all residents, particularly those who view tourism as a source of economic benefit or community development. Interestingly, some studies suggest that rural residents may be less sensitive to noise pollution than urban counterparts, potentially due to a lack of awareness about its long-term effects or because the perceived economic and social benefits of tourism outweigh these concerns. For instance, improved infrastructure, increased business opportunities, and enhanced local facilities linked to tourism might offset concerns about noise for some residents. This underscores the dual nature of tourism impacts, where the same activities can be seen as both beneficial and disruptive, depending on the perspective.

Table 17. Noise pollution

		Noise pollution			Total
		Much worse	Worse	No change	
Gender	Male	0	112	144	256
	Female	4	96	112	212
Total		4	208	256	468

Source: Panić, 2024

The Pearson Chi-Square test result of a p-value of 0.077 indicates that the relationship between noise pollution perceptions and gender is not statistically significant at the conventional threshold (Table 18). One explanation for this consistency could be the localized or temporary nature of noise disruptions in rural tourism. Noise generated by activities such as seasonal events, increased traffic during peak tourism periods, or construction projects tends to be confined to specific times or areas. As a result, its impact may not be substantial enough to create noticeable disparities in how it is perceived by different demographic groups. In addition, rural tourism areas, by their nature, often maintain a baseline of quiet, making occasional noise spikes more apparent to all residents, regardless of their roles or daily routines.

The lack of significant variation could also suggest that the sources of noise pollution, such as road traffic or outdoor recreational activities, are universally experienced within these communities. Unlike issues such as water use or land pollution, which may disproportionately affect certain groups due to their specific roles or responsibilities, noise pollution is likely to be encountered in common spaces, such as near roads, tourist attractions, or public venues, leading to more uniform perceptions across genders.

Table 18. Pearson Chi-Square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5,139[a]	2	,077

Source: Panić, 2024

The relatively high percentage of respondents (50.6%) reporting worsening conditions underscores growing concerns about tourism's impact on land quality (Table 19). This highlights the strain that tourism-related activities place on rural environments, particularly in areas where waste management systems are underdeveloped or inadequate. Issues such as littering, improper waste disposal, and the proliferation of single-use plastics are common in regions that experience seasonal surges in tourist numbers. These activities not only degrade the visual appeal of rural landscapes but also contribute to long-term ecological harm. One major factor contributing to these perceptions is the expansion of tourism infrastructure, which often encroaches upon natural landscapes. The construction of accommodations, roads, and recreational facilities, especially near ecologically sensitive areas like lakes and forests, can fragment habitats and reduce biodiversity. As noted by Jinghui et al. (2020), these land-use changes often come at the expense of natural beauty and ecological balance, eroding the very features that make rural areas attractive to tourists. Additionally, increased soil erosion, runoff, and nitrogen export associated with these developments can impair water quality in nearby ecosystems, further exacerbating environmental degradation. Such changes are often highly visible to residents, reinforcing the perception of worsening land conditions and amplifying concerns about the sustainability of tourism development.

Tourism's impact on land quality also highlights the challenge of balancing economic growth with environmental stewardship. While tourism can generate economic opportunities, its rapid and unregulated growth often creates unintended consequences, such as the overuse of natural resources and the loss of pristine landscapes. Rural communities that depend on these resources for their livelihoods may find their quality of life diminished as pollution and degradation increase. Residents often perceive these changes as direct threats to the sustainability of their environment, which can lead to tensions between tourism operators and local populations (Krstić et al., 2024).

Table 19. Land pollution

		Land pollution			Total
		Much worse	Worse	No change	
Gender	Male	5	159	92	256
	Female	8	78	126	212
Total		13	237	218	468

Source: Panić, 2024

The significant relationship between gender and perceptions of land pollution caused by tourism highlights how gendered roles and responsibilities shape environmental awareness. Women, often tasked with managing household waste and participating in community-level environmental activities, are likely more attuned to visible forms of land pollution, such as litter or improperly disposed waste, and its immediate impacts on daily life. Their proximity to these issues makes them more sensitive to changes in environmental conditions that affect their routines and responsibilities. This aligns with findings by Tantoh et al. (2021), who note that women in rural areas frequently face disenfranchisement in accessing and managing land resources, further exacerbating their vulnerability to environmental challenges like land pollution.

This limited access to land management and decision-making processes can amplify women's concerns, as they often have less agency in implementing or influencing conservation efforts. Despite their close interaction with the land, women may lack the formal authority to address pollution issues, leading to frustration and a heightened awareness of its negative effects. Conversely, men, whose interactions with the environment are often tied to outdoor labor or occupational activities, such as farming or construction, might evaluate land pollution differently. Their focus may be less on the visibility of waste and more on how pollution impacts the land's functionality and utility for economic activities. For instance, men may prioritize concerns about soil fertility or land availability over littering or waste disposal. These differing perspectives reflect the broader socio-cultural dynamics in rural communities, where gender roles influence how individuals interact with and perceive environmental issues. Women's concerns may also be driven by the cumulative impact of land pollution on family health, aesthetics, and community well-being, while men might view land degradation through the lens of productivity and resource use. This divergence underscores the importance of considering both perspectives when addressing land pollution in tourism areas.

Table 20. Pearson Chi-Square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	,387[a]	1	,534

Source: Panić, 2024

CONCLUSION

This study examined the ecological impacts of rural tourism development in selected villages, focusing on how residents perceive changes in various environmental indicators. The findings confirm that rural tourism development significantly affects ecological indicators, supporting the primary hypothesis (H1). Respondents identified several key environmental issues, including increased air and land pollution, higher water consumption, and risks such as ecosystem degradation and landslides. These findings align with global concerns about the environmental trade-offs of tourism development, particularly in fragile rural settings where ecosystems are more vulnerable to anthropogenic pressures. The study also underscores the importance of local perceptions as a valuable tool for assessing ecological impacts, as residents serve as direct witnesses to changes in their environment caused by tourism. This reinforces the need for participatory approaches in planning and monitoring rural tourism initiatives, ensuring that the voices of affected communities are heard. Moreover, the study highlights how these impacts are not uniform, with some respondents reporting no significant changes, suggesting that environmental challenges might be concentrated in high-tourism areas or periods. Understanding these dynamics can help policymakers design more localized and context-specific interventions to balance tourism growth with environmental preservation.

The study explored gender as a variable influencing perceptions of ecological impacts, providing strong support for H1b. Results show that women were more likely than men to perceive worsening conditions, especially in areas like ecosystem degradation, water use, and land pollution. These gender-based differences reflect the distinct roles and responsibilities traditionally held by men and women in rural communities. Women often manage resources such as water and household waste, which makes them more sensitive to the pressures tourism places on these systems. For instance, competition for water resources with tourism facilities may directly impact women's daily routines, such as cooking, cleaning, or agricultural activities that rely on consistent water availability. Conversely, men, whose interaction with the environment is often linked to outdoor work or farming, may be less focused on immediate resource competition and more attuned to broader operational challenges. This finding supports the growing body of literature emphasizing the gendered nature of environmental experiences and highlights the importance of including women in decision-making processes regarding tourism planning. By incorporating gender-specific perspectives, tourism policies can be better tailored to address the unique needs and concerns of all community members, ultimately fostering more sustainable and equitable outcomes.

The study also revealed trends that transcend gender, showing broader community concerns about tourism's environmental impacts. While a majority of respondents reported "no change" in some indicators, such as air pollution and noise, a substantial minority expressed concerns about worsening conditions. For example, increases in land and water pollution were commonly cited, likely driven by inadequate waste management systems and heightened demand for resources during peak tourist seasons. Tourism infrastructure expansion, such as road construction, lodging facilities, and recreational areas, can intensify these issues by disturbing natural habitats and introducing waste-intensive activities. These pressures are particularly acute in rural areas where infrastructure is often underdeveloped, leaving local systems unable to cope with sudden surges in demand. Additionally, localized effects, such as visible littering near popular tourist sites or increased vehicle emissions, may explain why some respondents experience more pronounced impacts than others. This uneven distribution of tourism's environmental consequences highlights the need for targeted interventions, such as zoning regulations, investment in waste management, and renewable energy initiatives. Ensuring that the benefits of tourism are equitably shared while minimizing ecological harm will be crucial for the sustainable development of rural tourism destinations.

Despite the study's significant findings, several limitations should be acknowledged, which could guide future research. First, the sample was restricted to specific villages, limiting the generalizability of results to other rural tourism destinations with differing environmental, cultural, or socioeconomic contexts. For example, rural areas with more robust infrastructure or higher environmental awareness among residents may experience and perceive tourism impacts differently. Second, while gender was a central variable in this study, other factors, such as age, education, occupation, or proximity to tourism hotspots, were not explored in-depth,

though these may also play a critical role in shaping perceptions. Third, the cross-sectional nature of the study captures perceptions at a single point in time, which may not reflect changes in attitudes or environmental conditions over the long term. Future research should consider conducting longitudinal studies to track how tourism impacts evolve and how community perceptions shift with the growth of tourism and implementation of sustainability initiatives. Additionally, expanding the scope of the research to include a greater diversity of rural settings would provide more comprehensive insights into the relationship between tourism and ecological sustainability. Integrating qualitative methods, such as in-depth interviews or focus groups, could also enrich the findings by capturing nuanced perspectives that might be missed in quantitative surveys. Ultimately, by addressing these gaps, future research can better inform policies and practices that promote sustainable rural tourism while safeguarding the ecological and social integrity of host communities.

The outcomes of this study contribute to the growing body of knowledge on rural tourism and its implications for rural development and quality of life. Future research endeavors should delve deeper into understanding the specific mechanisms that drive gender-based disparities and focus on developing strategies to empower women in rural destinations. Furthermore, addressing environmental concerns should remain a top priority, as rural tourism continues to evolve and shape the future of Western Serbia and similar regions. Ultimately, the findings emphasize the potential of rural tourism as a driver of positive change and prosperity in rural communities, and the importance of continued efforts to balance economic development with cultural preservation and environmental conservation.

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Ecotoxicological properties of the disinfectants, insecticides and rodenticides and their role in emergency situations

Ekotoksikološke osobine sredstava za dezinfekciju, dezinsekciju i deratizaciju i njihov značaj u vanrednim situacijama

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Abstract: Disinfectants, insecticides and rodenticides (DDD-agents) are classified as biocides. Thus, their impact on environment, aquatic and terrestrial wild animals, domestic animals and human must be considered during the use of these compounds in public health and agriculture. According to UNEP (United Nations Environment Program) reports from 1992 biocides are among the most studied chemicals in terms of their toxicity. Biocides must be effective in target organisms however they should not act on other plants, animals and humans. The selective toxicity of biocides is extremely important feature, but unfortunately many of them do not work only on the target organisms, but also on the non-target animals and plants in the environment. This article presents elements related to the toxicological and ecotoxicological properties of some DDD-agents which should be recognized. During emergency situation intensive contamination with DDD-agents is possible and this should be taken into account.

Keywords: ecotoxicology, veterinary medicine, biocides, nature.

Sažetak: Sredstva za dezinfekciju, dezinsekciju i deratizaciju (DDD) spadaju u biocide, koji za svoj položaj na tržištu a time i za mogućnost praktične upotrebe na području javnog zdravlja i zdravstvene zaštite životinja moraju imati osobine koje su prihvatljive što se tiče njihovog uticaj na prirodu, divlje životinje na kopnu i organizme u vodi, ptice, korisne insekte (pčele), domaće životinje i čoveka. Po podacima UNEP (Međunarodni program Ujedinjenih nacija za prirodu) iz 1992 godine biocidi spadaju u najbolje proučene hemikalije u smislu njihove toksičnosti. Biocidi moraju biti biotično efikasni a istovreme bezbedni za korisne biljke, životinje i čoveka. Selektivna toksičnost biocida je njihova izuzetno važna osobina, ali nažalost mnogi od njih ne deluju samo na ciljne organizme, nego i na ne ciljne životinjske i biljne vrste u prirodi. U radu su prikazani elementi vezani na toksikološke i ekotoksikološke osobine nekih predstavnika DDD sredstava koje moramo poznavati i poštovati, kako bismo sprečili štetne posledice DDD sredstava na životnu sredinu u kojoj je došlo do vanredne situacije i masovne kontaminacije tim sredstvima.

Ključne reči: ekotoksikologija, veterinarska medicina, biocidi, priroda.

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INTRODUCTION

According to UNEP (United Nations Environment Programme) data from 1992, biocides are among the best studied chemicals in terms of their toxicity. Biocides must be biotically effective and at the same time safe for beneficial plants, animals and humans.

In order to determine the ecotoxicological properties of a particular biocide, their manufacturers must provide the results of ecotoxicological studies that must be conducted according to OECD recommendations for ecotoxicological studies or according to the standards of good laboratory practice (GLP). In emergency situations such as floods, earthquakes, fires, etc., there could be greater uncontrolled contamination of the environment with these agents. Greater uncontrolled contamination could certainly have a greater toxic impact on all living beings, whether it manifests itself as their acute, subacute or chronic toxicity with all its consequences, primarily for domestic animals and humans.

In the ecotoxicology of biocides, a special problem is posed by preparations from the group of anticoagulants and organophosphates, which are used as agents for the destruction of mice and rats (rodenticides) or are used in public health as insecticides and in veterinary medicine as endo- and ecto-antiparasitics. In public health, anticoagulants are often used for mass deratization as rodenticides in a certain place in larger quantities and on a large number of animals, and in veterinary medicine they are important as toxic substances in accidental or intentional poisoning of domestic animals. Substances from the group of anticoagulants are characterized by being very stable, accumulating in the body in an active form, and their long excretion from the body and their toxic effect on non-target animal species are also problematic.

Organophosphates are no longer used for plant protection in many countries today, but some of their representatives are still used for the destruction of external and internal parasites in domestic animals, as well as in public health for disinsection. A special problem in ecotoxicology is represented by preparations containing organophosphates and marketed as sprays. Sprays are a very problematic pharmaceutical form from the point of view of environmental protection and the possibility of affecting non-target animal species.

The paper presents elements related to the ecotoxicological properties of some representatives of DDD agents that we must know and respect in order to prevent the harmful effects of DDD agents on the environment in which an emergency situation and mass contamination with these agents occurred.

Significant pollutants of nature and the environment are DDD agents that are used in animals for a long time, simultaneously in a large number of animals or are used in premises and their living environment. Residues of these agents can accumulate in nature and the environment in unchanged form or as their active and inactive metabolites. From an ecotoxicological point of view, the problem is DDD agents in unchanged form or their active metabolites that can appear in larger quantities during natural disasters and other emergency situations.

The widespread use of biocides in veterinary medicine and public health represents a major problem from the point of view of nature protection, the environment, human health and animal health.

In veterinary medicine, biocides are used in animal health care for disinfection, deratization and disinfestation with the aim of destroying the causative agent of the disease (microorganism or parasite) or the vector of the causative agent of the disease. Disinfectants, rodenticides and insecticides can be used directly on animals or in their immediate environment. The use of drugs from the above groups in veterinary medicine has recently decreased somewhat. In animal health care, their use is under strict control of the veterinary profession worldwide.

Monitoring and controlling the presence of natural pollutants from the biocide group has recently become a very important task for the veterinary profession itself. With this, the veterinary profession is actively involved in the system of solving problems in the field of nature protection and the production of safe food for humans. To solve problems in the above-mentioned area, the veterinary profession, in cooperation with other professions, must systematically monitor the toxic and ecotoxicological effects of biocides on various organisms in nature and the human environment, systematically study various possibilities and methods of their elimination from nature, and also study various possibilities and methods of reducing their ecotoxicological effects in nature and in the human environment itself.

In order for the use of these products in animal health protection to be safe, biocide manufacturers must conduct ecotoxicological and residual studies, on the basis of which it is possible to obtain important data on the ecotoxicological and residual properties of the biocide and the preparation itself.

Due to the accumulation of biocides in unchanged form or in the form of active metabolites, significant changes occur in the properties of manure and even changes in the properties of agricultural areas (fields, pastures, etc.).

Based on ecotoxicological studies that are stable in unchanged form or in the form of active metabolites in nature, the burden of biocides can be assessed. When conducting ecotoxicological studies, all standards prescribed by the EU in the field of nature and environmental protection and the international program The International Cooperation on the Harmonisation of Technical Requirements for the Registration of Veterinary Medicinal Products (VICH) must be observed. The aforementioned program precisely states the importance of ecotoxicological studies for biocides used in veterinary medicine and as medicines before they are placed on the market and thus used. Ecotoxicological studies are listed in the document VICH GL 6 (Ecotoxicity) - Environmental Impact Assessment (EIAs) for Veterinary Medicinal Product (VMPs) code EMEA/CVMP/055/96. The document was prepared in 1997 by The European Agency for the Evaluation of Medicinal Products, Veterinary Medicines Evaluation Unit, and was published in January 1998.

In the process of registering new biocides on all world markets, the results of ecotoxicological studies are also necessary. The elements of ecotoxicological studies prescribed by the directive VICH GL 6 (Ecotoxicity) – Environmental Impact assessment (EIAs) for Veterinary Medicinal Products (VMPs) are:

The document was prepared in 1997 by The European Agency for the Evaluation of Medicinal Products, Veterinary Medicines Evaluation Unit, and was published in January 1998.

The results of ecotoxicological studies are also necessary in the process of registering new biocides on all world markets. The elements of ecotoxicological studies prescribed by the VICH GL 6 (Ecotoxicity) – Environmental Impact assessment (EIAs) for Veterinary Medicinal Products (VMPs) directive are:

- type of DDD agent;
- method and frequency of use of DDD agents;
- cokinetics of DDD agents in nature;
- concentration and distribution of DDD agents in nature and the human environment;
- impact of DDD agents on aquatic organisms;
- impact of DDD agents on terrestrial organisms;
- risk of use of DDD agents for nature and the human environment expected when using a
- DDD agent (Environmental Risk Assessment).

