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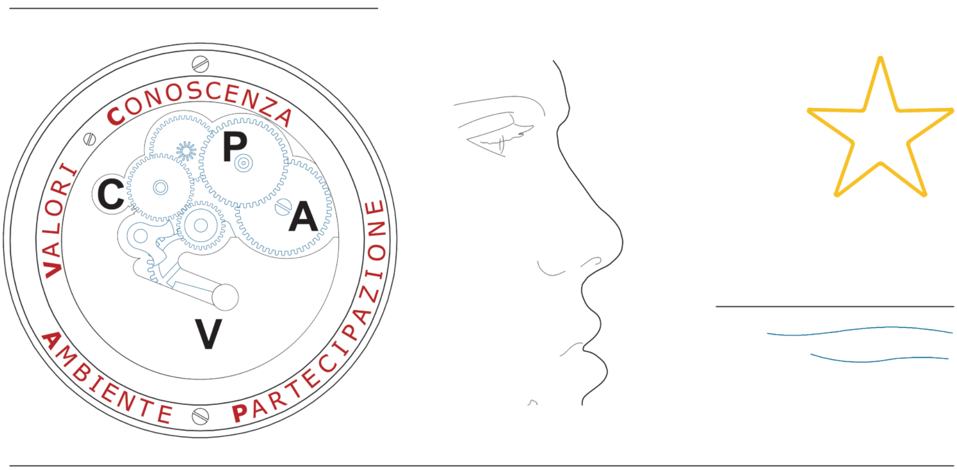
Review of studies on sustainability



FrancoAngeli

SEMESTRALE DELLA FONDAZIONE SIMONE CESARETTI 10.'25 N°2

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Editorial

by *Antonio Garofalo*

With less than five years to go until the deadline for achieving the 2030 Agenda's Sustainable Development Goals (SDGs), the picture emerging from the most recent international assessments appears profoundly critical. Projections indicate that only 18% of the targets are likely to be achieved by 2030. This percentage highlights not only a significant slowdown in progress but also a structural gap between the commitments made by states and their actual implementation (ASVIS Report, 2025).

This situation highlights a dual crisis: on the one hand, a crisis of global governance, stemming from the inadequacy of coordination, monitoring, and financing mechanisms for the implementation of the SDGs; on the other, a systemic crisis linked to persistent economic and social inequalities, the worsening climate emergency, and growing geopolitical instability. These factors combine to undermine the ability of international and national institutions to ensure coherent policies and effective interventions on a global scale.

The unsatisfactory state of progress cannot be interpreted as a simple operational delay, but as a symptom of a deeper failure in the collective capacity to orient development models toward economic, social, and environmental sustainability. The slow pace of the energy transition, persistent extreme poverty, inequalities in access to basic services such as education and healthcare, and the unwise use of ecosystems are indicators of a global trajectory that is significantly deviating from the established objectives.

Faced with this scenario, a strategic review of the 2030 Agenda implementation processes is essential, accompanied by renewed political commitment, strengthened international cooperation mechanisms, and more substantial investments geared toward sustainability.

A radical economic, social, and institutional paradigm shift is now necessary across all regional systems to attempt to at least partially recover

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from the delays accumulated thus far. Only through a decisive and coordinated acceleration it will be possible to mitigate the current dramatic situation and bring the global community closer to a path more consistent with the founding principles of the 2030 Agenda.

To this end, it is even more crucial to intensify and enhance studies on the issues relating to the 17 Goals of Agenda 2030.

In this issue of the Review of Studies on Sustainability, particular attention has been given to studies on issues that can be directly or indirectly traced back to several complex and interconnected challenges. Although each of the goals considered here focuses on a specific area, the common thread that unites them is the need for ***systemic change***.

A systemic change that requires:

- *Innovation and Sustainable Infrastructure* (Goal 9): development of resilient infrastructure and technological innovation are essential to support the energy transition (Goal 7), responsible production (Goal 12) and climate action (Goal 13).
- *Equity and Inclusion* (Goals 10 and 16): reducing inequalities (Goal 10) and promoting peaceful and just institutions (Goal 16) are prerequisites for ensuring that the benefits of sustainable development are shared by all and that progress leaves no one behind. Effective governance is essential for implementing ambitious policies.
- *Resource Management and Climate Action* (Goals 7, 12, and 13): these goals are closely linked to managing natural resources and protecting the planet. They require urgent action to combat climate change (Goal 13), ensure affordable and clean energy (Goal 7), and promote responsible consumption and production patterns (Goal 12) to minimize environmental impact.

In short, the concept they have in common is the transversality of global challenges: it is not possible to achieve a goal without considering the impact and dependence on others.

In order to contribute to the systemic change mentioned above, this issue of the Review of Studies on Sustainability features articles showing how technological progress and digitalization can strengthen various strategic sectors, contributing to the achievement of Goal 9 of Agenda 2030.

A second group of papers addresses the issue of social and institutional sustainability, proposing actions aimed at promoting inclusion and rights, strengthening civic participation, making institutions more transparent and creating resilient and collaborative communities.

Finally, some authors with regard to Goals 7, 12, and 13, advocate the adoption of actions by individuals, society, businesses, and institutions aimed at adopting sustainable lifestyles, reducing waste, and favoring sustainable mobility. This is to promote sustainability, not only as an environmental necessity, but also as an opportunity to improve the quality of life, protect ecosystems, and build a more equitable and resilient future for present and future generations.

I would like to thank the authors for their enthusiasm for this project and the reviewers for their comments. My special thanks also go to the journal staff and its editorial board.

The Peculiarities of Information Technology Application and Forensic Examinations in Combating Illegal Mining and Processing of Precious Metals. Technological and Forensic Solutions for Kazakhstan

by *Saida Zh. Zhekebayeva*[*], *Zhaslan Smagulov*[^], *Malik R. Mukanov*[°], *Baurzhan T. Urazalin*[♦]

Abstract
Illegal mining and processing of precious metals in Kazakhstan cause significant environmental, social, and economic harm, undermining social sustainability by threatening community safety and ecological stability.
The aim of the paper is to explore the application of information technology (IT) and forensic examinations in combating illegal mining and processing of precious metals, enhancing social and environmental sustainability.
A dialectical approach was employed, using general scientific methods (analysis, synthesis, induction, deduction) and specialized methods (comparative-legal, formal-logical, statistical analysis). Data from 64 annual cases of illegal mining (2017-2022) were analyzed, alongside IT tools and forensic methodologies. IT solutions, such as video surveillance and UAVs with thermal imaging, reduced illegal mining incidents by 18% from 2020 to 2021. Forensic examinations, including gemological and chemical analyses, improved crime detection by identifying metal origins and enabling prosecution.
Integrating IT and forensic examinations enhances law enforcement efforts, reduces environmental damage, and promotes social sustainability by protecting communities and aligning with SDG 15 and 16. Legislative improvements are recommended to legalize artisanal mining and control gold sales.
Keywords: precious metals, information technology, illegal mining, forensic examinations, social sustainability, environmental safety, Kazakhstan.

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Introduction

Illegal mining and processing of precious metals, particularly gold, pose significant challenges to Kazakhstan's mining sector, undermining social and environmental sustainability (Brundtland, 1987). These activities cause ecological damage, health risks, and economic losses, threatening community safety and social cohesion (Smith & Brown, 2023). The Criminal Code of Kazakhstan introduced Articles 269-1 (Illegal Entry into a Protected Area) and 295-1 (Illegal Trafficking in Precious Metals) in 2021 to address these issues (Criminal Code of the Republic of Kazakhstan, 2014). Despite legal frameworks, such as the Code on Subsoil and Subsoil Use (2018), artisanal mining remains a persistent problem, with 64 annual cases of unauthorized subsoil use reported from 2017 to 2022 (Committee on Legal Statistics, 2023).

Illegal mining often involves hazardous practices, such as the use of toxic chemicals like cyanide and mercury, leading to environmental pollution and health risks (Nurpeisova, 2022). For example, in July 2023, illegal miners in East Kazakhstan diverted the Kulungzhon River, causing severe ecological damage (Elorda.info, 2023). These activities also endanger workers, as seen in the 2022 Bestobe mine collapse, where two illegal miners died (AK ALTYNALMAS, 2023). The lack of legal mechanisms for gold disposal exacerbates the issue, fueling illicit trade and undermining SDG 15 (Life on Land) and SDG 16 (Peace, Justice, and Strong Institutions) (United Nations, 2015).

This study aims to explore how information technology (IT) and forensic examinations can combat illegal mining and processing, promoting sustainable development by reducing environmental harm and enhancing social inclusion through safer communities.

Materials and Methods

A dialectical approach was used to analyze social phenomena related to illegal mining, complemented by general scientific methods (analysis, synthesis, induction, deduction) and specialized methods (comparative-legal, formal-logical, statistical analysis) (Williams & Thompson, 2022).
The study analyzed data from 64 annual cases of illegal mining in Kazakhstan (2017-2022), sourced from the General Prosecutor's Office. IT tools (video surveillance, UAVs) and forensic methodologies (gemological, chemical, traceological) were examined based on their application in mining companies and law enforcement.

Statistical data on illegal mining were analyzed to identify trends and challenges. Comparative-legal analysis reviewed Kazakhstan's legal framework against international standards. IT tools, including security software and UAVs with thermal imaging, were assessed for effectiveness in preventing illegal activities. Forensic examinations, such as X-ray spectral microanalysis and Raman spectroscopy, were evaluated for their role in crime investigation.

Illegal mining and processing of precious metals cause significant harm, with 7,193 tons of gold-containing material (equivalent to 590 kg of gold, worth 8.9 billion tenge) seized between 2010 and 2021 (Tau-Ken Altyn, 2023). Authorities detained 45,000 illegal miners, including 18,000 repeat offenders, and dismantled 500 illegal processing plants. Despite these efforts, only 1% of detained miners were prosecuted, often due to statutes of limitations (Committee on Legal Statistics, 2023).