The main objectives of ecotoxicological testing of DDD agents are to understand the problem of pollution of nature and the environment with residues of these agents, especially those that are used in veterinary medicine simultaneously on a large number of animals (disinfectants, rodenticides, insecticides) and often without special control by the veterinary profession. During ecotoxicological studies of DDD agents, researchers develop optimal procedures for monitoring pollution of nature and the environment, the impact of these agents on organisms in water, air and on land, optimal programs for protecting nature and the environment from these agents, which is especially important in conditions of natural disasters when uncontrolled pollution of nature with these agents may occur by release from larger warehouses affected by the disaster itself.

A special problem in ecotoxicology is represented by agents for the destruction of mice and rats (rodenticides) from the group of anticoagulant substances that are on the market as biocidal agents. During mass rodent control operations, which are carried out systematically and under professional supervision in urban areas by applying large quantities of anticoagulant-based preparations to a smaller, limited area or not, other animals, especially dogs and cats, as well as humans and especially children, may be exposed to these preparations.

It is characteristic of rodenticides from the anticoagulant group that they remain in the animal's body, accumulating as active substances, which means that poisoned animals can be a source of poisoning for other animals. Rodenticides from the aforementioned group are very stable substances in nature, but due to their low water solubility, they do not pose a major problem for animals in water and soil.

Rodenticides from the anticoagulant group often appear as a cause of poisoning in dogs, cats and omnivorous animals (pigs). Poisoning of the above animals can occur due to criminal poisoning (deliberate preparation of food with the addition of rodenticides) or by animals eating bait or a dead poisoned animal, usually mice or rats (Ćupić, 1999; Worting, 1987).

According to data from the literature (Einstein et al., 1994; Katzung, 1998; Worting, 1987; Priručnik, 1998; Kobal & Ćupić, 2008), 20 substances are classified as rodenticides based on their mechanism of action and their use. In Slovenia, preparations containing difethialone, chlorophacinone, brodifacoum and bromadiolone as active substances are registered and on the market (Priručnik, 1998). All of the above active substances inhibit the synthesis of

prothrombin in the liver, resulting in impaired blood coagulation in poisoned animals (Katzung, 1998; Means, 2004).

The mechanism of toxic action of coumarin rodenticides is the inhibition of the synthesis of blood coagulation factors, namely prothrombin (factor II), procovertin (factor VII), Christmas factor (factor IX) and Stuart-Prover factor (factor X) in the liver, which is a consequence of the interference of these poisons with the conversion of vitamin K1. Namely, anticoagulants from the group of coumarin derivatives inhibit the conversion of K-epoxide (phylloquinone epoxide), a metabolite of vitamin K1, thereby causing the accumulation of the aforementioned epoxide, which is an inhibitor of vitamin K1. The basis for this is the inhibition of epoxide reductase, an enzyme that catalyzes the regeneration of vitamin K. Vitamin K is a cofactor in the postribosomal modification, or carboxylation, of blood coagulation factors.

In addition to the above mechanism of action, coumarin rodenticides damage the capillary endothelium. The consequence of all of the above is hemorrhagic diathesis, acute anemia, tissue hypoxia, which can be the cause of degeneration of tissue cells of parenchymal organs, especially the liver (Worthing, 1997).

In order to be able to talk about the toxicological significance of certain substances from the group of anticoagulants, we must know their basic chemical, physical and toxicological properties (Ćupić, 1999; Einstein et al., 1994).

Biotransformation of coumarin and other coumarin derivatives is carried out by the hydroxylation process catalyzed by microsomal enzymes of the liver (Srebočan 1993).

2. MATERIALS AND METHODS

In this paper, we have limited ourselves to presenting agents from the rodenticide and ectoendo antiparasitic group. There are a large number of rodenticide and ectoendo antiparasitic preparations on the market in various forms containing active substances in different concentrations.

Chlorophacinone

Chlorophacinone is a slightly yellow crystalline substance, very slightly soluble in water (100 mg/L of water at 20°C) and very soluble in methanol, ethanol, acetone, ethyl acetate, acetic acid, benzene and various oils.

Table 1 - Presentation of the toxicological properties of chlorophacinone

Anticoagulant name (substance)	Oral LD_{50} (mg/kg b.w.)	Dermal LD_{50} (mg/kg b.w.)	Inhalation LC_{50} (μg/L of air/hour)	LC_{50} for fish (mg/L water/96 hours)* LC_{50} for water flea (mg/L water/48 hours)**	Toxicity to bees
Chlorophacinone	For lab. rats 6,26	We did not find the data	For lab. rats 9,3	0,35 to 0,62* 0,42**	Non-toxic

After oral administration, the highest concentration of chlorophacinone in the blood serum is 4.5 hours after administration or after the animal has eaten bait or a poisoned animal. The elimination half-life ($t_{1/2}$) is approximately 10 hours.

After repeated application, chlorophacinone accumulates in the liver. 90% of applied chlorophacinone is excreted from the body with feces in an unchanged state already in the first 48 hours.

Based on the LD_{50} of chlorophacinone for rats after oral administration, the WHO (World Health Organization) classified chlorophacinone in the Ia group of toxic substances with the labels T+ (highly toxic), R27/28 (highly toxic after consumption and after contact with skin and mucous membranes).

Preparations containing the substance chlorophacinone are on the market as grain baits or as an oil concentrate that have incorporated chlorophacinone in a concentration of 0.0075% to 0.25%. Oil concentrate and grain baits that have incorporated chlorophacinone due to low solubility in water do not represent a major ecotoxicological problem due to contamination of flowing and stagnant waters, but they bind to water sludge and contaminated soils..

Difethialone

Difethalion is a powdery substance of a light yellow color, it dissolves very poorly in water (0.39 mg/L of water at a temperature of 25°C), it dissolves very well in methanol, ethanol, acetone, ethyl acetate, acetic acid, benzene, hexane and chloroform.

Table 2 - Presentation of the toxicological properties of difethialone

Anticoagulant name (substance)	Oral LD_{50} (mg/kg b.w.)	Dermal LD_{50} (mg/kg b.w.)	Inhalation LC_{50} (μg/L of air/hour)	LC_{50} for fish (mg/L water/96 hours)* LC_{50} for water flea (mg/L water/48 hours)**	Toxicity to bees
Difethialone	for lab. rats 0,56 for lab. mices 1,29 for dogs 4,00 for pigs 2,00-3,00 for poultry 0,264	for lab. rats (f.) 7,9 for lab. rats (f.) 5,3	for lab. rats 1 to 19,39,3	51 to 75* 4,4**	Non-toxic

Based on the LD_{50} of difethialone for rats after oral administration, WHO classified difethialone in the Ia group of toxic substances with the labels T+ (highly toxic), R27/28 (highly toxic after consumption and after contact with skin and mucous membranes).

Preparations containing the substance diphetialon are on the market as grain baits or as paraffin cubes that have incorporated diphetialon in a concentration of 0.0025% to 0.005%. Baits made from grain that have incorporated difethialone can represent a greater ecotoxicological problem due to the contamination of flowing and stagnant water as well as arable land, while paraffin blocks are less problematic from the point of view of ecotoxicology.

Bromadiolone

Bromadiolone is a powdery substance of a soft yellow color, it dissolves very poorly in water (19 mg/L of water at a temperature of 20°C), it dissolves very well in methanol, ethanol, acetone, ethyl acetate, acetic acid, benzene, hexane and chloroform.

After repeated administration, bromadiolone accumulates in the liver (Priručnik, 1998).

Based on the LD_{50} of bromadiolone for rats after oral administration, WHO classified bromadiolone in the Ia group of toxic substances with the markings T+ (highly toxic), R27/28 (highly toxic after consumption and after contact with skin and mucous membranes).

Table 3 - Presentation of the toxicological properties of bromadiolone

Anticoagulant name (substance)	Oral LD_{50} (mg/kg b.w.)	Dermal LD_{50} (mg/kg b.w.)	Inhalation LC_{50} (μg/L of air/hour)	LC_{50} for fish (mg/L water/96 hours)* LC_{50} for water flea (mg/L water/48 hours)**	Toxicity to bees
Bromadiolone	for lab. rats 1,125 for lab. mouses 1,75 for dogs >10,00 for rabbits 1,00 for poultry 138,00 for cats >25,00	for rabbits 1,71	for lab. rats 0,43	1,40 to 3,00* 2,00**	Non-toxic

Preparations containing the substance bromadiolone are mainly marketed as grain baits containing bromadiolone in a concentration of 0.005%. Grain baits containing bromadiolone may pose a major ecotoxicological problem due to contamination of running and standing waters as well as arable land.

Brodifacoum

Brodifacoum is a light brown powdery substance, it dissolves very poorly in water, acetone, ethyl acetate, chloroform and benzene (10 mg/100 g of water at a temperature of 20°C, 60 mg/100 g of acetone at a temperature of 20°C, 6 mg/100 g of benzene at a temperature of 20°C, 30 mg/100 g of chloroform at a temperature of 20°C and 60 mg/100 g of acetone at a temperature of 20°C).

Based on the LD_{50} of brodifacum for rats after oral administration, WHO classified brodifacum in the Ia group of toxic substances with the labels T+ (highly toxic), R27/28 (highly toxic after consumption and after contact with skin and mucous membranes).

Table 4 - Presentation of the toxicological properties of brodifacoum

Anticoagulant name (substance)	Oral LD_{50} (mg/kg b.w.)	Dermal LD_{50} (mg/kg b.w.)	Inhalation LC_{50} (μg/L of air/hour)	LC_{50} for fish (mg/L water/96 hours)* LC_{50} for water flea (mg/L water/48 hours)**	Toxicity to bees
Brodifacoum	for lab. rats (f.) 0.27 for lab. rats (f.) 0.30 for lab. mouse (f.) 0.40 for guinea pigs (f.) 2.80 for dogs 0.25 to 1.0 for cats 0.25 for poultry 4.5	for rabbits 1.71	for lab. rats 0.0005 to 0.005	0,051 to 0,165* 0,064**	Non-toxic

Preparations containing the substance brodifacoum are mainly available as paraffin blocks that have brodifacoum incorporated in a concentration of 0.005%. Paraffin cubes do not dissolve in water, so they are less problematic from the point of view of ecotoxicology.

3. SIGNS OF RODENTICIDE POISONING FROM THE GROUP OF ANTICOAGULANTS

From the anamnesis, we can determine that the animal ate the poison approximately 3 to 10 days before the first symptoms appeared. In animals that have been poisoned by rodenticides from the group of anticoagulants, hydroxycoumarin derivatives, we can clinically diagnose pale mucous membranes, difficult breathing, bruises on the body, blood in feces, blood in urine, sometimes in nasal secretions, and pathoanatomically we can determine blood in hollow organs, body cavities, as well as flowing blood on a cross-section of organs and musculature. Animals usually die due to bleeding into organ cavities (Worting, 1997; Ćupić et al., 2007; Kobal, 1987).

4. TREATMENT OF ANIMALS POISONED BY RODENTICIDES FROM THE GROUP OF ANTICOAGULANTS

- Gastric lavage.
- Separator application.
- Cleansing enemas.
- Vitamin K1 is a pharmacological antidote to the aforementioned rodenticides. It is given either slowly i.v. or s.c. in a dose of 5 to 10 mg/kg of body weight for 8 to 10 days.
- Vitamin C.
- Homologous blood transfusion, 5 to 250 ml per day for several days.
- Cardiacs.
- In cases of secondary infection with microorganisms and antibiotics (Worthing, 1997).

5. ORGANOPHOSPHATES

The basic mechanism of action of organophosphates is the inhibition of the activity of acetylcholinesterase in the brain and erythrocytes, serum and liver pseudocholinesterase, certain hydrolases, phosphatases, peptidases and proteases. Inhibition of acetylcholinesterase activity is a consequence of the covalent bond of organophosphates to the enzyme acetylcholinesterase, which is why these substances are labeled as anticholinesterase substances. The binding of organophosphate to the enzyme has the characteristics of an irreversible reaction, the phosphorylated enzyme is very stable, up to more than a hundred hours, and is also subject to the aging process. The mechanism of action of organophosphates is the same in insects, animals and humans. Organophosphates first act on non-specific cholinesterase, which is found in blood plasma. Only higher doses of organophosphates affect specific cholinesterases, which are found in nerve tissue and erythrocytes. Decreased cholinesterase activity in the blood by 20 to 40% has no significant pharmacological effects. If the activity decreases by 70% or more, important pharmacological effects can already be seen, which are manifested with muscarinic, nicotinic and central effects. If the activity of acetylcholinesterase in the brain decreases to 10 to 15% of the physiological value in a poisoned animal, death occurs.

The cholinergic effects of organophosphorus substances are the result of the accumulation of endogenous acetylcholine (Ach), a chemical mediator in the transport of stimuli, in preganglionic and postganglionic sympathetic and parasympathetic neurons, motor nerve endings in skeletal muscles and in nerve synapses of the central nervous system. The accumulation of endogenous Ach leads to disturbances in neurotransmission at the receptor level (Delak, 1985; Srebočan 1993).

The consequence of inhibition of acetylcholinesterase outside the central nervous system is miosis, sweating, fasciculation of body muscles, increased tone and peristalsis in the digestive tract, increased contraction of smooth muscles in the urinary bladder and uterus, increased secretion of bronchial glands and bronchoconstriction.

The consequence of inhibition of AchE in the central nervous system is the appearance of fear, anxiety, depression and convulsions.

Organophosphates are used to destroy insects on plants, to a lesser extent in public hygiene and to destroy ecto- and endo-parasites in domestic animals.

Of the ecto- and endo-parasites of domestic animals, fleas, mites, some nematodes, and above all ascarids are sensitive to organophosphorus insecticides. Medicines for use in veterinary medicine may contain only those organophosphates that are already included in the List of Poisons based on the Chemicals Act.

Organophosphorus insecticides and their metabolites are excreted through bile in feces or with urine, in smaller quantities with sweat and milk (5, 6, 8, 9, 10).

Antiparasitic spectrum of organophosphates

Insects (mosquitoes, flies, ticks, lice, fleas, gnats and their developmental stages).

Nematodes (*Gastrophilus larve, Haemonchus spp., Trichostrongylus spp., Ostertagia spp., Cooperia spp., Bunostomum spp., Oesophagostomum spp., Ascaridi, Hyostrongylus, Trichuris, Oestrus ovis, Habronema spp., Stephanofilaria, Schisostoma nasale, Dirofilaria imitis, Ancylostoma caninum, Ancylostoma brasiliensis, Ancylostoma tubaeforme, Uncinaria stenocephala, Trichuris vulpis, Trichuris suis, Gastrophilus intestinalis (equi), Parascaris equorum, Oxyuris equi, Strongylus vulgaris, Haemonchus contortus, Oesophagostomum radiatum*).

TRICHLORFON or METRIFONATE is used to destroy ectoparasites (lice, fleas) and endoparasites (*Gastrophilus nasalis, Gastrophilus intestinalis-equi, Parascaris equorum, Oxyuris equi, Strongylus vulgaris, Haemonchus spp., Ostertagia spp., Coperia spp., Trichostrongylus spp. Stephanofilaria spp., Oesophagostomum radiatum, Haemonchus spp., Ostertagia spp., Coperia spp., Trichostrongylus spp., Stephanofilaria spp., Bunostomum spp., Oestrus ovis, Ascaridi, Trichuris suis, Hyostrongylus rubidus, Oesophagostomum spp.*)

Trichlorfon can also be used to destroy nematodes in aquarium fish.

Trichlorfon doses:

- horses 44 mg/kg body weight;
- dogs 75 mg/kg body weight;
- fish 0.25 mg/L water.

The tolerable dose of trichlorfon for calves is 5 mg/kg body weight, for cattle 50 mg/kg body weight, for sheep and horses 100 mg/kg body weight, and the toxic dose for calves is 10 mg/kg body weight, for cattle 75 mg/kg body weight and for sheep and horses over 100 mg/kg body weight. The toxicity of chlorfon is higher if animals are fed fresh food (green grass). Many studies have proven that stressed animals are less sensitive to trichlorfon.

Ten days before and ten days after the use of trichlorfon, animals must not be given drugs that inhibit acetylcholinesterase, other cholinomimetics and muscle relaxants.

In the organism of animals, trichlorfon is rapidly and completely biotransformed. More than 6 to 8 hours after the cows received therapeutic doses of trichlorfon using the prescribed methods, we cannot find trichlorfon or its metabolites in the milk of the treated animals.

COUMAPHOS is a slightly toxic substance that can be used to destroy ecto and endo parasites. It can be applied as an aqueous solution or mixed with food. CUMAFOS can also be used in lactating cows.

HALOXONE is an organophosphorus anthelmintic with the largest therapeutic range. Antiparasitic spectrum of haloxone: *Trichostrongylus spp., Cooperia spp., Strongyloides, Haemonchus spp., Ostertagia spp.*

Therapeutic doses: 50 mg/kg body weight. for all animals.

FENTHION is used as a systemic insecticide that can be applied orally with food at a dose of 1 to 3 mg/kg of body weight per day or locally on the skin as a 0.25-0.5% aqueous solution.

Tolerable dose for cattle after i.m. application is 2.5 mg/kg of body weight

Toxic doses of fenthion to cattle after p.o. application is 25 mg/kg of body weight/day

Toxic doses of fenthion for cattle after i.m. application is 5 to 10 mg/kg of body weight

Lethal dose for sheep after p.o. application is 50 mg/kg of body weight/day.