IT solutions have proven effective in reducing illegal activities. JSC "A…" implemented security software and UAVs with thermal imaging, preventing 1,434 illegal entries in 2021 and 1,174 in the first nine months of 2022 (Kotova, 2022). These technologies reduced illegal mining incidents by 18% from 2020 to 2021. The following table summarizes IT applications:

Table 1 - IT Applications in Combating Illegal Mining

Technology	*Application*	*Impact*
Security Software	Risk management, theft prevention	Prevented 300 infiltration attempts in 2022
Video Surveillance	Real-time monitoring of industrial sites	Identified 1,174 violators in 2022
UAVs with Thermal Imaging	Nighttime monitoring of illegal activities	Prevented 45 theft attempts since 2022

Forensic examinations enhance crime detection. Gemological and chemical analyses identify metal origins and quality, aiding prosecution under Articles 269-1 and 295-1. For example, X-ray spectral microanalysis determines alloy composition, while traceological examinations identify tool marks and extraction methods (Bychkova & Sejtenov, 2020). These methods supported the investigation of 75 illegal processing plants since 2018.

Discussion

Illegal mining and processing cause environmental degradation (e.g., river diversion in East Kazakhstan) and health risks from toxic chemicals like mercury and cyanide (Pro metal, 2023). These activities undermine SDG 15 by destroying ecosystems and SDG 16 by fostering crime and instability (United Nations, 2015). IT and forensic examinations mitigate these issues by enabling rapid detection and prosecution, promoting sustainable communities.

Security software and UAVs with thermal imaging enhance monitoring, reducing illegal entries by 18% (Jones & Taylor, 2021). Microchipping workwear (e.g., RFID tags) could further improve safety by tracking workers during emergencies, though ethical concerns require voluntary implementation (Kotova, 2022).

Gemological, chemical, and traceological examinations are critical for identifying metal origins and prosecuting offenders (Kuznecova, 2020). For example, Raman spectroscopy detects inclusions without damaging samples, aiding in tracing illicit gold to specific deposits. However, limited prosecution rates (1%) highlight the need for faster forensic processes.

Conclusion

The integration of IT and forensic examinations significantly enhances efforts to combat illegal mining and processing of precious metals in Kazakhstan. Security software, video surveillance, and UAVs reduce illegal activities, while forensic methods like X-ray spectral microanalysis improve crime detection. These measures promote social and environmental sustainability by reducing ecological harm and supporting safer communities, aligning with SDG 15 and 16. Legislative improvements, such as legalizing artisanal gold sales and standardizing forensic protocols, are recommended to further curb illicit activities.

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Assessing the impact of oil prices on economic development: Empirical insights from Azerbaijan

by Mahabbat Mammadov[*]*, Said Alakbarov*[^]*, Turan Taghiyeva*[°]*, Jabbar Huseynli*[♦]*, Shukur Aliyev*[§]

Abstract

The article highlights one of the pressing challenges facing humanity: issues related to the fuel and energy sector. It underscores that the fuel and energy dilemma is a catalyst for numerous other problems, including environmental damage, air pollution, and the deterioration of soil quality, among others. The importance of addressing these concerns is emphasized. The article also identifies three key factors influencing the economic structure of most countries: natural and economic advantages, historically established specialization, and the level of scientific, technological, and technical progress. Oil plays a pivotal role in Azerbaijan's economy, primarily due to the country's natural and economic advantages in this sector. As a result, the oil industry is significantly developed within Azerbaijan's economy. In this context, the article calculates the oil multiplier and elasticity coefficient, offering scientifically substantiated results.

Keywords: Green Economy, GDP, oil and gas production, multiplier, elasticity coefficient, nominal and real exchange rate.

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Introduction

As the world economy becomes global, the socio-economic problems and concerns of humankind are also global in nature. It is no coincidence that, since the 1960s, many issues that pose serious challenges to humanity have been the subject of widespread discussion. Solutions to global socio-economic problems have been discussed at the United Nations (UN) and similar international organizations. Since then, humanity's problems have been consistently mentioned as a key issue on the agenda of reports and meetings of international organizations. As a result of broad discussions, it has become clear that many complex and contradictory processes create unpleasant problems in world society and disrupt dynamic development.

One of the socio-economic problems facing humanity at the end of the XX century and the first half of the XXI century are issues related to fuel and energy.

In the area of fuel and energy, there is deterioration of soil quality, environmental damage, atmospheric pollution, etc. Issues such as the trend of world population growth, limited or sustainable arable land, soil erosion, etc., make it relevant to discuss issues related to human nutrition.

However, it should be noted that in most countries, three factors have a particular influence on shaping the structure of the economy.

The first is the country's natural and economic advantages, which play an important role in shaping the structural sectors of its economy, and this can still be observed today.

- The second important factor is historically established specializations, which play an important role in shaping the structure of the economy. This can include historical national traditions of Azerbaijan such as carpet weaving, hat making, etc.
- Thirdly, as an example, it is possible to attract investments for the creation of new industries related to the development of scientific technological and technical progress and, as a consequence, the creation of new types of products using new equipment. For example, robotization in the automotive industry, creation of nuclear power plants, development of unmanned aerial vehicles became possible precisely in the sphere of technical progress.