DICHLORVOS is an organophosphorus antiparasitic that acts on *Ancylostoma caninum, Ancylostoma brasiliensis, Ancylostoma tubaeforme, Uncinaria stenocephala, Trichuris vulpis, Gastrophilus intestinalis (equi), Gastrophilus nasalis, Oesophagostomum spp., Trichuris suis*.

Granular preparations of dichlorvos cannot be used for ruminants and poultry because of their too slow movement in the digestive system and therefore a more pronounced toxic effect on the target animal species.

Therapeutic doses of dichlorvos for horses are 30 to 40 mg/kg body weight, all of a sudden, for foals 20 mg/kg b.w., for pigs 11 to 21 mg/kg b.w., for adult dogs 27 to 33 mg/kg body weight, for young dogs and cats 11 mg/kg body weight. Prophylactic doses for horses and foals are 10 mg/kg body weight, all of a sudden, and every 3 to 4 weeks.

Contraindications for the use of dichlorvos

Dichlorvos is not allowed to be used simultaneously with other AchE inhibitors (carbamates), with other anthelmintics, psychosedatives, skeletal muscle relaxants and live virus vaccines. Dichlorvos is contraindicated to use in dogs, which are invaded with parasites on the heart (Dirofilaria imitis), since migration of the parasites and blockage of the pulmonary artery or some of its larger branches may occur. We do not give Dichlorvos to animals that have constipation or diarrhea, to horses that are prone to colic, as well as to dogs and cats in the first weeks of life.

6. SIGNS OF POISONING WITH ORGANOPHOSPHORUS INSECTICIDES

Acute poisoning with organophosphates can occur during natural disasters, when higher concentrations of organophosphates occur uncontrollably, primarily in running and stagnant surface waters as well as in underground waters. Typical symptoms of organophosphate poisoning in target animal species appear when AchE activity is reduced by 70% of its physiological activity. Due to the inhibition of AchE, the amount of endogenous acetylcholine (Ach) in the body increases, and this results in highly expressed muscarinic, nicotinic and central effects of Ach.

Muscarinic effects are a consequence of inhibition of AchE in parasympathetic end synapses. As a result, there is an increased contraction of the smooth musculature of the digestive and uro-genital tract, as well as an increased activity of glands with external excretion (bronchial and salivary glands).

Nicotinic effects are a consequence of inhibition of AchE in the autonomic ganglia and in the motor plate. The nicotinic effects of organic phosphorus compounds are manifested in fasciculation of the skeletal muscles, contraction of the muscles in the hair follicles. Fasciculation of the skeletal musculature can easily progress to paralysis of the skeletal and respiratory musculature, leading to suffocation.

Symptoms from the side of the central nervous system are the result of the action of an increased amount of endogenous Ach. An increased amount of endogenous Ach appears due to the inhibition of AchE in the synapses of the central nervous system. Because of this, the animals are anxious, fearful and confused. Animals, if untreated, may die due to paralysis of the respiratory and cardiac centers in the spinal cord.

In addition to functional disturbances in the functioning of the cholinergic nervous system, organophosphorus insecticides can also cause organic damage to the structure of the nervous system in the musculature and embryonic tissue. In these cases, demyelination and degeneration of motor nerve axons occurs. The consequences of this can manifest as paresis or paralysis.

In animals, chronic poisonings can also occur, poisonings after repeated administration of smaller amounts of organophosphorus insecticides at a time when the inhibited AchE in the organism of the target animal species (treated animals) has not yet been fully restored. In these cases, the animals experience disturbances in movement, reproduction and disturbances in the animal's behavior itself.

7. TREATMENT OF ANIMALS POISONED BY ORGANOPHOSPHORUS INSECTICIDES

For the treatment of animals poisoned with organophosphorus insecticides, we have a specific antidote at our disposal, which acts on the basis of competitive antagonism with Ach for the same cholinergic receptors.

Dosage and method of administration of atropine:

2-4 mg/kg of body weight every 5 to 10 minutes. We first apply atropine i.v. until the state of atropinization (until the state when the pupil dilates to a normal, physiological size) and the remaining amount of atropine is applied to the animal i.m.

In addition to therapy using a specific antidote (atropine) in poisoned animals, we can also use a specific reactivator of inhibited AchE, pralidoxime or PAM.

Dosage and method of administration of atropine:

20-50 mg/kg of body weight pralidoxime or PAM i.m., i.v. or as an intravenous infusion in the first 24 hours. After 24 hours, there is such a degree of "aging" of the phosphorylated enzyme that the action of pralidoxime is no longer successful.

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Sustainable tourism as an integrated component of regional economic development

Održivi turizam kao integralna komponenta regionalnog ekonomskog razvoja

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Abstract: Modern tourism has numerous interconnected functions that form a unique whole that can have a strong impact on the regional economic development of a specific place. By that, the challenges that the tourism sector is facing today require particular attention from competent and involved economic subjects that must lead this industry towards sustainable development in the future. In this context, and concerning the complex connection between the environment and the economy, the main topic of the paper is the role of tourism in regional development. In this regard, the paper aims to refer to the possibility of measuring the impact of tourism on environmental factors through the presentation of qualitative and quantitative indicators and highlight the potential contribution of sustainable development to regional development. To encourage tourist activity in the new context of respecting environmental factors and factors of regional economic development, the conclusion proposes several courses of action. Aiming to encourage sustainable tourist activity and increase regional economic competencies, it would be desirable that both regions with developed economies and the less developed ones follow the courses of action.

Keywords: Regional economic development, Sustainable tourism, Environment, Economic impact.

Sažetak: Savremeni turizam ima brojne funkcije koje su međusobno povezane čineći jedinstvenu celinu koja može imati snažan uticaj na regionalni ekonomski razvoj određenog mesta. U skladu sa tim, izazovi sa kojima se sektor turizma danas suočava zahteva posebnu pažnju nadležnih i uključenih privrednih subjekata, koji ovu industriju moraju voditi ka održivom razvoju u budućnosti. U tom kontekstu, uz uvažavanje složene povezanosti životne sredine i privrede, osnovna tematika rada je uloga turizma u regionalnom razvoju. S tim u vezi, cilj rada je da se kroz prikaz kvalitativnih i kvantitativnih indikatora upućuje na mogućnost merenja uticaja turizma na faktore životne sredine i istakne potencijalni doprinos održivog turizma regionalnom razvoju. Kako bi se podstakla turistička aktivnost u novom kontekstu poštovanja faktora životne sredine i regionalnog ekonomskog razvoja, u zaključku se formulišu nekoliko pravaca delovanja. U cilju podsticanja održive turističke aktivnosti i povećanja ekonomske kompetentnosti regiona, poželjno bi bilo da pravce delovanja slede kako regioni sa razvijenom privredom tako i slabije razvijeni.

Ključne reči: Regionalni privredni razvoj, Održivi turizam, Životna sredina, Ekonomski uticaj.

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INTRODUCTION

The World Tourism Organization, an agency of the United Nations in charge of the promotion of responsible, sustainable and accessible tourism, defines tourism as "a social, cultural and economic phenomenon which entails the movement of people to countries or places outside their usual environment for personal or business/professional purposes" (https://quizlet.com/ph). The experts emphasize that tourism is one of the fastest growing global industries, and therefore, it is the main source of income for many countries. Namely, tourism as an economic activity enables the involvement of people from the local community in various ways, which help reconstruct local economy (Prnjat, 2024). The development of tourism is conditioned by the quality of the environment, so the degree of its preservation and attractiveness has a direct impact on the development opportunities in a certain area. In addition to being responsible for the economic, social and cultural environment, tourism also bears a significant responsibility for the natural environment. In general, two groups of factors influence the quality of the environment. The first group consists of objective factors that arise from the manifestation of unfavorable natural phenomena. There are also subjective factors caused by human activities.

Research of the relationship between tourism and sustainable development has become a prominent topic among researchers since the publication of the Brundtland Report in 1987. In recent decades, the principles put forward by this report, starting from the central idea of "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Sonuç, 2023), have provided a framework for the development of tourism. Bearing in mind the above, further development of tourism faces the task of achieving a balance in which meeting the current needs of tourists will not compromise meeting the needs of future generations. It follows that the relationship between tourism and the environment is of particular importance and its protection and preservation is the primary condition for establishing a sustainable and responsible development. Accordingly, the Swiss professor J. Krippendorf (1982) emphasized: "If we can lose, and then rebuild our capital in other fields of economy, the same is not true in tourism, where the basic substance is the landscape, and the land – once lost, is irretrievably lost".

Starting from the fact that space is transformed under the influence of tourist activity, the development of sustainable tourism gains more and more importance as a convincing concept for reconciling the economic benefits of tourism with the imperative to preserve the environment. With the increasing importance of the sustainability of the tourist industry for economy, a large number of scientists has researched the link between the sustainable development of tourism and the economy. Their results indicate that there is a strong connection (Ainou et al., 2022, Danish, Wang 2018, Pulido-Fernández & Cárdenas-García, 2020).The importance of tourism and its contribution to overall regional development was recognized by Hunziker and Krapf in 1942. In their research, the two researchers proved that depending on the inbound and outbound tourist flows, tourism can have positive, as well as negative, effects on the scope and degree of regional economic development. Starting from this research, the attention of many theoreticians has been focused on analyzing various economic impacts of tourism on the regional development of certain areas. A special focus of the research falls on the regions in which industry and other economic branches are not developed and, to some extent, are not economically prosperous. Their conclusions indicate that it is precisely in such regions that an extremely large amount of investment is made in tourist offer if there is a tourist potential. By investing in this kind of tourist offer, economic underdevelopment is compensated in some way and conditions are created for the development of the region itself, making it competitive in relation to other regions (Lakićević et al., 2019). The existing literature on tourism related to remote regions focuses on the role of tourism as a potential driver of economic growth (Hall, 2013); on the issues of employment, management or entrepreneurship (Brouder, 2013; Dinis, Krakover, 2016; Salvatore et al., 2018). Several authors research the path of tourism development in remote regions (Todes, Turok 2018; Rogerson, 2019), and the reasons why successful tourism development in remote regions is such a complex and challenging process. With the facts in mind, the goal of the paper was to emphasize the role of sustainable tourism in the economic development of a region.

1. SUSTAINABLE TOURISM AND REGIONAL DEVELOPMENT

According to the interpretation of the World Tourism Organization and the UN Environment Program, "sustainable tourism" implies the development of activities that respect and satisfy the needs of tourists as demand bearers, without impairing the possibility of achieving economic, social and environmental goals at the same or higher level in the future". More precisely, the concept of sustainable development should be the basic guideline

in managing tourist activity. The concept implies respect for the needs of tourists in order to realize social, economic and aesthetic goals, but on the other hand, with the protection of cultural values, social integrity, key ecological processes and biological diversity (Pavlovic, 2018). It is a long-term integrated process with broader economic, social and environmental policy considerations with the overall framework of sustainable development that maximizes economic, environmental, social and cultural benefits to the environment (Kahle-Piasecki, 2013). In his research, Bosak, 2016 argues that it is a community activity that relies on long-term planning and balanced action between traditional financial goals and environmental-social goals. Therefore, the primary goal of sustainable tourism is to enable tourists to enjoy and gain knowledge about the natural, historical and cultural characteristics of the environment, while at the same time preserving the integrity of the destination and encouraging economic development and the well-being of the local community (Munitlak Ivanović et al. 2023). More precisely, sustainable development must not stop the development of tourism but should enable its development so that tourists see and experience what they want without destroying what attracted them (Beljanski, 2018). As a concept, sustainable development is based on an integral and complex approach that puts equal emphasis on the five components (Stefanovic, Azemovic, 2012):

1. Preservation of the environment,
2. Affirmation of social integrity,
3. Nurturing cultural peculiarities of the local population,
4. Optimal satisfaction of tourist needs, and
5. Realization of economic profit.

Based on the approach of Agyeiwaah et al. (2017), Mai & Smith (2015), Lee & Hsieh (2016), sustainable tourism generally connects and requires efforts of all the interested parties in tourism development, but it is a guarantee of the preservation of economic, as well as environmental and cultural values. At the same time, this type of tourism ensures stable economic development and equal distribution of opportunities for everyone.The defined components impose the need to develop and adopt nation tourism development plans which would enable combining experiences and positions of the main economic entities. This includes: state administrations, employers' organizations, professional and social associations and organizations. Sustainability and environmental protection are a global problem and are related to all the countries in the world. All this has led to the necessity to create and prescribe regulations, rules and measures at the international level. In order to reduce the negative and uncontrolled development of tourism to a minimum, all international regulations contain (EU, 2021):

- Creation of institutions and frameworks necessary for the implementation of sustainable tourism;
- Ensuring the preservation and protection of basic tourist resources;
- Mobilization of the tourism industry sector to practice sustainable tourism in accordance with ecological requirements;
- In the economic-financial area: including environmental costs in the collection of income for tourist activities, with the idea that the polluter must bear certain taxes related to the form of pollution, which indirectly contributes to the preservation of the environment;
- Making reports on the degree of implementation of the proposed projects at the international, national and regional level;
- Using the influence of domestic and international markets to identify new tourist markets, comply with environmental requirements and create joint partnerships for the implementation of the new concept of ecotourism as a supporting element of sustainable tourism;
- Gaining benefits from environmental marketing through the development and sale of compatible tourist products;
- In the social area: introducing active education about protection in other sectors that benefit from the natural and cultural resources of tourist industry, with an understanding of environmental issues;
- Cooperation with other sectors involved in environmental protection (forestry, agriculture, regional planning, etc,);
- Creation of models and projects to support the sustainable development of tourism, with the presentation of models and application possibilities;
- Evaluation of positive results from the past in order to determine new proposals for sustainable development while transferring positive projects and experiences through national and international bodies.

In order for the concept of sustainable tourism to take root in practice, it is necessary to establish such a development model that will maximize positive relationships between the mentioned categories of goals (economic, environmental and social), and minimize the negative ones. The goals which are

pursued are also prerequisites for their realization. Unlike the current practice, it is necessary that the new approach to the development of tourism emphasizes the importance of environmental protection in the foreground, while the economic dimension loses importance in a relative sense. One-sided profit-oriented tourism can make good economic results in a short period and satisfy many tourist needs, but, on the other hand, produce negative consequences for the environment and the life of local population (Jakovljević et al., 2020).

2. MODELS FOR EVALUATING THE SUSTAINABILITY OF TOURISM

In many countries, tourism is recognized as an important factor of economic development. It is clear that economic factor is a positive effect of tourism. However, due to its mass and extremely fast global development in recent decades, tourism has brought a large negative impact on the environment, in addition to its positive contribution to the economic progress of society. Precisely because of these reasons of increasing pressure on natural resources, there is a need to plan and control tourism. Consequently, the concept of sustainable development of tourism within a tourist destination should represent the basis of long-term development (Khoja et al., 2021). Starting from the previously presented aspects, the relationship between tourism and sustainable regional development can be seen through the following considerations (Cernat, Gourdon, 2012):

- Tourism activity has a great impact on the economy. On the one hand it has positive effects on the environment and the community (increased employment, greater contribution to GDP, better quality services, higher salaries, higher production, capital generation, larger local budget through tax collection, attracting investors to the area, etc.). On the other hand, the negative impacts of tourism on the environment are the impacts on natural resources, generation of pollution and waste and damage to the ecosystem;
- Most studies that assess the economic impact of tourism activities usually take into account data on the number of arrivals, revenue per tourist, average length of stay and other economic indicators. Unlike many studies that treat only the physical and human environment, (Miller, 2010) presents a series of indicators that cover many aspects related to sustainability: environmental issues, employment, financial leakages from the system, aspects related to the client (satisfaction level), consumer behavior, the degree of social responsibility of tourism companies, etc.).

At the same time, the degree of development of a territory, through its economic, social and cultural characteristics, but also through the natural resources it possesses, is a factor that affects the predisposition of the population of the territory to travel, and implicitly, affects their behavior later on to the destination, and the effects on it (Table 1).

Table 1. Relations between tourism and sustainable development

Geographical elements of the tourist system	**Area of origin** **Dimension**	**Transit area***	**Area of destination** **Effects**
Interactions between tourism and sustainable development	ECONOMIC DIMENSION The level of economic development influences the income of potential tourists;	- investments for the development of transport infrastructure for the accommodation of tourists;	- economic growth; - profit from local resources that do not require major investments; creating jobs; -the development of transport infrastructure and public utilities; **- price increase (land, goods, services),** **- poorly paid jobs and affected by seasonality;** **- addiction to tourism.**
	SOCIAL AND CULTURAL DIMENSION Access to education (the educational level of the population); cultural values;	- over time, it can become a destination, becoming specific to its impact and relationships;	- improving the quality of life; - diversifying the job offer; - the revitalization of the region; - the revival and protection of local cultural values; **- acculturation;** **- overcrowding;** **- potential conflicts;**

	ENVIRONMENTAL DIMENSION	**- pollution and degradation of landscapes;**	- encouraging environmental protection; - conservation of historical buildings/monuments;
			- pollution;
			- degradation of landscapes, historical sites, monuments;
			- changes in wild habitats;
			- constructions inconsistent with the environment

Bold - negative efect

* The transit area is specific to the transport infrastructures intended to ensure tourists from the area of origin to the destination. Depending on the distance covered, various other elements of the tourist system may be present: infrastructure, leisure, tourist attractions.

Source: Manea, Cozea, 2022.

Given the significant potential of tourism industry to create jobs and income for local community and investors, the economic externalities of tourism are often substantiated and supported by empirical studies (Garcia et al., 2015).

The approaches concerning the impact of tourism on the environment are based on complementary perspectives aimed at monitoring natural resources in order to evaluate the transformations that tourism activities cause on the environment. The negative effects of tourism on the environment are of interest in academic circles.

The evaluation methods used vary from surveys aimed at analyzing the perception of residents, local actors or even tourists about these effects, to complex quantitative analyses. These analyses include data related to energy consumption or emission of various chemical compounds associated with the tourism industry or other indicators (Table 2), (Gossling, Peeters, 2019).

Table 2. Indicators regarding the Regional sustainability of tourism

Indicators within the Environmental Sustainability pillar
1.The strictness of environmental regulations
2. Application of environmental protection regulations
3. Sustainability of the development of the tourism sector
4. Carbon dioxide emissions
5. Concentration of harmful particles
6. Endangered species
7. Ratification of environmental protection treaties

Source: Manea, Cozea, 2022.

Tourism is one of the most important drivers of a country's economic development. There is no doubt that tourism has two sides. On the one hand, it contributes in various ways to the economic prosperity of the region, and on the other, it implies that tourism must be based on the principles of sustainable development. Therefore, the need to adapt tourist activities to the increasingly diverse and complex needs of tourists determines the emergence of specific activities.

In order to measure the global competitiveness of a country's travel and tourism, the World Economic Forum calculates the index annually. This index is calculated as the arithmetic mean of several variables: regulatory framework of tourist policy, business operations in tourism, the environment, infrastructure, natural and cultural resources, tendencies towards travel and tourism, etc. Thus, in terms of competitiveness in tourism, regions can be classified into regions that are efficient or inefficient, but also highlight the tendency to emphasize tourist activities in more developed areas and the endangerment of environmental factors.

If economic growth occurs as a result of an increase in macroeconomic, synthetic indicators, assuming the efficient use of environmental factors (while emphasizing the qualitative side), according to quality, economic growth can be viewed as (Manea, Cozea, 2022):

- Negative economic growth – reduction of the measurement indicator over time or economic recession;
- Stationary economic growth – means zero rate of the measurement indicator (also called replacement economic growth or zero growth);
- Balanced economic growth – characterized by a positive rate of the measurement indicator, and in addition, the growth rate in different sectors or branches maintain constant relations between them;
- Efficient economic growth – shows that the growth rate is positive and the degree of

utilization of a certain production factor is satisfactory;

- Optimal economic growth – shows that the growth rate is positive and that the optimization criterion is satisfied depending on the case (either through maximization or minimization) under certain restrictive conditions, explicitly formulated.

Over the years, the creation of models has aimed at steady economic growth and thus shaped several types of models. Most of the tourism development strategies formulated in the last two decades include an approach from a sustainability perspective and include environmental, socio-cultural and economic components (Kisi, 2019). In this way, on a theoretical level, they offer potential benefits at all levels, while at the same time proposing a holistic approach to tourism activity (Ibanescu, Cehan, 2022).

3. INDICATORS OF SUPPORT CAPACITIES FOR TOURISM

The expansion of research in economic and social sciences, as well as their connection with the tourism economy, has led to the definition of the following capacities for the further development of tourism (Espino-Rodriguez, 2019; WTTC, 2020):

Ecological capacity refers to the establishment of the development of tourist structures and activities without negative impact on the environment and degradation of its components. In this case, natural components (air, water, soil, vegetation) are considered. In addition, it includes the process of production and recovery of economy, which does not require investment costs that would be caused by the degradation of certain tourist destinations.

Physical capacity has a decisive role in determining the degree of saturation that tourism activities can reach in terms of environmental problems. In recent years, the rapid growth of tourism has influenced the increase in the volume of many forms of pollution (coastal, mountainous, etc.). One way to protect the physical capacity of a territory can be achieved by investing in high-performance technology. On the other hand, the provision of high quality services can give contribution.

Social-receptive capacity aims to maintain good relations between hosts (local population) and visitors (tourists). In a situation where the local population realizes that tourist activities lead to the degradation of the natural and cultural environment, on their part there may be a reduction in the threshold of tolerance with the final result of rejecting tourists. In order to avoid such unpleasant situations, it is necessary to respect the traditional way of life of the inhabitants and their habits when developing a tourist area or locality in a certain territory. Starting from the fact that a friendly interaction between visitors and local residents creates significant effects on visitors' satisfaction with the destination, maintaining positive attitudes of local residents towards the development of tourism is extremely important.

Economic capacity emphasizes the valorization of all existing resources through tourism activities. This capacity implies the maintenance of the tourist function of the given territory, where the efficiency of exploitation is measured by the ratio between costs and benefits. The size of benefit can be increased by using high-performance technologies, while the level of costs is expressed by the qualitative and quantitative value of resources (natural, cultural, workforce, general infrastructure, etc.).

Psychological capacity is related to the negative perception of tourists towards a tourist destination. This occurs as a result of degradation of the environment or inadequate attitude of the local population. More precisely, psychological capacity is related to the motivation of tourists to visit a certain destination as well as the maintenance of their personal satisfaction. Its application is conditioned by the quality of managerial activity. Ultimately, the quality of managerial activity can affect the loyalty of requests.

All the capacities mentioned above are closely related to tourism activity. They determine the material or immaterial, measurable or non-measurably boundary of the space it has or to which a tourism function can be attributed. Although these capacity indicators do not offer a standard formula, some components of the natural or cultural framework are difficult to quantify through statistical-mathematical data series. Taking into account the above, the support concepts motivate and encourage the sustainable development of tourism and indicate to which the impact of tourism on the environment can reach. Accordingly, they also provide the possibility of identifying ways to reduce degradation caused by transport and tourist activities.

Due to the fact that the intensification of the process of globalization of the world economy during the past few decades has also affected tourism, it is necessary to take into account the socio-economic ties between nations around the world. Accordingly, international tourism stands out as an important area of economic development and a significant factor in the international economic exchange of services between people located on different continents. However, the global character of international tourism in today's conditions makes this activity very sensitive.

CONCLUSION

In theory, there is a high degree of agreement regarding the position that tourism provides opportunities and perspectives for additional sources of income in many countries, but that it also has some negative impacts that must be stopped. Consequently, sustainable tourism must focus on creating a synergy between the realization of tourism objectives and the protection of nature, landscape and cultural heritage. For this, an integrated government approach is necessary, which encourages and supports the increase in the level of competitiveness and the sustainable development of tourism. Essentially, this represents an effort to research and discover the best practices of social responsibility for sustainable development. More precisely, it implies the implementation of an ambitious politics aimed at favorable positioning of tourist destination. All this includes awareness of the beneficial effects of tourism on economic growth (income generation, jobs, adequately trained human resources, economies of scale, etc.).

In order to achieve more sustainable forms of tourism, it is necessary to focus on less economically developed areas, but with ecological potential. In finding weaknesses and turning them into probable strengths that attract tourists, this can be achieved by intensively involving multiple actors. That is why the priority directions of the development of the state policy in the field of tourism should be a sustainable approach that will be supported by the economic development policy, the creation of sustainable development plans with the provision of quality services, but at the same time with the reduction of excessive and inadequate use of natural and cultural heritage. The permanent nature of environmental education from the earliest period (childhood) is also extremely important. Competitiveness, environmental and social issues of sustainable tourism development can be solved together by applying innovations and fostering the principles of sustainable consumption. In addition, the provision of new tourism services with respect to the needs of local communities and the priorities of the sustainable development of tourist destination make an additional contribution.

The tourism industry still remains a well-defined current branch. Its development in each phase depends on the degree and rate of development of other branches of the national economy. In this sense, the contribution of tourism to economic and social progress and the intensity of its action differ significantly from country to country, depending on its degree of development and the policy promoted towards it. In the end, it should be emphasized that legislation and regulations play a key role in the development of forms of tourism based on sustainable principles.

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Fiscal environmental protection policy and environmental taxes

Fiskalna politika zaštite okoliša i ekološki porezi

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Abstract: Fifty years ago, pollution problems were much less serious than today, when they pose a serious threat to people's health, not to mention concern for future generations. It seems that the time has come for a green tax reform, but while the literature is already well equipped with theoretical results, more empirical research is needed, especially in some developing countries, such as the Republic of Croatia. The issue of environmental protection transcends national borders and has no national affiliation. Considering the number of countries that are interested in solving them, we see the problems as bilateral (between two neighboring countries), multilateral (where a larger number of countries that are not necessarily neighboring countries participate) and global. Environmental taxes are one of the ways to solve them. The founding of the modern European community of states shed light on the problems that the EU must deal with, but also new possibilities and policies for environmental protection and sustainable development and general environmental management. It is the primary responsibility of each member state of the European Union to regulate its own environmental policy, but the European supranational common policy determines the direction in which it must move and harmonize its own regulations with the European ones. It is a big drawback that despite the implemented environmental tax reforms, by strengthening the pressure of European legislation on EU member states towards stronger taxation of production, products and services harmful to the environment and human health, no significant increase in income from environmental taxes was achieved.

Keywords: environmental protection policy, environmental taxes, EU, Republic of Croatia.

Sažetak: Pre pedeset godina, problemi zagađenja bili su mnogo manje ozbiljni nego danas, kada predstavljaju ozbiljnu pretnju po zdravlje ljudi, a da ne govorimo o brizi za buduće generacije. Čini se da je došlo vreme za zelenu poresku reformu, ali dok je literatura već dobro opremljena teorijskim rezultatima, potrebno je više empirijskih istraživanja, posebno u nekim zemljama u razvoju, kao što je Republika Hrvatska. Pitanje zaštite životne sredine prevazilazi nacionalne granice i nema nacionalno opredeljenje. S obzirom na broj zemalja koje su zainteresovane za njihovo rešavanje, probleme vidimo kao bilateralne (između dve susedne zemlje), multilateralne (gde učestvuje veći broj zemalja koje nisu nužno susedne) i globalne. Porezi na životnu sredinu su jedan od načina da se oni reše. Osnivanje moderne Evropske zajednice država rasvetlilo je probleme sa kojima se Evropska unija suočava, ali i nove mogućnosti i politike zaštite životne sredine i održivog razvoja i opšteg upravljanja životnom sredinom. Primarna je odgovornost svake države članice Evropske unije da reguliše sopstvenu politiku zaštite životne sredine, ali evropska nadnacionalna zajednička politika određuje pravac u kome ona mora da se kreće i usklađuje sopstvene propise sa evropskim. Velika je mana što uprkos sprovedenim reformama ekološkog poreza, jačanju pritiska evropskog zakonodavstva na članice Evropske unije ka većem oporezivanju proizvodnje, proizvoda i usluga štetnih po životnu sredinu i zdravlje ljudi, nije došlo do značajnijeg povećanja prihoda od ekološke porezi.

Ključne reči: politika zaštite okoliša, ekološki porezi, Evropska unija, Republika Hrvatska.

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INTRODUCTION

Because of the increasing environmental pollution, focusing on ensuring environmental quality has become much more important than ever before. For this reason, various countries have been applying environmental taxes in various areas. Hence, countries target various points including stimulating clean energy use, enabling carbon-free sources, and making transportation much more eco-friendly. To achieve these targets and benefit from environmental taxes practices, countries put environmental taxes into effect. Today, there is environmental taxes practice in almost all countries. Among all countries, G7 countries, which represent developed countries, have a leading role. They represent 43% of the total world economy (World Bank, 2023). Also, G7 countries have been applying an environmental taxes structure in various areas and collected a high amount of environmental taxes revenues in these areas. Therefore, G7 countries' practices have been followed by other countries because G7 countries, as the developed countries, have a lighthouse position for the remaining countries (Kartal, 2024). There are three countries among G7 that are members of European Union (EU) - Germany, Italy and France. We must also mention United Kingdom – member of the EU until Brexit officially took place on 31 January 2020.

It was realized early on that the problems of environmental pollution cannot be kept within national frameworks because pollution does not know national borders, so there is a need to harmonize policies and solve this problem at the international level.

In the prevention of environmental protection at the European level, the European Union also became involved, acting through its specific institutions and passing rules through various acts, which member states

1. ENVIRONMENTAL PROTECTION POLICY IN THE EUROPEAN UNION

The role of the European Union is of great importance for the preservation of the environment and the reduction of pollution, in a way that it exerts pressure and thus motivates large companies to reduce greenhouse gases, which are, among other things, one of the biggest polluters of the environment. The member states of the European Union are introducing various measures to control the state of the environment, in order to make citizens aware that the state of the environment is necessary for life, and that we are destroying it through irrational use. Each environmental protection policy instrument has its advantages and disadvantages, and which instrument will be applied depends on the state of each country.

The most important EU body that has expressed its commitment to work towards environmental protection goals is the European Commission (Commission), followed by the European Environment Agency (EEA), whose goal is to provide independent, relevant and timely information to both political power holders and the public. The role of the European Union is to actively encourage a coordinated and balanced development of economic life within the Union and to "...enable long-term, non-inflationary and ecologically sustainable developm-ent (Luttenberger, 2003).

It is the primary responsibility of each member state of the European Union to regulate its own environmental policy, but the European supranational common policy determines the direction in which it must move and harmonize its own regulations with the European ones.

The basic document available on the official websites of the EU and the Commission is the European Green Deal. With the European Green Plan, "Europe wants to be the first climate-neutral continent by becoming a modern and resource-efficient economy" (Communication on The European Green Deal, 2019), and at the same time part of the economic recovery plan of the entire Union, especially due to the consequences of the fight against the COVID-19 pandemic (called Next Generation EU).

During the creation of the European Union and the planning of the stages of its expansion, constant attention was paid to the issue of the environment, which does not only apply to countries that are perceived as the most developed and at the same time environmentally conscious, such as the Scandinavian countries and the countries of the north of the EU, but also to all countries that during joined the EU regardless of their level of development and transition. This kind of attempt has also existed at the global level ever since the Brundtland Commission and their efforts that "... concern for the global environment does not relegate the problem of human needs and poverty to the background." (Blewitt, 2017), i.e. that the differences in the level of development between the European north and south through the common policy of the EU, try to overcome in such a way that the advantages of some are used as a driving force for the development of less developed ones.

The common environmental policy is defined by the new European Green Plan, which states that the European strategy "...seeks to protect, preserve and increase the natural capital of the EU and to protect the health and well-being of citizens from risks related to the environment and the impact of the environment on them. This transition must be fair

and inclusive at the same time. At the same time, people must come first, and attention should be paid to regions, industries and workers..." (European Commission, 2019).

Activities related to environmental taxation began in 1973, in the form of 6 environmental programs, with the last one ending in 2010. Each of the environmental programs emphasized a specific component of the environmental policy:

- the first program lasting from 1973 to 1976 defined the primary goals of European environmental policy along with a plan to reduce pollution and improve the quality of life;
- the second program from 1977 to 1981 focused on the management of natural resources, prevention of air and water pollution, and forest conservation;
- the third program lasting from 1982 to 1986 defined the environmental protection policy through noise reduction and waste management and increased cooperation with developing countries;
- the fourth program from 1987 to 1992 focused on transport and agriculture;
- with the fifth program lasting from 1993 to 2000, the basics of the concept of sustainable development were defined for the first time;
- the sixth program lasting from 2001 to 2010 proposed five future priorities in strategic activities: 1) improvement of existing laws, 2) closer cooperation on the market, 3) integration of bodies involved in environmental policy, 4) helping people to change behavior, 5) planning in environmental protection.

In all EU member states and those countries that wish to become one, the basic contents of environmental policy are present, which focus on issues of waste management, air, water and soil quality, the concept of sustainable development, global warming and insufficient preservation of natural resources.

2. ENVIRONMENTAL TAXES IN THE EUROPEAN UNION

An environmental tax is a tax on something that has a proven, specific negative impact on the environment. The tax base can be a physical unit, for example litres of gasoline, or a proxy of a physical unit, for example taxes on nuclear power stations. The tax is always a monetary amount, such as euros (Eurostat, 2024).

The EU defines environmental tax as: "... a tax related to the environment whose tax base is a physical unit (or a substitute for a physical unit) of something that has a proven specific negative effect on the environment..." (Regulation (EU) No 691/ 2011 of the European Parliament and of the Council). Such taxes are increasingly preferred as an integral part of the policy environmental protection according to the "polluter pays" principle.

The political obstacle to the greening of tax systems was implemented by harmonizing taxes on the territory of the European Union according to consumption taxes. Thus, the members of the European Union are limited in introducing new taxes and in changing the elements of existing taxes. Such a change is aimed directly at members of the European Union, and indirectly at countries that expect to become members of the European Union. Each member has the right to apply its own environmental regulations in its territory instead of European Union regulations if they are stricter than the Union regulations.