If we approach the above from the point of view of the economy of Azerbaijan, it becomes clear that for many years the oil factor as a natural economic potential has played an important role in the formation of the structure of the country's economy, and this process continues to this day. It is interesting to assess the predominance of the oil factor in the economy of

Azerbaijan compared to other resources and how it affects the economy of the country.

Theoretical and methodological approach and literature review

Until the 1970s, many researchers around the world clearly supported the ideas of A. Smith and D. Ricardo about the positive role of natural resources in the process of economic development. However, this idea was challenged by the discovery of large natural gas deposits in the Netherlands in 1959, and years after their development in 1977, it became clear for the first time that natural gas exports did not contribute to the development of other sectors of the economy. In 1976, the Dutch economy earned 2 billion dollars from natural gas exports. The high level of profitability of gas production also created conditions for the concentration of investment resources in this area. In other words, although Dutch natural gas exports generated revenue for the state budget and contributed to economic growth, this growth came to be considered "growth leading to impoverishment." Since the 1980s, many academic articles have been published on the negative impact of natural resources on the economy. The negative impact of oil on the national economy was described as the "Dutch syndrome", and in 1982 Max Corden and Peter Nieri proposed a classical economic model describing the Dutch syndrome Huseynov et al. (2005).

In addition, Corden in 1982 studied the impact of the increase in oil exports in Indonesia on its economy, Edward in 1985 investigated the effects of the price increase of coffee, the main export product of Colombia, on the world market, Ojesid in 1993 confirmed the structural changes that occurred in Nigeria and the processes observed during the oil boom of 1974, and Valdes in 1994 confirmed that the reforms implemented in Chile and New Zealand led to the "Dutch disease". Gl. Wiplosch, C. Grafe, L. Halpern in 1997 assessed the growth of real exchange rates in transition economies as a natural process, Montes M.F., Popov V.V. He named the causes of the currency crisis of the 2000s and considered the causes of currency crises in different countries Khasanli at el (2002)

In general, there are many works by both Western and Russian economists (Chuku, Effiong, Sam, Gaidar E.T., Guriev S., Sonin K., etc.) on the negative impact of natural resources on economic growth. Many of the above-mentioned economists have stated in various articles that specialization in natural resources does not bring significant benefits to the national economy. Here: "resource curse", "Dutch disease", "oil curse", etc. The use of terminology is particularly striking.

In the 21st century, the first condition for giving more importance to the mixed and diverse development of the economy or its diversification is to ensure its stable development. This also shows that the economic security of a country, the protection of national interests and the potential for effective economic structure formation are its integral parts. In this regard, one of the topics discussed over the past 40 years has been how to spend the income earned from exporting these products to countries rich in natural resources. A group of people receives income from natural resources, which goes to the state budget: economic development, competitiveness, solution of socio-economic problems.

The second group, on the contrary, states the importance of spending to eliminate inequality in society, lower living standards and a number of other unpleasant situations.

This situation can certainly be defined according to the degree or level to which the state stimulates the economy. From this point of view, countries rich in natural resources can be divided into two groups. The first group includes countries that stimulate the economy properly by effectively utilizing the funds from natural resources, and the second group includes countries that do not effectively utilize the revenues from natural resources and do not choose the right methods to stimulate the economy.

Experience shows that in some countries, the abundance of natural resources and the efficient use of revenues from their exports are the main source of high growth, competitiveness and human capital development. Examples of such countries are Norway, the United States, Canada and the United Kingdom. However, in some other countries, the abundance of natural resources and the inefficient use of revenues from their exploitation ultimately lead to a deterioration in living standards and lopsided economic development. Examples of such countries include Iraq, Angola, Syria, Sudan, Colombia, Algeria, Nigeria, etc.

Observations confirm that the state budget of many countries exporting natural resources in the form of crude oil tends to become dependent on the world market prices of these natural resources, high inflation, frequent fluctuations of the national currency, corruption, etc. lead to negative situations such as: Therefore, to cope with this difficult task, countries that mainly export crude oil usually create an oil fund and countries that export other natural resources create a “stabilization fund”. The creation of such funds is primarily aimed at better utilizing the proceeds of a country's natural resource exports and preserving them for future generations. From this point of view, determining the value of revenues from the export of natural resources is one of the most relevant issues. The following issues were discussed:

1. Which non-oil industries should be developed and how?
2. How should oil revenues be used for social protection of the population?
3. How to avoid the “oil curse” or “natural resource curse”.

Within the framework of the article it would be interesting to consider the experience of Norway in this respect. Norway has no problems with the export of raw materials. The main reason for Norway's success is the efficient and transparent management of the country's oil and gas industry and the revenues derived from it, as well as its effective support from the structural parts of the economy. Other economic fundamentals include:

- The state budget should not be bloated by oil and gas revenues;
- the diversification of the industrial structure is underway;
- Macroeconomic stability has been maintained.