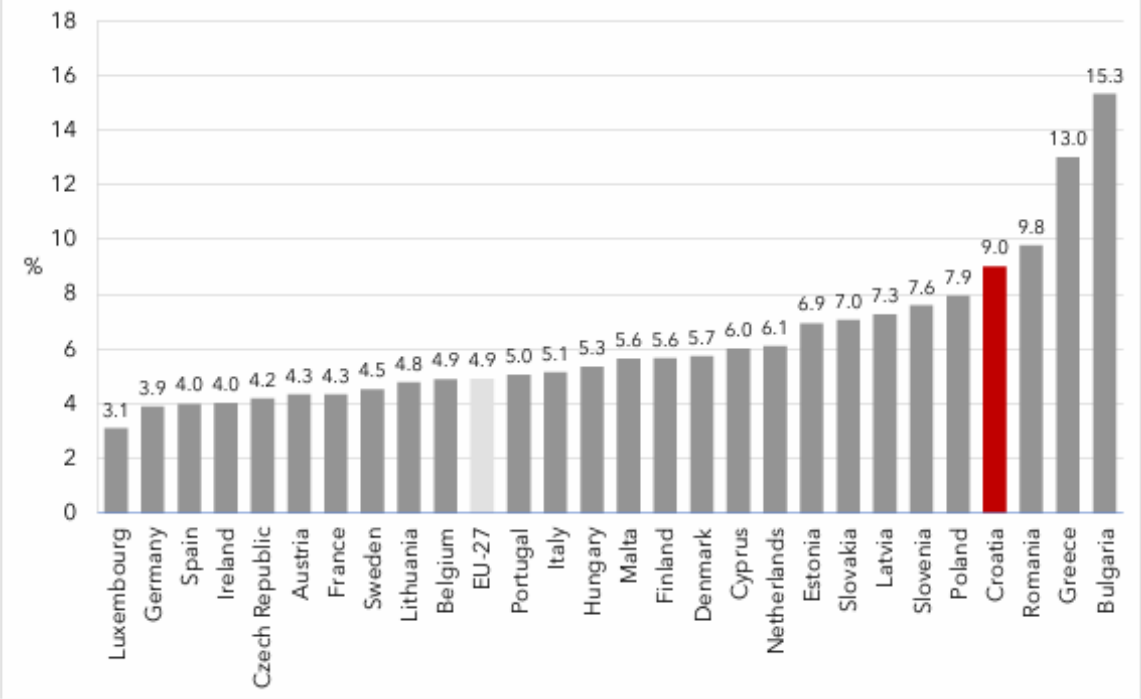
Apart from excise duties on energy products that have been harmonised at the EU level, many member states implemented additional specific national measures that add to or even go beyond the framework of harmonised tax policies. Names of all environmental taxes can be found in the National Tax Lists (NTL), where they have been classified into three tax categories in line with the guidelines provided by the European system of national and regional accounts (ESA2010). The three categories are: Taxes on production and import (D2), Current income taxes (D5) and Capital gain taxes (D91) (Srdelić, 2024).

The legal system of the European Union categorizes three basic types of environmental taxes, all broken down into 64 industry groups, households and non-residents who pay these taxes (Regulation (EU) No 691/2011 of the European Parliament and of the Council):

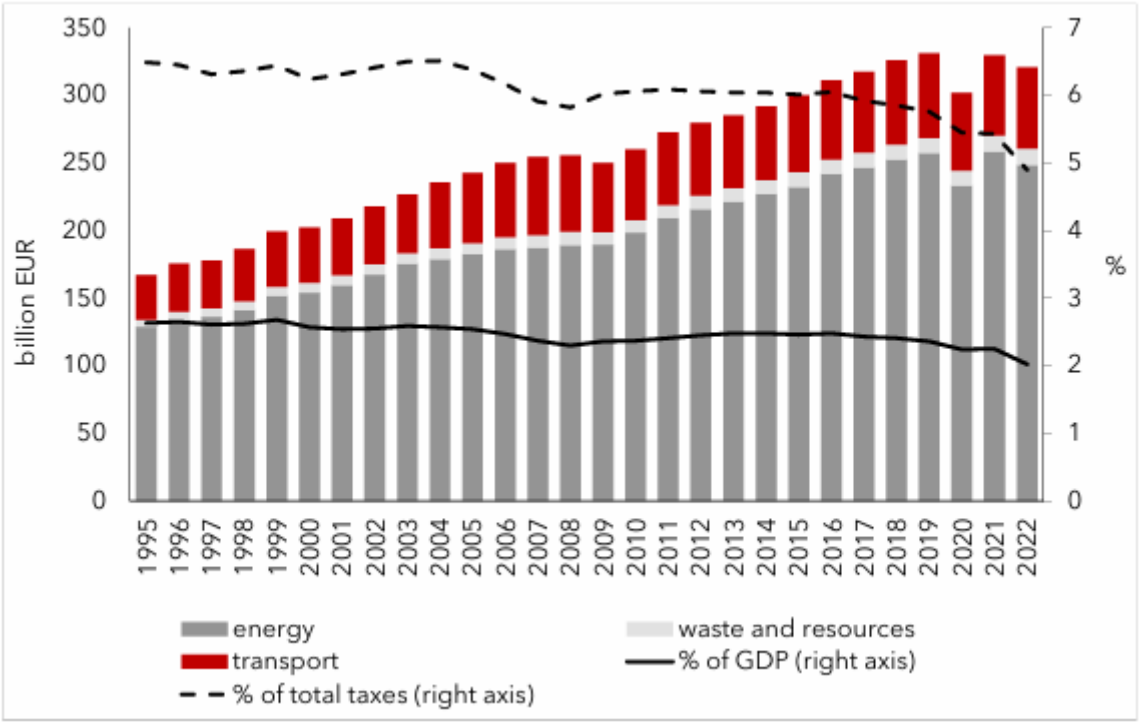
1) tax on energy products (excise duty) - tax on mineral oils and motor fuels, gasoline (leaded and unleaded), diesel, fuel oil, kerosene, natural gas and electricity consumption;

2) transport tax - tax on registration and use of motor vehicles, import and sale of motor vehicles, tax on the use of roads and highways, insurance of luxury yachts and air travel;

3) tax on pollution and natural sources - tax on pesticides and artificial fertilizers (water protection), on metal, plastic, glass, ceramic packaging, on waste (and landfills), on air pollution (CO_2, SO_2, NO_x), on batteries , tires, disposable containers, waste water (domestic and industrial), on plastic bags, water pollution, on CFC, HFC, PFAC and SF6 (ozone pollutants), and on nuclear energy (Mitić et al., 2023).



Graph 1. Share of environmental taxes in total tax revenues in EU countries in 2022
Source: Eurostat, https://doi.org/10.2908/ENV_AC_TAX



Graph 2. EU-27: Annual revenues from environmental taxes by category (1995-2022)
Source: Srdelić, 2024

At the EU level, revenues from environmental taxes have been steadily increasing, with the years 2008 and 2020 being exceptions, when revenues decreased due to declines in economic activities caused by the financial crisis and COVID-19 pandemic respectively. In total, revenues from environmental taxes in the EU have been growing by 2.5% per year on average and increased from EUR 166.9

billion in 1995 to EUR 320.8 billion in 2022. Similar to the situation in Croatia, the majority of this growth can be attributed to taxes on energy products, which nearly doubled their revenues, from EUR 128.7 billion in 1995 to EUR 248.4 billion in 2022 (Srdelić, 2024).

More than three quarters of environmental taxes in the European Union are energy taxes (77%), 20% comes from transportation taxation, and the rest from those related to pollution and resources (Dozan, 2019).

The introduction of environmental taxes aims to achieve multiple goals and fiscal measures of direct and unequivocal influence on the producer/polluter to reduce pollution, adaptability when choosing the level and method of reducing pollution, and reducing the costs of their implementation.

The Scandinavian countries were the first to start environmental tax reform in the early nineties of the 20th century. Sweden and Finland, and later Denmark, introduced environmental taxes in their tax systems while simultaneously applying compensatory measures within the tax system in the form of a reduction in the income tax rate.

Revenues from environmental taxes can be used not only for the benefit and preservation of the environment, such as financing eco-innovations, but also for the benefit of the economy. They can be directed as compensation to households and legal entities that are burdened with a high eco-tax, usually in the form of a reduction of income/profit tax or tax benefits for certain groups.

It is a big drawback that despite the implemented environmental tax reforms, by strengthening the pressure of European legislation on EU member states towards stronger taxation of production, products and services harmful to the environment and human health, no significant increase in income from environmental taxes was achieved. According to Eurostat's 2020 report on the revenues from environmental taxes in the EU member states, it is stated that they constitute a revenue of 324.6 billion euros. Although significant, this amount refers to only 2.4% of the European GDP and 6% of the total EU income from taxes and social security contributions. The largest part of that income, as much as 77.7%, is collected from energy taxes. If we look at the period from 2009 to 2016, we see that the share of environmental taxes in the GDP of EU member states grew slightly, which was considered a consequence of the global economic crisis of 2008. Since 2016, as a result of the recovery from the crisis, a slight decline or stagnation of that type of income. According to Srdelić (2024) with its 3.3%, Croatia is one of the countries with the highest share of revenues from environmental taxes in GDP in the EU and that in Croatia this share has been rising whereas at the EU level it has been on the decline. This general trend of growing revenues from environmental taxes in GDP suggests that the process of separating economic growth from demand for fossil fuels in Croatia is somewhat slower.

The second most fiscally generous are transport taxes, mostly in Denmark and Malta. Taxes on pollution and natural resources make up the smallest share of revenue from environmental taxes, which is not surprising since in many EU member states they were introduced later, after taxes on energy and transport, so their share is a consequence of their shorter application.

Eurostat's research (2020) is a significant indicator of the necessary changes by European and national legislation. The research shows that of all the energy taxes collected at the European level, as much as 49% goes to households, while the revenues from energy taxes from service and production activities amount to almost the same amount - 48%. This is a clear indication that environmental policies and activities aimed at environmental protection, including the concept of sustainable development, are not part of the everyday life of the European population. This refers to a sustainable way of housing and living in existing residential buildings, building new residential buildings, energy self-sufficient units, using various types of public transport, changing shopping habits, etc.

3. PROBLEMS CONCERNING ENERGY TAXATION

The tax on coffee, cigarettes, beer, alcohol and non-alcoholic beverages burdens the economic strength of the citizen who is a consumer of these products. A tax on the consumption of oil and oil derivatives or a tax on any other source of energy exceeds the limits of personal consumption. Oil tax is a form of energy tax, not a tax on personal consumption. As a tax on energy, it causes an increase in the prices of all products for the production of which oil is used. Experts suggest three possibilities:

1. simultaneous introduction of energy tax into the tax systems of European countries that are important participants in international trade,

2. refund of energy tax paid when exporting a product,

3. the introduction of an energy tax that would be borne by private energy consumers. By accepting this option, the entrepreneur would be in a more favorable tax position than an individual who uses energy for personal needs when consuming energy to perform economic activities (Šinković, 2022).

According to Greenpeace, if a country decides to introduce energy taxes, it should apply the lowest possible rate of this tax. Thus, the introduced energy tax would have the effect of an "ecological signal" and would not have harmful consequences. Exceptions to the application of the principle of equality in taxation could be justified in the following cases:

1. when exempted from paying energy tax when using new forms of energy, such as wind energy and solar energy, because they are not environmental pollutants.

2. When applying tax breaks to entrepreneurs who are large consumers of energy, in order to avoid the "suffocation" of their economic activities, and on the other hand, moving their activities to the territory of the state with a lower tax burden when using energy (Šinković, 2022).

Environmental protection policy in the Republic of Croatia

The most important sources and institutional frameworks of Croatian environmental law that form the basis of environmental protection and sustainable development policy in Croatia are:

1. The Constitution of the Republic of Croatia (Official Gazette, No. 56/90, 135/97, 08/98, 113/00, 124/00, 28/01, 41/01, 55/01, 76/10, 85/10, 05/14) - by which the state is ordered to take all necessary measures to justify the term "social state", which is stated in Article 1 of the Constitution of the Republic of Croatia, and as stated in Article 3 "...nature conservation and human environment... are the highest values of the constitutional order of the Republic of Croatia".

2. Nature Protection Act (Official Gazette, No. 80/13, 15/18, 14/19, 127/19, 155/23) - which regulates the system of protection and preservation of nature and its parts, and other issues, which are listed in Article 1. In terms of this law, nature is the overall biodiversity, landscape diversity and geodiversity, and that nature and parts of nature are of interest to the Republic of Croatia and enjoy its special protection, as stated in Article 2. of this law.

3. Environmental Protection Act (Official Gazette, No. 80/13, 153/13, 78/15, 12/18, 118/18) - which regulates: principles of environmental protection within the concept of sustainable development, protection of environmental components and protection of the environment from the impact of loads, environmental protection entities, sustainable development and environmental protection documents, environmental protection instruments, environmental monitoring, information system for environmental protection, ensuring access to information about the environment, public participation in issues related to the environment... which are listed in Article 1. of this law. The environment is of interest to the Republic of Croatia and enjoys its special protection, which is stated in Article 3, paragraph 2. of this law

4. Declaration on environmental protection in the Republic of Croatia (Official Gazette, No. 34/1992) - which focuses on the preservation of nature and the human environment as the highest value for the Republic of Croatia.

However, the segment of the legal system of the Republic of Croatia that directly or indirectly relates to environmental protection includes over 200 legal and secondary regulations, such as the Law on Protection from Noise (Official Gazette, No. 30/09, 55/13, 153/13, 41/16, 114/18, 14/21), the Law on Financing Units of Local and Regional (Regional) Self-Government (Official Gazette, No. 127/17, 138/20, 151/22, 114/23), the Law on Local Taxes (Official Gazette, No. 115/16, 101/17, 114/22, 114/23), etc. which specifically implement environmental protection policy at the national level. However, Croatian legislation consists of so-called plural purpose laws where the primary goal is not necessarily ecological. For example, the Spatial Planning Act (Official Gazette, No. 153/13, 65/17, 114/18, 39/19, 98/19, 67/23) does not directly touch on environmental protection, but indirectly aims to ensure the conditions for the use, protection and management of the space of the Republic of Croatia, which is viewed as a particularly valuable and limited national asset, which places it in the sphere of environmental protection.

The institutional framework for the collection of environmental revenues and taxes in the Republic of Croatia is made up of the Fund for Environmental Protection and Energy Efficiency (Law on the Fund for Environmental Protection and Energy Efficiency, Official Gazette, No. 107/03, 144/12) as an umbrella body. In addition to the aforementioned Fund, the institutional framework consists of Croatian Waters, which manages water, that is, takes care of the availability and purity of water and the protection of all citizens from floods. In addition to the Law on the Fund..., the legal framework of the Fund's income is also the Law on Waste Management (Official gazette, No. 84/21), which regulates a number of fees aimed at the disposal of plastic and packaging waste, as well as fees for waste management that are classified depending on the type of waste, such as that for the management of waste batteries and accumulators, electronic waste management, municipal waste disposal fee associated with an incentive fee for reducing the amount of mixed municipal waste, etc. The third source of income of the Fund

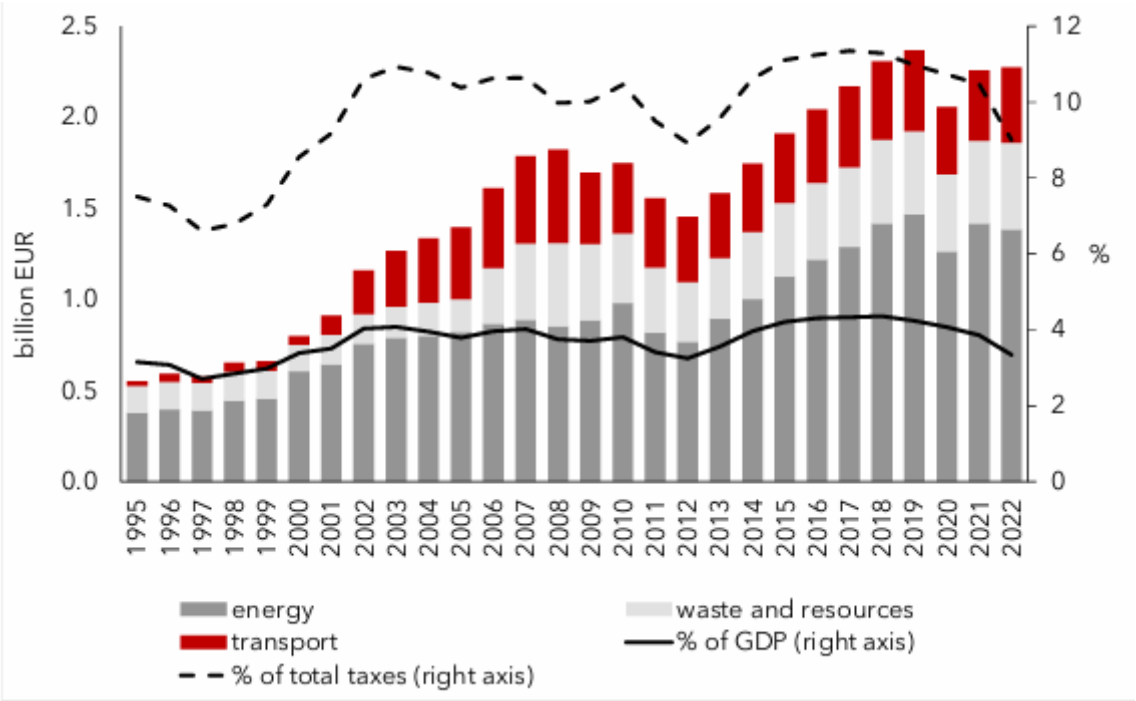
is the Air Protection Act (Official Gazette, No.127/19, 57/22) , which regulates the fee for the destruction of controlled substances and/or fluorinated greenhouse gases. According to the Financial Plan of the Fund for 2021, "...planned revenues amount to EUR 271,538,778,23 and consist of fees, revenues from trading greenhouse gas emission units, revenues from financial assets, other revenues, and assistance from the budget based on the transfer of EU funds and assistance from the budget of local and regional self-government units" (Ministry of Finance, 2021).

4. ENVIRONMENTAL TAXES IN THE REPUBLIC OF CROATIA

In the Republic of Croatia, care for environmental protection and sustainable development is divided between the state and regional and local self-government units. Article 15 of the Environmental Protection Act (Official Gazette, No. 80/13, 153/13, 78/15, 12/18, 118/18) stipulates that "sustainable development...is achieved...with the cooperation and joint action of the Croatian Parliament, the Government, counties, the City of Zagreb, large cities, towns and municipalities and all other stakeholders in order to protect the environment.. ." The state and local self-government units are obliged to act and act in solidarity in working with international organizations and cooperating with other states. The revenues collected through environmental taxes will belong to different levels of government and, depending on their affiliation, will fill both state, county and municipal/city budgets.

The legislator envisages three types of public revenues for the protection and improvement of the environment: special taxes, contributions and fees. These are revenues that primarily achieve the primary fiscal goal, but at the same time have ecological features, because they are charged:

1. to products whose production or use pollutes the environment,
2. for the use of natural resources,
3. or are used for ecological purposes, i.e. those determined by the environmental policy.



Graph 3. The republic of Croatia: Annual revenues from environmental taxes by category (1995-2022)
Source: Srdelić, 2024

Graph 3 shows that total revenues from environmental taxes in Croatia increased from EUR 0.6 billion in 1995 to EUR 2.3 billion in 2022 which equals an average annual growth rate of 5.8%. The majority of this amount is accounted for by taxes on energy products, while taxes on transport, pollution and natural resources contribute to only a smaller share (Srdelić, 2024).

This is best seen in the application of a special tax on petroleum products. The tax object of tax on oil derivatives is unleaded gasoline and oil derivatives that are exported. Water contributions are

partly used for arranging watercourses and for protecting the harmful effects of water. Fees are charged for the use of natural resources, for example: water use fee, water protection fee, sand and gravel extraction fee (Law on the Financing of Water Management, Official Gazette, No. 153/09, 90/11, 56/13, 154/14, 119/15, 120/16, 127/17, 66/19, 36/24). Road fees are annual fees for the use of public roads, fees for the use of public roads by motor vehicles and trailers registered outside the territory of the Republic of Croatia (Law on roads, Official Gazette, No. 84/11, 22/13, 54/13, 148/13, 92/14, 110/19, 144/21, 114/22, 114/22, 04/23, 133/23). Agricultural and forestry fees are, for example: fee for changing the use of agricultural land and fee for general utility functions of forests (Law on Forests, Official Gazette, No. 68/18, 115/18, 98/19, 32/20, 145/20, 101/23, 36/24).

There are four main categories of tax revenues and fees for the environment in the Republic of Croatia:

1. on energy sources,
2. on transport,
3. on pollution and
4. on natural resources.

5. ENERGY TAXES

One of the main functions of the energy tax is to reduce energy consumption, i.e. to protect limited energy sources. For example, due to the fiscal burden of any energy source, the user of that source will perhaps look for another, more affordable source. This contributes to the protection of energy sources that are limited or at least reduces their consumption. Also, it should be mentioned that energy taxes are a very important source of income. According to Srdelić (2024) with its 3.3%, Croatia is one of the countries with the highest share of revenues from environmental taxes in GDP in the EU and that in Croatia this share has been rising whereas at the EU level it has been on the decline. This general trend of growing revenues from environmental taxes in GDP suggests that the process of separating economic growth from demand for fossil fuels in Croatia is somewhat slower. Specifically, the growth of share of revenues from environmental taxes in GDP is primarily the consequence of higher demand for energy products, fossil fuels in particular.

Taxes on energy products are a group of taxes that includes taxes on energy products that are used for transport and stationary purposes. Taxes on energy products or excise duties are taxes on mineral oils and motor fuels, gasoline (leaded and unleaded), diesel, heavy fuel oil, kerosene, natural gas and electricity consumption. Also, taxes on carbon dioxide (CO_2) are included in the energy tax and not in pollution taxes. Energy taxes significantly affect economic activities in any national economy.

Nowadays, electricity is a necessary basis for many social activities, but also for the personal life of every person, since it serves to satisfy numerous elementary needs in all areas of life. The price of electricity directly and indirectly determines the level of living standards: directly through the consumption of electricity in households, and indirectly through the price of all products and services.

The legal basis for taxation of energy products is the General Tax Law (Official gazette, No. 115/16, 106/18, 121/19, 32/20, 42/20, 114/22), which defines excise duties as special taxes; the Law on Excise Duties (Official gazette, No. 106/18, 121/19, 144/21), which defines the most important tax-terminological concepts, such as excise products, which include energy products; Ordinance on excise duties (Official gazette, No. 114/23) and a series of other ordinances regulating excise duties for certain types of energy products. Energy taxes are extremely fiscally abundant and make up a large part of public revenues, and their ecological function is manifested in the rationalization of their use due to the fiscal burden on them, which leads to changes in personal and social habits. Taxation of energy sources has a significant impact on economic activities, which is felt by end consumers and consumers of services and products, which is why taxes on them must not "...prevent the use of energy sources in the amount needed by every individual in modern society, and on the other hand, they must for the sake of protection nature to limit their consumption, without harming the competitiveness of domestic entrepreneurs on the foreign market" (Lončarić-Horvat et al., 2003). That is why EU legal principles related to the regulation of the energy tax system are important not only for solving the above-mentioned aspirations and goals of taxation, which are in collision , but also for the process of harmonizing the laws of the member states, including the Republic of Croatia, with the acquis of the EU and, specifically, the harmonization of national regulations on primarily indirect taxes. These principles refer to the prohibition of the introduction of discriminatory domestic duties (which would be the case if the energy tax as an environmental duty would have an effect similar to customs duties), the prohibition of the application of state measures such as subsidies (in the case of the introduction of tax benefits for individual energy producers and whether this makes them subsidies) and bans on the application of

quantitatively determined import and export restrictions and similar measures with the same effect (so that these restrictions would not stop or significantly hinder the free circulation of a form of energy that a specific country would stop using, which would result in its import being highly taxed).

With the accession of the Republic of Croatia to the European Union, the introduction of a system of taxation of motor vehicles based on carbon dioxide emissions began. The goal of this environmental taxation criterion is to encourage the purchase of environmentally friendly vehicles and to reduce the prices of motor vehicles with low carbon dioxide emissions. Upon joining the European Union, the Republic of Croatia introduced a system of taxation of motor vehicles based on carbon dioxide emissions. One of the fundamental features of this tax is the emission of carbon dioxide expressed in grams per kilometer, which in some countries is the only criterion for taxation. The introduction of carbon dioxide emissions into the taxation of motor vehicles is an important measure to achieve the goals of the European Commission for reducing greenhouse gas emissions and to fulfill the obligations of the European Union in accordance with the Kyoto Protocol (Ministry of Economy and Sustainable Development, 2024).

The revenue from environmental taxes that Croatia achieves is still among the highest in the EU. According to Eurostat data for 2018 (Eurostat, 2020), the total amount of environmental taxes in the European GDP is 6%, and the data for Croatia show that total revenues from environmental taxes amounted to 9%, which is above the EU-27 average. According to a comparative analysis by Eurostat, their share in total tax revenues is 9.1 percent, and it is higher in only three member states (Latvia, Greece and Slovenia), while in the EU as a whole, every fifteen kuna of taxes or 6.1 percent comes from environmental taxes. In absolute terms, this is reflected in the less than 370 billion euros (data for 2017 are available) of the budget revenues of the EU states.

However, in the same year, the goal of energy consumption from renewable sources was not reached, 432 kilograms of municipal waste was generated per capita with a low rate of recycled municipal waste of 25%. The Republic of Croatia is below the European average in terms of greenhouse gas emissions produced and measured per capita, and the energy dependence on mineral oils and gasoline products is still (un)expectedly high, a full 82% of the total energy consumed, which means that the revenues from these types of taxes are also on energy sources the highest.

6. TRANSPORT TAXES

Transport taxes is a group that includes taxes related to the ownership of motor vehicles and their use. Taxes on other means of transport (eg. aircraft) and related transport services (eg. tax on charter flights or scheduled flights) are also included here, when they fit the general definition of environmental taxes. Transport taxes can also be one-off taxes associated with the import or sale of equipment or permanent taxes such as annual road tax. Taxes on gasoline, diesel and other transportation fuels are included in energy taxes. So, according to Eurostat, transport taxes include taxes on:

1. registration and use of motor vehicles
2. import and sale of motor vehicles
3. use of roads and highways
4. insurance of luxury yachts and,
5. noise and passengers in air transport (tax on flights and tickets) (Eurostat, (2016), Environmental taxes by economic activity (NACE Rev. 2) (env_ac_taxind2).

In the Republic of Croatia, taxes are collected that are classified as transport taxes, namely:

1. tax on passenger cars, other motor vehicles, vessels and airplanes, which is a generous income of the state budget;
2. a special environmental fee for motor vehicles that is paid at the time of registration for all motor vehicles in good condition and represents "the second most important source of income for the Fund" (Grdinić et al, 2017);
3. tax on road motor vehicles, which represents the income of the county budget;
4. tax on vessels, which represents the income of the county budget.

Since transport taxes are the responsibility of the member states, they cannot be easily harmonized at the EU level (Činčurak Erceg & Jerković, 2019).

Sales taxation can have a significant impact on customer preferences when purchasing a car. Transport taxes can be used to address sources of pollution associated with car use and vehicle ownership that are not addressed through fuel taxation. Road traffic creates costs in terms of CO_2 emissions and also creates noise, air pollution and congestion. Therefore, the member states, in addition to excise duties on energy, collect taxes on vehicles. Vehicle taxation includes registration tax (charged when buying a car) and vehicle sales tax (charged annually on vehicle ownership) (European Commission, 2015).

Taxes classified as transport taxes in the Republic of Croatia are:

- tax on passenger cars, other motor vehicles, boats and aircraft;
- special environmental fee for motor vehicles;
- county tax on road motor vehicles;
- county tax on vessels.

7. TAXES ON POLLUTION AND NATURAL RESOURCES

Taxes on natural resources include taxes related to the extraction or use of natural resources such as water, forests, wild flora and fauna. These activities deplete natural resources.

A number of different fees are paid for the pollution of nature and natural sources - for air pollution, water use and waste management fees, mentioned according to the difference between the entities that collect them and the level of government for which they are collected.

In the Republic of Croatia, a number of fees are paid for pollution and natural sources, namely: fees for air pollution, fees for water use and fees for waste management:

- fees for air pollution;
- fees for waste management.

Also, it is important to mention here the water fees that are paid to Croatian Waters, which are:

- water contribution;
- fee for water treatment;
- water usage fee (www.voda.hr/hr/vodne-naknade).

CONCLUSION

The regulations that have been put in place to prevent air, water and soil pollution are not enough. Society needs to allocate more and more resources to ensure sufficient supplies of drinking water, clean air and enough unpolluted soil. In order to get rid of the danger of people suffocating in the impurities of their own waste, in many countries more and more funds are allocated to the preservation of the environment in which people perform their activities and live. Allocating funds for this purpose is not only an obligation to yourself, but also a debt to future generations.

Although environmental taxes violate the constitutional and tax law principle of distributing the tax burden according to economic power, their application can be justified by the fact that the goal of environmental taxes is in accordance with the principle of general good and benefit: the protection of human health and the preservation of the natural environment as a very important condition for human life and other living beings.

The low ecological standards of a country correspond to the economic interests of its producers because they increase their individual profits. At the same time, they harm them, because the quality of the nature that surrounds them decreases. Furthermore, they cause damage by increasing the cost of remediation of the nature of those countries that have high ecological standards, if pollution has spread to them. Namely, by taxing all those factors that have a harmful impact on the environment, one contributes not only to the protection of the environment but also to the state budget and budgets of local self-government units (Jerković, 2022).

The basic purpose of environmental taxes is to reduce environmental pollution by increasing the costs of harmful activities, such as the burning of fossil fuels. Then the trading companies would have to include the costs of their own actions on the environment in the price of the product or service. In order for this to work, it is important that the amount of the tax be equal to the monetary value of the damage caused to the environment.

The institutional framework for the assessment and collection of environmental taxes in the Republic of Croatia has been established, and the national legislation is harmonized with European legislation. The Republic of Croatia also has available methods and technology of substitutes acceptable to producers, which are not particularly expensive. Also, according to the Eurostat report, the Republic of Croatia was at the top of the ranking among EU member states when it comes to the share of renewable sources in total energy consumption, which is highly commendable. On the other hand, the growth of share of revenues from environmental taxes in the Republic of Croatia is primarily the consequence of higher demand for energy products, fossil fuels in particular.

It can be concluded that the awareness of environmental protection when it comes to the Republic of Croatia is at a good level, at least in terms of instruments for environmental protection. Namely, environmental taxes in the Republic of Croatia are a significantly higher burden compared to the average of the European Union. However, considering that the Republic of Croatia is a tourist country for which tourism is one of the most important, if not the most important, source of income, this type of tax is necessary in order to preserve the environment for which the Republic of Croatia is recognized in the world.

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Recognizability importance of decarbonization of the construction sector through the aspect of climate change

Prepoznatljivost značaja dekarbonizacije građevinskog sektora kroz aspekt klimatskih promena

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Abstract: Due to the increase in the global population, and thus the rapid increase in urbanization, the needs for living space and all resources are constantly growing. The construction of new buildings should primarily provide a safe and healthy space, but also meet the criteria of sustainable development through the reduction of negative impacts on the environment and climate change that the construction sector is experiencing. It is estimated that more than a third of carbon dioxide emissions come from the construction sector, either as emissions from the process of material production and construction of buildings, or as gas emissions that occur during the operational work of the building (heat and electricity). By reducing those emissions, it would contribute to mitigating the impact on climate change, as well as the entire environment. In addition, the obligations of all signatory countries of the Green European Agreement, as well as the Green Agenda for the Western Balkans, among which Serbia is, are to significantly reduce their greenhouse gas emissions in all sectors that contribute to this. According to the Directives of the European Union, the facilities will have to meet certain criteria, all with a deadline of 2030. This paper deals with the analysis of attitudes and recognition of the importance of decarbonization of the construction sector of the population of Serbia, giving opinions on who is most responsible for its implementation.

Keywords: decarbonization, construction objects, climate change, environmental protection.

Sažetak: Povećanjem globalne populacije, a time i rapidnim porastom urbanizacije, potrebe za životnim prostorom ali i svim resursima konstantno rastu. Izgradnja novih objekata treba da obezbedi prvenstveno bezbedan i zdrav prostor, ali i da zadovolji kriterijume održivog razvoja kroz smanjenje negativnih uticaja na životnu sredinu i klimatske promene koji građevinski sektor beleži. Procenjeno je da više od trećine emisija ugljen-dioksida upravo dolazi iz građevinskog sektora, bilo kao emisije iz procesa proizvodnje materijala i izgradnje objekata, ili kao emisije gasova koje nastaju prilikom operativnog rada objekta (toplotna i električna energija). Redukovanjem tih emisija, doprinelo bi se ublažavanju uticaja na klimatske promene, ali i celokupnu životnu sredinu. Osim toga, obaveze svih zemalja potpisnica Zelenog evropskog dogovora, kao i Zelene agende za Zapadni Balkan, među kojima je i Srbija, jesu da značajno redukuju svoje emisije gasova sa efektom staklene bašte u svim sektorima koji tome doprinose. Objekti će, prema Direktivama Evropske unije, morati da ispunjavaju određene kriterijume, a sve sa rokom od 2030. godine. Ovaj rad se bavi analizom stavova i prepoznavanja značaja dekarbonizacije građevinskog sektora stanovništva Srbije, dajući mišljenja o tome ko je najodgovorniji za njeno sprovođenje.

Ključne reči: dekarbonizacija, građevinski objekti, klimatske promene, zaštita životne sredine.

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INTRODUCTION

The European Union has established a clear legally binding framework for achieving the goals of the Paris Agreement from 2015, and ambitious goals for 2030 have been established in terms of renewable energy sources, energy efficiency and the reduction of greenhouse gas emissions. The European Green Deal (EU Green Deal), through the *Fit to 55%* strategic goal, is part of the EU sustainable development strategy for the 21st century (Agenda 2030) and primarily deals with environmental and climate change issues - how to develop the EU economy without accelerating climate change. The European Commission defines this strategy as a new growth strategy with the aim of transforming the EU into a fair and wealthy society, with a modern and competitive economy that uses resources efficiently, with net zero greenhouse gas emissions by 2050, and economic growth that is separated from resource exploitation.

Decarbonization in the construction sector implies the reduction or complete elimination of greenhouse gas emissions that occur in the process of material production, transportation, construction of buildings, but also during the lifetime of the building. This refers to carbon dioxide emissions as the most dominant. The building sector emits 37% of all greenhouse gas emissions, of which two-thirds are generated by the use of energy for heating, cooling and lighting of buildings (operational emissions), and the remaining one-third is generated during the life cycle of buildings, from the extraction and production of materials, construction and all to demolition (built-in emissions), activities that will contribute to increasing the energy efficiency of buildings are very important, which is also an important goal of the United Nations (Mijatović et al., 2023).

According to the Green European Agreement, all new public buildings from 2028 and all new other buildings from 2030 must have zero emissions, while all existing residential buildings must reach the "D" level of energy efficiency by 2033. Greenhouse gas emissions will need to be more accurately predicted and assessed using Life Cycle Analysis (LCA) of any future building (Stojkov Pavlović, 2023). Manufacturers will be required to indicate how much the "carbon footprint" of each construction product is more favorable than a conventional product. The question arises as to how much the public is aware of these obligations and goals and whether there are capacities for implementation.

The problem of climate change also requires an accelerated change and harmonization of regulations related to the production and use of construction materials, because everyday innovations in this area many times exceed the existing legal solutions and represent an obstacle to the development of innovative solutions.

Green building is in great expansion, therefore there is a need for innovative building materials whose production and application require minimal CO_2 emissions. Numerous health problems (allergies, asthma) have caused an increasing interest in the use of natural building materials for the construction of residential and recreational facilities (ecotourism).