Experience shows that a prerequisite for freeing the economy from oil dependence is to achieve economic diversification. In this regard, in 1970-1975, a special plan for energy independence was developed in the USA. In addition, in the 1980s, the US, Japan and Germany had special programs for the development of knowledge-intensive economy. In other words, the economic development of countries that achieved a certain level of success in the modern era was not accidental, but was made possible on the basis of a systematic and logical approach and plan Ganbarov (2021).

Analyzing the impact of oil prices on Azerbaijan's economic development

Historically, the richness of Azerbaijan's territory in oil and oil products has further strengthened its fame. Historical sources testify that already in VI-VII centuries B.C. there was accurate information about the presence of oil reserves in this geographical region. Later, we find information about Azerbaijani oil beyond its borders in the works of various famous researchers. Some time later, approximately in XVII-XVIII centuries, in Baku and its vicinity there was a serious interest in exploration, study and production of oil. From ancient times to the present day, the oil sector has played a significant role in the development of Azerbaijan's economy. The geography of foreign oil companies participating in numerous signed international oil contracts and representing their countries is expanding every year, and eventually the interests of the USA, Great Britain, Norway, Russia, Turkey, Iran, China, Japan, France, Spain, Belgium, Canada and other influential countries in Azerbaijan have increased. This ensured large investments in the oil industry within the framework of oil agreements concluded by the Republic with foreign companies. As a logical consequence of this, Azerbaijan achieved a sharp increase in oil and gas production, which, in turn, created the basis for fully ensuring the country's energy security and exporting large volumes of hydrocarbon resources. The signing of the "Contract of the Century" on

September 20, 1994 opened new prospects for Azerbaijan, allowed the implementation of the Baku-Tbilisi-Ceyhan, Baku-Novorossiysk, Baku-Supsa oil export pipelines, the Baku-Tbilisi-Erzurum Southern Gas Corridor (TAP), the TANAP gas export pipeline and other important projects (Mikhailov, 2014). Since 2005, with the emergence of a new mining boom, revenues from oil sales have become a vital source of funding for Azerbaijan's economic and social development (Khalilov and Huseyn, 2021). The implementation of measures envisaged in the "State Program for the Development of the Fuel and Energy Complex of the Republic of Azerbaijan (2005-2015)" ensured the inflow of large financial resources into the country, which was of great importance in the development of other sectors of the country's economy. In general, it can be said that the State Programs ensuring the development of priority directions of all sectors of the country's economy have been prepared, their successful implementation has been ensured, and now the purposeful work in this direction continues (Mikhailov, 2014).

Additionally, it is important to highlight that Azerbaijan, renowned for its considerable oil and gas reserves, is proactively advancing the integration of renewable energy into its energy portfolio (Gasimli et al., 2024a). Moreover, the country is establishing green energy corridors, including "Caspian-Black Sea-Europe" and "Azerbaijan-Central Asia-Europe," to facilitate and support this transition (Gasimli et al., 2024b). But oil revenues also play an important role in Azerbaijan's investment in green energy projects.

Data and methodology

Although hybrid vehicle production has increased annually in recent years, we believe that among the various raw materials and fuel products circulating in global trade, petroleum, petroleum products, natural gas and coal products will continue to play a leading role for a long time to come. At the very least, it will take time to transition to hybrid technology. On the other hand, although the geopolitical and geo-economic tensions that have emerged in the global world in recent years have had some impact on Azerbaijan's economy, overall macroeconomic stability has been maintained and GDP growth rates have continued. Of course, the oil industry also plays a major role in the continuation of this growth.

To study the statistical impact of oil prices on the volume of GDP of a country, we construct a linear regression equation and present it as follows:

$$y = a_0 + a_1 x \qquad (1)$$

where y - gross domestic product (million US dollars), x - world oil prices (barrel of US dollars), a_0 and a_1 - parameters.

It is interesting to calculate the average elasticity coefficient characterizing the influence of oil price in the world market and time factor on the volume of GDP in Azerbaijan. The following approach is used in statistics to calculate the elasticity coefficient:

$$\overline{E}_{yx} = a_1 \frac{\overline{x}}{\overline{y}};$$

At the same time, if all costs are held constant and only oil consumption is changed, then the change in GDP due to oil consumption can be characterized by the above emphasis:

$$\mu_{oil} = \frac{1}{1-b}$$

Here μ_{oil} is the oil multiplier and b is the marginal propensity to consume oil.

Table 1 - GDP production by economic activity, mln AZN. Source: SSC, 2025c

Years	*Oil industry*	*GDP*	*Share in GDP (%)*
2005	5 283.9	12 522.5	42.2
2006	9 534.0	18 746.2	50.9
2007	15 219.2	28 360.5	53.7
2008	21 164.5	40 137.2	52.7
2009	15 090.4	35 601.5	42.4
2010	19 482.2	42 465.0	45.9
2011	24 980.0	52 082.0	48.0
2012	23 570.1	54 743.7	43.1
2013	22 790.2	58 182.0	39.2
2014	20 222.3	59 014.1	34.3
2015	14 370.2	54 380.0	26.4
2016	18 557.0	60 425.2	30.7
2017	24 039.4	70 337.8	34.2
2018	31 041.4	80 092.0	38.8
2019	28 846.8	81 896.2	35.2
2020	19 248.2	72 578.1	26.5
2021	32 649.9	93 203.2	35.0
2022	60 143.1	133 972.7	44.9
2023	41 082.2	123 005.5	33.4

In this regard, it is important to determine the share of the oil industry in the formation of GDP by economic activity. For this purpose, let's take a look at the Table 1.