In the Republic of Serbia, several decades-old legislation regarding the construction and production of construction materials is still in force, and the topic of low-carbon materials has only recently become relevant in Europe and the world, while it is very little mentioned in Serbia. The most important legal act that regulates this area is the Law on construction materials ("Official Gazette of RS", No. 83/2018).

1. MATERIALS AND METHODS

During the preparation of the paper, available literature was collected and analyzed in the field of regulations of the European Union and the Republic of Serbia, especially in the field of the environment, climate change and the construction sector.

An analysis of the questionnaire carried out by the authors of the work through the project activities of the network of civil society organizations "Blue-green Network Futura" was also carried out as part of the ECO-SYSTEM program implemented by the Young Researchers of Serbia and under the auspices of Sweden at the end of 2023. The online questionnaire included a survey of the views of the civil sector, representatives of public institutions, the educational sector and young people about awareness, knowledge and the importance of decarbonisation of the construction sector in Serbia. The results of the analysis will be presented in the next chapter of this paper.

2. RESULTS AND DISCUSSION

The Republic of Serbia adopted the Declaration from Sofia on the Green Agenda for the Western Balkans in October 2020 and undertook to implement its actions through the Regional Action Plan. On the international level, Serbia has signed and ratified all important international environmental agreements, including the 2030 Agenda for Sustainable Development, the UN Framework Convention on Climate Change, and the Paris Agreement. In March 2021, the Government of the Republic of Serbia adopted the Law on Climate Change, which establishes the main policies and principles

related to climate change, with the aim of establishing a system that leads to the reduction of greenhouse gas emissions, based on which the Government of the Republic of Serbia is adopted the Low Carbon Development Strategy for the period 2023-2030. with projections until 2050. The Law on Climate Change influenced the adoption of the first Program of Adaptation to Changed Climate Conditions for the period from 2023 to 2030 with an Action Plan for its implementation. With the revised Nationally Determined Contribution (NDC), adopted by the Government in August 2022, Serbia increased its climate ambitions three times and thereby contributed to the achievement of the global goal of reducing greenhouse gas emissions (33.3% compared to the level of emissions in 1990, in all relevant sectors). In April 2021, Serbia adopted a package of important energy laws, including new laws on renewable energy sources and energy efficiency. At the beginning of 2024, Serbia adopted the Integrated National Energy and Climate Plan (INECP).

The results of a survey in which 44 respondents participated speak about the state of awareness and attitudes of citizens of Serbia in the area of the importance of decarbonization of the construction sector.

The largest number of those who agreed to answer the requested questions are representatives of the civil sector (29.5%), the education sector (27.3%) and in third place students (25%) (Figure 1). And if the questionnaire was intended for the general public, we assume that ignorance of the topic was the most important reason for refusing to participate in it, as indicated by the answer of 63.6% of survey participants who answered affirmatively to the question about whether they were familiar with the concept of decarbonization in the context construction sector.

When self-assessing their own knowledge and understanding of the importance of decarbonization of the construction sector, on a scale from 1 to 5, where grade 1 represented the lowest grade and knowledge, and grade 5 the highest, the largest number of responses (34.1%) were graded 3, while the grade 5 given to themselves by 27.3% of respondents (Figure 1).

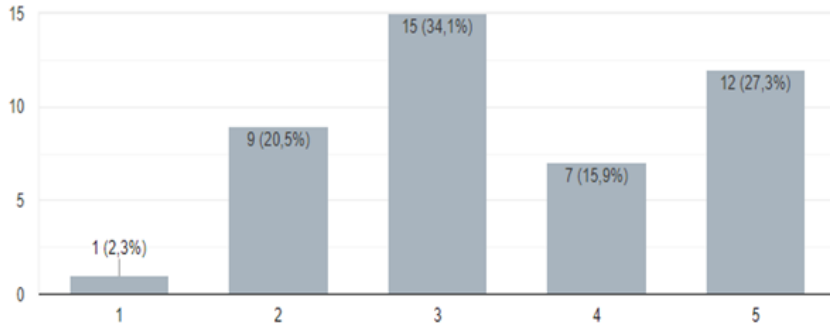

Figure 1. Self-assessment of knowledge and understanding of the concept of decarbonization (grade 1 is the lowest and grade 5 is the highest)

Based on the answers offered about what contributes to the decarbonization of the construction sector, the largest number of answers included all the above answers (use of recycled materials, renewable energy sources, energy efficiency, etc.), while several respondents wrote answers such as, for example: Fiscal decentralization, return to the countryside, return to traditional values of life (Figure 2).

Figure 2. Answers to the question about what contributes to the decarbonization of the construction sector

That the visible activities of state institutions in the field of decarbonization of the construction sector are not known to the majority of the population or they think that they do not exist at all, answered 75% of respondents, of which 43.2% of respondents gave a rating of 2 and 31.8% a rating of 1 (Figure 3).

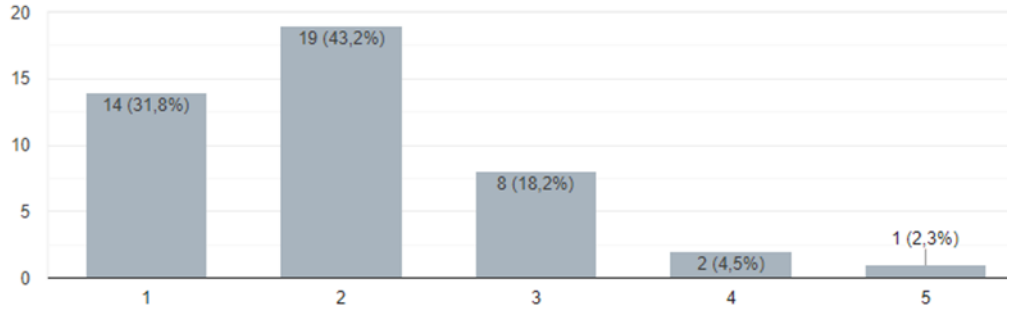

Figure 3. Evaluation of the involvement of state institutions in the matter of building decanonization (grade 1 is the lowest and grade 5 is the highest)

The efficiency of the Government of Serbia in solving the needs of decarbonization was not rated any better, so an equal number of responses were for ratings 1 and 2 (34.1%), rating 3 was given by 27.3% of respondents, while 4.5% gave a rating of 5 as an excellent rating in the engagement regarding the decarbonization of the building (Figure 4).

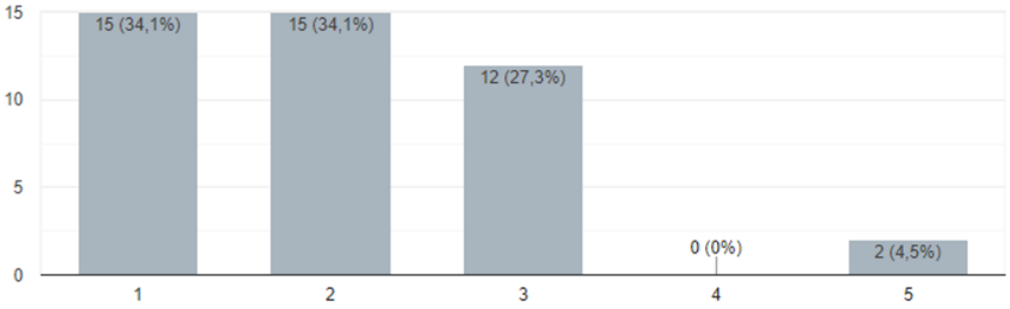

Figure 4. Evaluation of the efficiency of the Government of Serbia regarding the decarbonization of the construction sector (grade 1 is the lowest and grade 5 is the highest)

When asked whether the respondents are familiar with any concrete policies of the Government of the Republic of Serbia or initiatives related to sustainable and low-carbon practices in the construction industry in Serbia, more than half of the respondents (28) answered in the affirmative, citing as answers:

- Energy rehabilitation of family houses (replacement of joinery, boilers, thermal insulation, subsidies for solar energy...);
- Law on rational use of energy;
- Public calls for improving energy efficiency;
- Energy passports for new buildings;
- Agreements between foreign companies and the Ministry of Mining and Energy in the field of renewable energy sources;
- Low-carbon development strategy.

Comparing the answers to the previous two questions, where initially the respondents declare that the Government is not working efficiently enough on the issue of decarbonization of the construction sector, and on the other hand, most of them know certain activities of the Government in this matter, it gives indications that something, although very slow and unknown enough to the public, works in that field in the Republic of Serbia. This is also indicated by the answers to the question whether public awareness and participation should be increased in promoting decarbonization practices in the construction sector, where the largest number of respondents answered that it is "very necessary" to increase public awareness and participation in the field of decarbonization, giving a score of 5 (Figure 5).

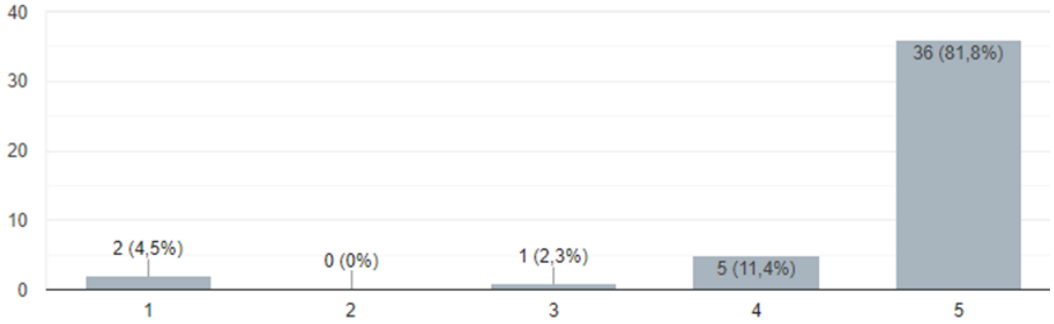

Figure 5. Assessing the need for public participation in promoting decarbonization (grade 1 is the lowest and grade 5 is the highest)

When asked whether the Government should provide incentives to individuals or companies that adopt decarbonization practices in the construction sector, 95.5% answered "YES", while 6.8% of respondents did not have a sure answer to that question. In the next question, the respondents were asked to determine from the offered answers what are the biggest challenges that the public sector can face in promoting and implementing decarbonization practices in the construction industry, with the possibility of adding another answer if not offered. The largest number of responses (51.2%) believe that the public does not recognize the importance, while 30.2% believe that the biggest challenge is that the business sector is obstructing. A smaller number of comments considered some other challenges more significant (Figure 6).

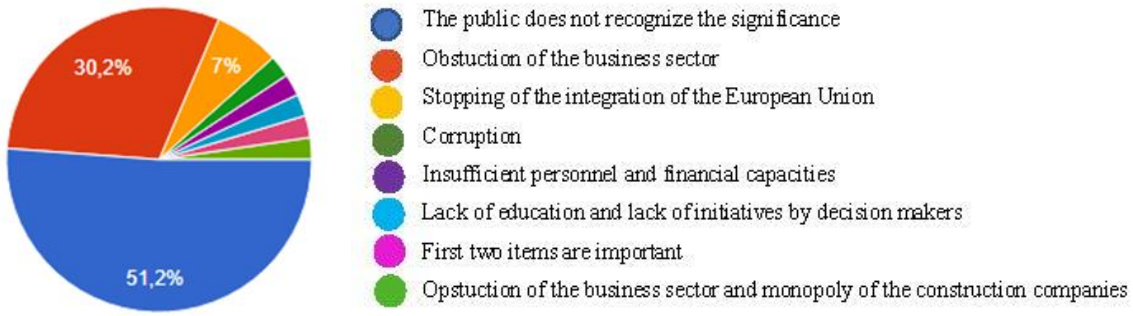

Figure 6. Challenges that the public sector may face in promoting and implementing decarbonization practices (grade 1 is the lowest and grade 5 is the highest)

Respondents did not show significant optimism regarding the future of low-carbon construction in Serbia, evaluating it as moderately optimistic (52.2%), while 29.5% of respondents answered that they were quite pessimistic about this issue (Figure 7).

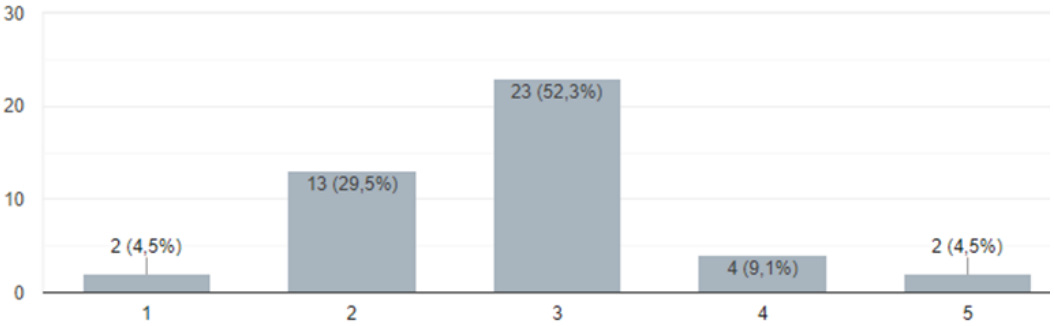

Figure 7. Optimism regarding the future of decarbonization of buildings in Serbia (grade 1 is the lowest and grade 5 is the highest)

At the end, the respondents were supposed to give a proposal of concrete measures or actions that they think the Government should take in order to speed up the adoption of decarbonization practices in the construction sector, where the answers were:

- Introduction of a mandatory minimum percentage of use of bioconcrete, bio-building material in the construction of new or renovation of existing buildings.
- Education, promotion, marketing, development of plans in accordance with this area and public discussion at the level of the public sector or LGU.
- Adoption and application of procedures in new construction, adaptation and rehabilitation of energy inefficient buildings.
- Raising awareness and stimulating the private sector through subsidies.
- Adoption of standards that have the force of law. Implementation of a penal policy for companies that comply with the legislation.
- Changes in public policies through public dialogue with the scientific, economic, civil and media sectors.
- Information, education, action.
- Simpler procedures, incentive measures, greater application of the ESCO model.
- Defining incentive measures in that area.
- Pressure from the Ministry of Construction and Energy on the business sector. Subsidies.
- No preferential and no exceptions policy.
- Fight against corruption.
- Insisting on the implementation of current measures and solutions in capital projects financed by the Government - with an accompanying information campaign about them!
- To get closer to European integration, to work on raising the awareness of enterprises and companies engaged in construction.
- Subsidies as a positive link, fees for investors who do not respect the principles of decarbonization as a negative link.

CONCLUSION

Based on the survey conducted and the answers we received, we believe that there is a certain awareness of decarbonization, that the respondents are informed about the basic activities and improvement opportunities in the field of decarbonization of the construction sector, but that work must be done on the implementation of concrete measures by the state, decision makers and individuals , as well as promoting the concept to the general public.

The obligations that Serbia assumed by signing the Green Agenda for the Western Balkans and the Paris Agreement impose responsibility in the implementation of the same in a very short time frame. And if Serbia has made great progress by adopting a number of legal and by-laws, the speed of implementation of action plans must be at a higher level in order to achieve not only the goals of the European Union in the carbon neutrality of the continent, but also its own tendency to preserve natural resources, protect, preserve and improve the environment and all individual media (water, air and soil) which will contribute to the benefits of all residents.

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Overview of nuclear energetics development in Europe and Serbia's perspectives

Pregled razvoja nuklearne energetike u Evropi i perspektive Srbije

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Abstract: Despite all expectations of a decline in interest in energy in the 21st century, the issue of energy seems more relevant than ever. The problem of energy supply has become universal and all-encompassing. The entire global economy has been impacted by the energy crisis due to fuel shortages, rising costs, and increasing consumption. Serbia, like the rest of the world, is facing tremendous challenges in the energy sector: the use of fossil fuels, slow development of technologies, and the adoption of renewable energy sources or nuclear power development. The energy system of Serbia is the backbone of the economy, but also a source of progress in sustainable and green development. The energy potential of alternative and renewable sources is underutilized due to the dominance of outdated technologies, especially in the energy sector of Serbia, while plans for nuclear energy are still in development. European countries, in contrast, use nuclear energy, thereby obtaining large amounts of energy while avoiding dirty technologies. Currently, a special focus is on the development of small modular reactors (SMR), which could be a sustainable option for Serbia, which has yet to use nuclear energy.

Keywords: Electricity system, Nuclear power, Climate change, Decarbonization, SMR.

Sažetak: Uprkos svim očekivanjima o padu interesovanja za energetiku u 21. veku, pitanje energetike se čini aktuelnijim nego ikad. Problem snabdevanja energijom postao je univerzalan i sveobuhvatan. Cela svetska ekonomija je pogođena energetskom krizom zbog nestašice goriva, rastućih troškova i sve veće potrošnje. Srbija se, kao i ostatak sveta, suočava s ogromnim izazovima u energetskom sektoru: korišćenje fosilnih goriva, spor razvoj tehnologija, usvajanje obnovljivih izvora energije ili razvoj nuklearne energije. Energetski sistem Srbije je okosnica privrede, ali i izvor napretka u održivom i zelenom razvoju.
Energetski potencijal alternativnih i obnovljivih izvora je nedovoljno iskorišćen zbog dominacije zastarelih tehnologija, posebno u energetskom sektoru Srbije, dok su planovi za nuklearnu energetiku još u izradi. Evropske zemlje, nasuprot tome, koriste nuklearnu energetiku, čime dobijaju velike količine energije, a izbegavaju prljave tehnologije. Trenutno je poseban fokus na razvoju malih modularnih reaktora (SMR), koji bi mogli da budu održiva opcija za Srbiju koja još uvek ne koristi nuklearnu energiju.

Ključne reči: Elektroenergetski sistem, Nuklearna energija, Klimatske promene, Dekarbonizacija, SMR.