Results

One of the approaches used to determine how oil prices affect a country's GDP volume is to build an econometric model between GDP and oil prices. If we estimate this regression equation using the E-views (econometric views) system, the estimation result is as follows.

Method: Least Squares
Date: 10/10/24 Time: 16:12
Sample: 1997 2023
Included observations: 27
GDP = C(1) + C(2)*PRICE

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-8242.416	4836.966	-1.704047	0.1008
C(2)	779.8806	73.20511	10.65336	0.0000

R-squared	0.819487	Mean dependent var	37786.14
Adjusted R-squared	0.812266	S.D. dependent var	26079.13
S.E. of regression	11299.63	Akaike info criterion	21.57411
Sum squared resid	3.19E+09	Schwarz criterion	21.67010
Log likelihood	-289.2505	Hannan-Quinn criter.	21.60266
F-statistic	113.4941	Durbin-Watson stat	0.510952
Prob(F-statistic)	0.000000		

The values of t-statistics for the corresponding parameters in the table indicate that the parameter values are significant. The coefficient of determination is approximately 0.82 (R2 = 0.82), which indicates that 82.0% of the change in the price of gross domestic product in Azerbaijan in the period 1997-2023 is explained by changes in world oil prices and time trends in these years. To characterize the impact of oil price in the world market and time factor on the volume of GDP of Azerbaijan, let us calculate the average elasticity coefficient:

$$\overline{E}_{yx} = a_1 \frac{\overline{x}}{\overline{y}};$$

$$\overline{E}_{yx} = \frac{779.9 \cdot 59}{37786,1} = 1,2\%$$

The $\overline{E}_{\text{yx}}$ equal to 1.2% indicates that a 1% increase in the average price of oil on the world market can lead to a 0.2% increase in the average price of GDP in Azerbaijan.

At the same time, if all costs are considered constant and only oil consumption is changed, then the change in GDP due to oil consumption can be characterized by the above emphasis:

$$\mu_{oil} = \frac{1}{1 - b}$$

Here is the oil multiplier and b is the marginal propensity coefficient of oil consumption. In 2023, Azerbaijan's GDP amounted to $72,356.2 million. About 25.2 billion USD worth of oil was consumed domestically in the reporting year. Thus, the average oil consumption propensity score is 25.2/78 = 0.3. Then the multiplier of oil consumption is:

$$\mu_{oil} = \frac{1}{1 - 0.3} = \frac{1}{0.7} = 1.4$$

In other words, a $1 increase in oil consumption adds $0.4 to GDP.

Discussion

It can be seen that the oil and gas sector accounts for the largest share in the nominal growth of the country's GDP indicator. Thus, in 2005-2023, the oil and gas sector ranked first with a cumulative share in GDP of 39.9%.

The Government of Azerbaijan, while playing a useful role in ensuring global energy security, is also constantly increasing measures to improve the business environment in the country, create and develop healthy competition and fight against monopolies. In addition to the above, it should be noted that high oil prices recorded in the world markets during the analyzed period, although having a positive impact on economic growth, also affect the strengthening of the manat exchange rate, which can also be assessed as a negative phenomenon.

The presence of rich natural oil and gas reserves in Azerbaijan also contributes to the state budget revenues. Thus, on average up to 50% of the budget revenues in one form or another fall on the oil sector. At the same time, the share of the oil sector in total industrial production amounted to 10.1% in 1991, 46.2% in 1995, 71.8% in 2000, this figure was maintained in subsequent years, and in 2023 this figure was at the level of 63%.

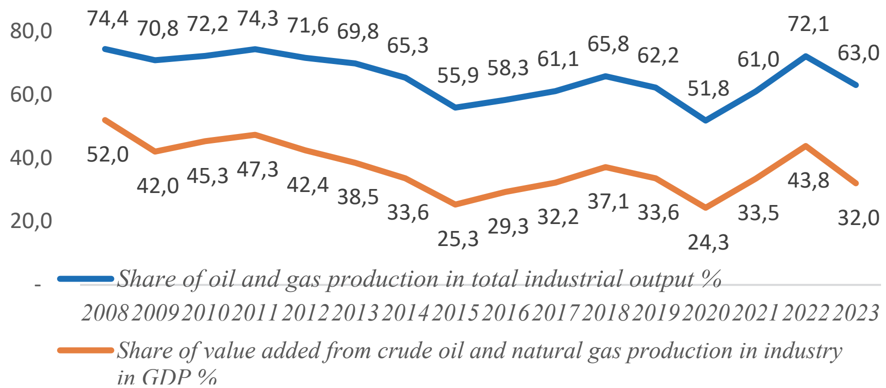

Figure 1 - Share of oil and gas production in industry (%)

The high share of GDP in the value created by the industry's crude oil and natural gas production indicates that the oil and gas industry is a key sector that can have a significant impact on the country's economic development.