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INTRODUCTION

The introduction of modern energy technologies into the existing energy system is generally aimed at improving the energy transition process, which is defined through the matrix of decarbonization, decentralization, digitalization, and democratization of the energy sector (Parović, 2023). Energy needs vary across different parts of the world, but the growth of the global population and the increasing energy demands of industries undoubtedly lead to a rising demand. On the other hand, questions are being raised about security, access, and sustainability. The energy trilemma addresses three often conflicting challenges: energy security, equitable access to energy, and environmental sustainability (Liu et al., 2022).

Primary energy can be obtained from non-renewable energy sources, such as fossil fuels and nuclear fuels, as well as from renewable energy sources. Nuclear energy is increasingly being discussed as an alternative energy source. Although it is a non-renewable source, nuclear energy, due to its low fuel consumption (high energy density) and high productivity in energy generation, can also be viewed in this way (Čučulović et al.,2024).

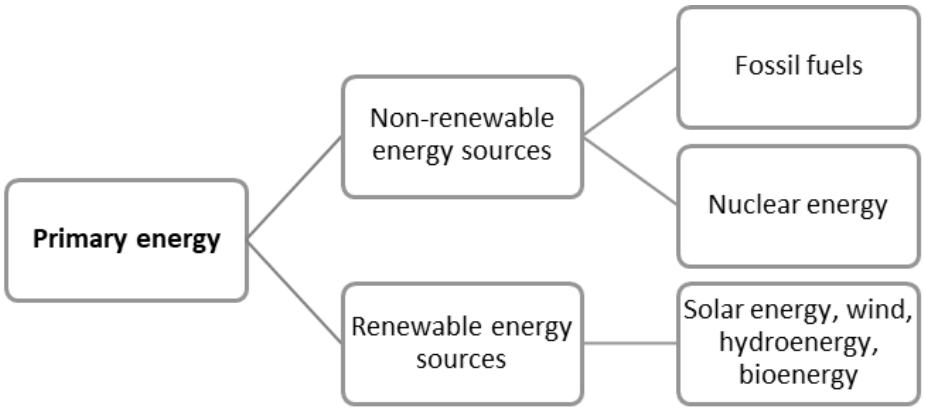

Figure 1 – Systematization of primary energy
Source: Author's figure

A higher presence of air pollutants promotes the generation of nuclear energy as an alternative to fossil fuel energy sources. While nuclear energy generation produces no air pollution, it does impose significant land use requirements, potentially leading to ecosystem degradation. Factors such as uranium extraction, nuclear waste management, disposal, and accidents contribute to this impact (Soto & Martinez-Cobas, 2024).

Nuclear energy and the promise of cost-effective small modular reactors (SMRs) is high on the EU's policy agenda, against the backdrop of a difficult global geopolitical context and the Union's energy security and climate ambitions. The EU is building a comprehensive strategy for the development and deployment of SMRs, acknowledging their potential benefits and challenges. Innovative nuclear technologies are of significant strategic value, with big steps being taken to increase the supply of advanced nuclear fuels and research and innovation capacities in this area.

Conventional reactors typically require low-enriched uranium (LEU), defined as being enriched to less than 5 % U-235. HALEU is a type of nuclear fuel that is distinguished from LEU by continuing the enrichment process to the range of 5 % to 20 % U-235. This increase, although seemingly modest, paves the way for innovative reactor designs, enhancing efficiency and safety (EP, 2024).

This the development of SMRs is still promising, in the energy mixes of countries, there are operational conventional nuclear reactors, historically marked by accidents such as the one in Chernobyl in 1986. These reactors may not offer the same level of safety that SMRs with HALEU fuel could achieve, but they continue to generate energy that remains in use.

1. METHODOLOGY

This paper relies on a descriptive and analytical method, as well as a comparative analysis of European countries regarding nuclear energy based on World Nuclear Association database (WNA, 2025). Through a prediction method: SWOT analysis of potential nuclear energy utilization in Serbia, the foundation for the future development of nuclear energy in Serbia is presented. The research is divided into two sections. The first part presents an overview and comparative analysis of all European countries that utilize nuclear energy. The second part of the research focuses on the potential for nuclear energy development in Serbia.

2. RESULTS AND DISCUSSIONS

Uranium has characteristics that can enhance a country's energy supply security when nuclear energy is part of its energy mix. Uranium is a uniquely concentrated energy source, meaning that the required quantities are much smaller compared to coal or oil.

Table 1 – Nuclear fuel types

Fuel type	**Low-enriched uranium (LEU)**	**High-assay low-enriched uranium (HALEU)**	**Highly enriched uranium (HEU)**
Enrichment U-235	less than 5 % U-235	5-20% U-235	above than 20% U-235
Utilization	Conventional reactors	For advanced reactors to achieve smaller designs that get more power per unit of volume. HALEU will also allow developers to optimize their systems for longer operating cycles, increased efficiencies, and better fuel utilization.	Often associated with weapon-grade uranium, which is commonly considered to have been enriched above 90 % U-235

Source: Author‘s systematization

Currently, there are 439 operational reactors worldwide, providing 398,108 MWe. The nuclear share of global electricity generation is 9%. The top 10 countries by total operable reactor net capacity are: USA (96952 MWe), France (63000 MWe), China (56888 MWe), Japan (31679 MWe), Russia (26802 MWe), South Korea (25825 MWe), Ukraine (13107 MWe), Canada (12669 MWe), India (7425 MWe) and Spain (7123 MWe). In Europe, France, Russia, Ukraine, and Spain lead in nuclear energy production, but other countries also utilize nuclear energy or have plans to develop it. In Serbia, in 2024, amendments to the Energy Law lifted the moratorium on the use of nuclear energy, and the Nuclear Energy Development Program was included as part of the revised law. The program is divided into three phases: assessing the feasibility of adopting nuclear energy development, developing the program, and its implementation.

Overview of Operational Reactors in Europe

In European countries, there are currently 157 operational nuclear reactors, representing 35.8% of the total number of operational reactors worldwide.

Table 2 – Operable reactors in European countries

Country	**Total operable nuclear capacity (MWe)**	**Nuclear share of generation (%)**	**Nuclear generation (GWh) 2023**	**Number of units**
Belarus	2220	29	10997	2
Belgium	3463	41	31289	4
Bulgaria	2006	40	15488	2
Czech Republic	4212	40	28728	6
Finland	4369	42	32759	5
France	63000	65	323773	57
Hungary	1916	49	15092	4
Netherlands	482	3	3771	1
Romania	1300	19	10312	2
Russia	26802	18	203957	36
Slovakia	2308	61	17005	5
Slovenia	688	37	5332	1
Spain	7123	20	54371	7
Sweden	7008	29	46648	6
Ukraine	13107	15	49550	15

Source: Author‘s systematization

Stances and actions toward the use of nuclear energy vary from reactor shutdowns, as seen in Germany, to the construction or planning of nuclear energy implementation. However currently, 15 countries in Europe utilize nuclear energy: Belarus, Belgium, Bulgaria, Czech Republic, Finland, France,

Hungary, Netherlands, Romania, Russia, Slovakia, Slovenia, Spain, Sweden and Ukraine. Countries with a capacity below 1,000 MWe are: Netherlands and Slovenia.

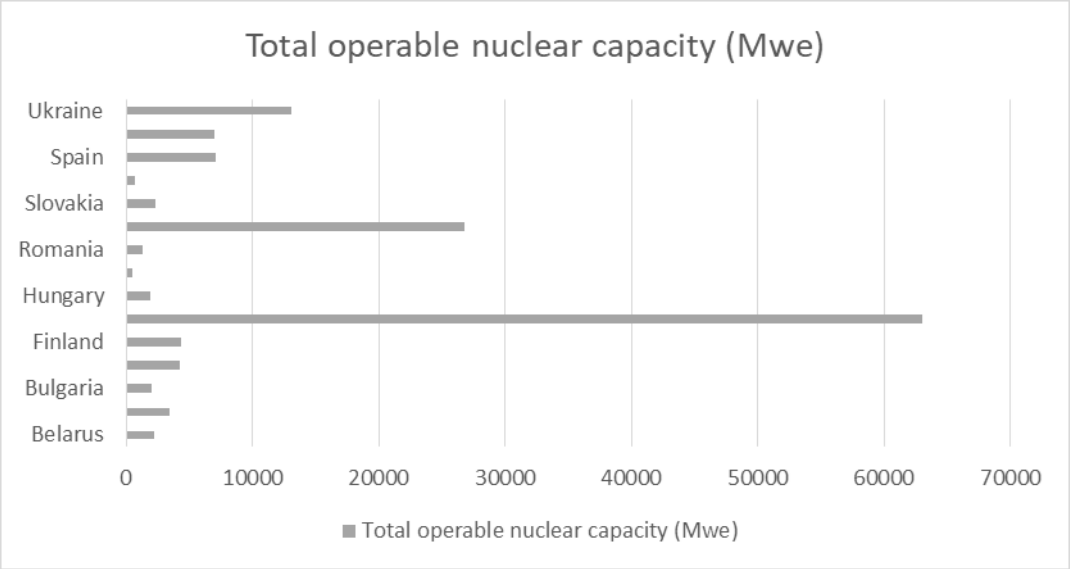

Figure 2 – Total operable nuclear capacity in MWe by country
Source: Author's figure

France is the largest producer of nuclear energy in Europe, Russia and Ukraine also have substantial nuclear capacities. France, Russia, and Ukraine each have a capacity of over 10,000 MWe. The majority of selected countries fall within the range of 1,000 to 9,999 MWe, and this group includes 10 countries: Belarus, Belgium, Bulgaria, Czech Republic, Finland, Hungary, Romania, Slovakia, Spain and Sweden.

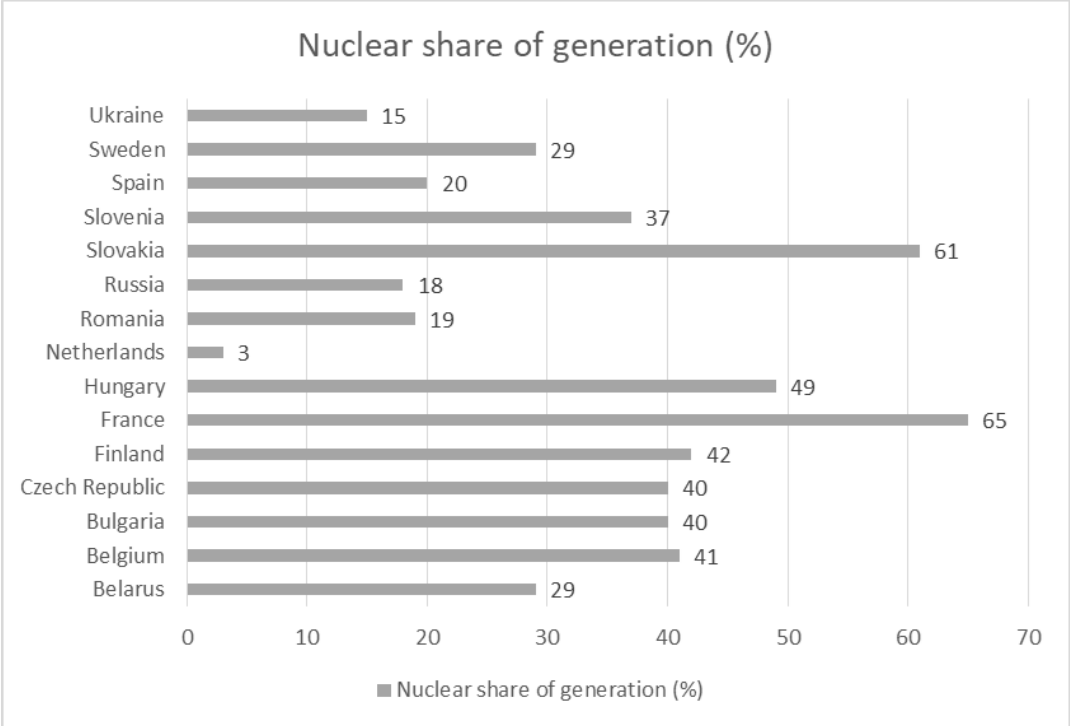

Figure 3 – Nuclear share of generation in %
Source: Author's figure

By researching nuclear share of generation the highest share has France, Slovakia and Hungary. The average share of nuclear generation in Europe is 33.86%. Above the average are 9 of 15 countries.

In achieving green goals, Serbia is primarily focused on the development of RES technologies and energy generation from renewable sources. However, as global uncertainty over energy resources grows, and despite the existing moratorium on the use of nuclear energy, interest in reopening this issue is emerging once again.

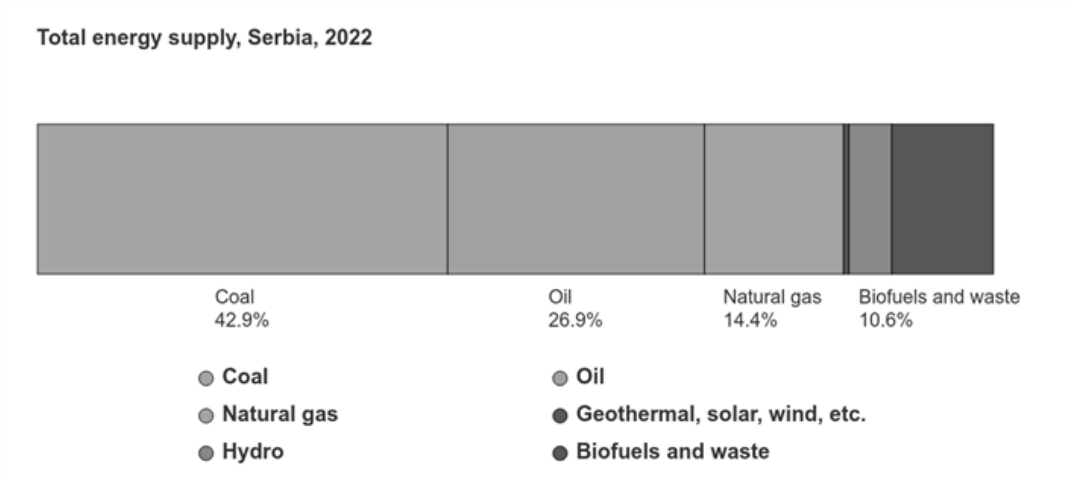

Figure 4 – Energy mix of Serbia (2022)
Source: IEA, 2025

By reviewing Serbia's energy mix, it is clear that fossil fuels play a significant role, accounting for 42.9% and development of RES is slow and unpredictable. The development of RES requires investments, and the same applies to nuclear energy. Nuclear energy brings both risks and benefits, and in this regard, a SWOT analysis has been conducted for the use of nuclear energy in Serbia.

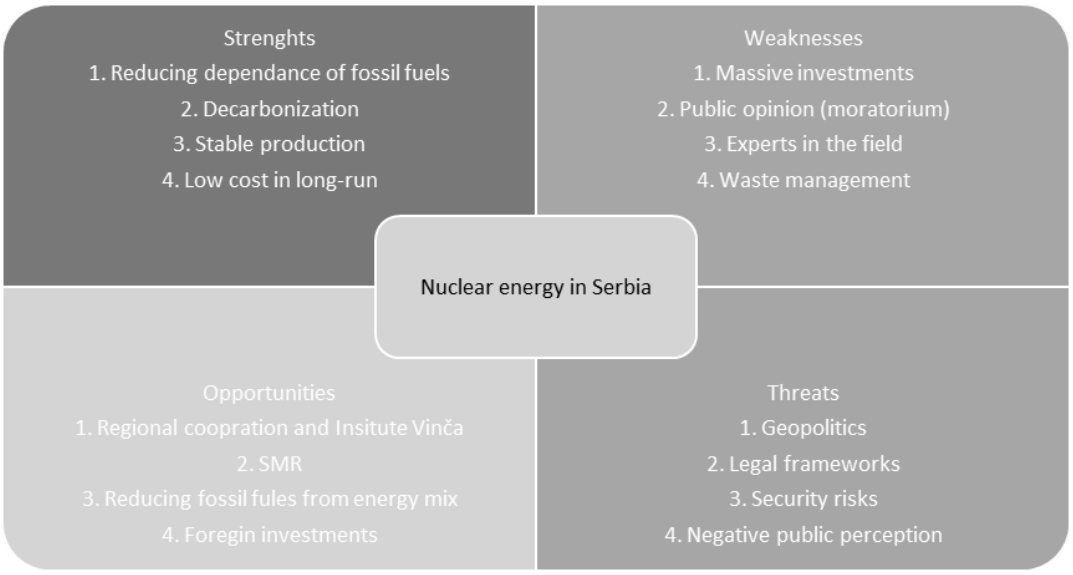

Figure 5 – SWOT analysis for nuclear energy utilization in Serbia
Source: Author's research

Serbia needs to decarbonize its energy mix, and nuclear energy could be one of the solutions for transitioning to renewable energy sources. In examining the current climate regarding nuclear energy, the SWOT analysis highlights the Institute of Nuclear Sciences Vinča, which has experts in this

field, as well as the accident in 1958, which could influence public opinion about nuclear energy. This issue requires further investigation in light of the growing energy needs and climate changes caused by the use of fossil fuels.

CONCLUSION

By reviewing the status of nuclear energy through a comparative analysis of European countries that utilize nuclear energy and analyzing the development of these technologies in Serbia, it appears that nuclear energy is emerging as one of the solutions. SMR technologies are promising, both in the context of the European nuclear energy challenge and when considering their application in Serbia. Another option could be international cooperation with neighboring countries such as Bulgaria or Hungary, which have a significant share of nuclear energy in their energy mixes, thus alleviating the pressure on the environment and represent an example of good practice.

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