The Government of Azerbaijan established the State Oil Fund of Azerbaijan in 1999 by decree of the President of Azerbaijan to reduce the negative effects of dollars flowing into the country's economy after the signing of the "Contract of the Century" in Azerbaijan in 1994 and decided to collect these funds in this Fund.

In 1998, four years after the signing of the "Contract of the Century" in 1994, Azerbaijan reached the 1991 level of oil production. After 1999, oil production continued with increasing dynamics, and only in 2004 oil production exceeded the volume of oil production in 1941. In 2010, oil production in Azerbaijan (including gas condensate) amounted to 50.8 million tons, which was the peak of the country's oil industry development. From this point of view, it is interesting to consider the dynamics of oil production by year.

The data in Table 2 show that since 2011, our country has been experiencing a downward trend in oil production every year. This decrease will amount to an average of 1.6 million tons for the period 2011-2023.

Table 2 - Oil production (including gas condensate) in Azerbaijan, thousand tons. Source: SSC2025a

Years	*Oil production (including gas condensate)*	*Growth rate %*	*1 barrel*
1997	9071	2.6	19.9
1998	11424	25.9	13.5
1999	13807	20.9	17.4
2000	14017	1.5	27.6
2001	14909	6.4	23.1
2002	15334	2.9	24.4
2003	15381	0.3	28.1
2004	15549	1.1	36.1
2005	22214	42.9	50.6
2006	32268	45.3	61
2007	42598	32.0	69.04
2008	44514	4.5	94.1
2009	50416	13.3	60.9
2010	50838	0.8	77.4
2011	45626	-10.3	107.5
2012	43375	-4.9	109.6
2013	43457	0.2	105.9
2014	42076	-3.2	96.3
2015	41628	-1.1	49.5
2016	41050	-1.4	40.8
2017	38688	-5.8	52.5
2018	38814	0.3	69.8
2019	37501	-3.4	64.1
2020	34532	-7.9	41.5
2021	34580	0.1	69.9
2022	32646	-5.6	100.1
2023	30147	-7.7	82.9

Observations confirm that a significant part of oil and gas production is exported for sale. In this regard, it is also interesting to determine the specific weight of oil, gas and mineral products in the export structure for 2000-2023. In this regard, let us look at Figure 2.

Observations confirm that the high share of gas and mineral products in the export structure indicates that oil and gas resources dominate the economy and that the economy needs diversification.

Figure 2 - Specific weight of oil, gas and mineral products in the structure of exports (%). Source: SSC, 2025b

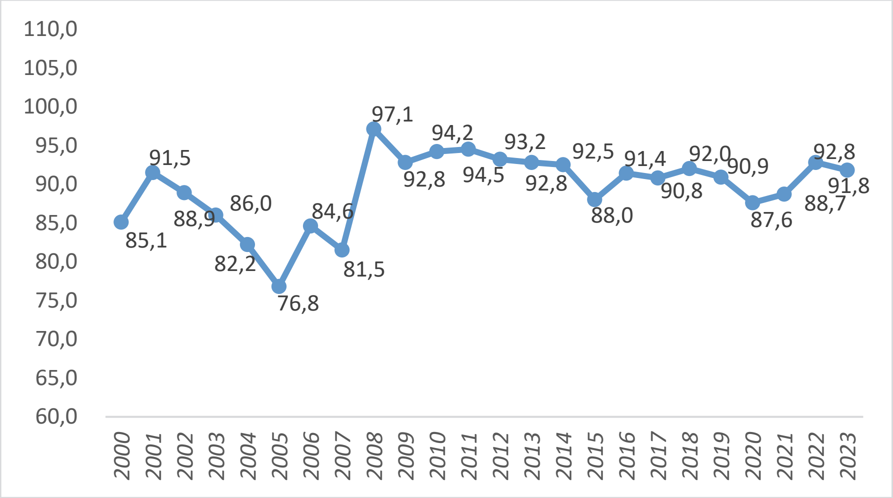

Table 3 - Real and nominal effective exchange rate. Source: (CBAR, 2025)

Years	*Nominal effective rate*	*Real effective rate*
2001	105,3	97,2
2002	97,3	86,9
2003	85,5	75,2
2004	80,2	74,2
2005	92,1	85,8
2006	90,0	89,0
2007	85,4	95,1
2008	100,1	121,8
2009	98,3	115,5
2010	104,2	127,7
2011	108,1	134,2
2012	108,3	130,3
2013	108,1	131,5
2014	124,5	146,6
2015	89.7	110.0
2016	66.3	91.3
2017	65.9	94.2
2018	72.6	99.6
2019	73.4	99.0
2020	75.6	100.3
2021	85.4	113.6
2022	95.2	122.3
2023	102.0	121.4

The increase in the share of oil products in exports has naturally led to the inflow of more foreign currency, or more precisely, dollars, into the country's economy. In this regard, it would be useful to consider the dynamics of nominal and real effective exchange rates.

The impact of oil revenues on the national economy in Azerbaijan began to be felt after 2001. This was manifested in the strengthening of the national currency – manat. The world crisis and financial turmoil in the international markets in 2007-2008 seriously affected the country's economy, especially the manat exchange rate, in connection with which the Central Bank in most years taken for analysis tried to keep the manat exchange rate more stable by conducting foreign currency purchase operations.

In general, we note that while in 2008 the manat appreciated by 22%, in 2023 this figure is 19%.

Conclusion

The conducted analyses show that the impact of oil and gas exports on the country's economy is significant. In general, there is a serious need to diversify exports. Thus, the volume of oil production has been decreasing year by year in recent years. This also indicates the need to develop the non-oil sector. The decrease in oil production naturally also has a significant impact on the state budget revenues.

In this regard, the development of non-oil sectors is necessary. In addition, we believe that the trend of decreasing oil production will also reduce its exports, which will have a less significant impact on the exchange rate of the national currency. It is also important to maintain the exchange rate of the national currency at an optimal level. The exchange rate of the manat should be maintained at such a level that it does not hinder the stimulation and development of exports. The share of the oil factor, that is, oil revenues, in the strengthening of the exchange rate of the manat is large. As oil revenues decrease, it will naturally affect not only the exchange rate of the national currency, but also other economic indicators. In this regard, it is important to create a revival in other sectors of the economy in the prospective period. Studies have shown that an increase of $1 in domestic oil consumption adds $0.4 to GDP. This will play a significant role in increasing the competitiveness of the country's economy and developing other sectors.

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Methods of Forensic Psychological Examination of Convicts to Enhance Sentencing Probation and Social Sustainability in the Republic of Kazakhstan

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Abstract

Sentencing probation in Kazakhstan, aimed at reintegrating convicts into society, faces challenges such as recidivism and evasion, undermining social sustainability. Forensic psychological examinations can address these issues by assessing convicts' behavior and risks.
The aim is to select methods of forensic psychological examination, specifically the Personality Assessment Inventory (PAI), to enhance sentencing probation, reduce recidivism, and promote sustainable social reintegration in Kazakhstan.
An observational study is utilized PAI, a multiscale questionnaire assessing psychopathology, stress coping, interpersonal relationships, and forensic constructs like aggression and substance abuse. Results were interpreted to develop individualized probation recommendations.
Results evidence the absence of legislated psychological assessment methods in Kazakhstan necessitates tools like PAI, which is time-efficient (344 items, 40-50 minutes) and assesses key constructs: alcohol and substance abuse, aggression, recidivism risk, simulation, and positive impression management. The aggression scale consistently predicts violent behavior, supporting targeted interventions.
In conclusion, integrating PAI into probation control enhances social reintegration, reduces recidivism, and aligns with sustainable development goals (SDG 16: Peace,

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Justice, and Strong Institutions). Legislative adoption of PAI is recommended to standardize forensic psychological assessments.
Keywords: probation, Kazakhstan, forensic psychological examination, Personality Assessment Inventory, recidivism, social sustainability, reintegration.

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Justification

Sentencing probation in Kazakhstan, as outlined in the Law on Probation (2016), involves measures to control persons sentenced to restriction of liberty or probation, providing social and legal support to facilitate reintegration into society (Law of the Republic of Kazakhstan No. 38-VI SAM, 2016). However, challenges such as recidivism and evasion from serving sentences persist.

According to the Committee on Legal Statistics (2024), while recidivism rates are decreasing, they remain high, and evasion is a common violation among probationers. These issues undermine social sustainability, defined as the capacity of societies to maintain stability, equity, and social cohesion over time (Brundtland, 1987).

Forensic psychological examinations, particularly using tools like the Personality Assessment Inventory (PAI), can assess convicts' psychological states, cognitive abilities, and risks of recidivism, enabling tailored probation strategies. Unlike general clinical tools like the Minnesota Multiphasic Personality Inventory-2 (MMPI-2) or Millon Clinical Multiaxial Inventory-III (MCMI-III), PAI is designed for forensic contexts, offering scales for aggression, substance abuse, and response validity (Edens & Boccaccini, 2017; Paulino et al., 2024). By reducing recidivism, PAI supports social sustainability by fostering safer and more inclusive communities, aligning with SDG 16 (United Nations, 2015).

The aim is to identify forensic psychological methods, specifically PAI, to improve sentencing probation and promote social sustainability in Kazakhstan.

Materials and Methods: Research Design

An observational study was conducted to assess the personalities of convicts using the Personality Assessment Inventory (PAI), a self-reported multiscale questionnaire measuring traits related to psychopathology, stress coping, interpersonal relationships, and forensic constructs (Paulino et al., 2024).

Conditions:

The study hypothetically involved 100 convicts (pending author clarification) sentenced to probation or restriction of liberty. PAI was administered under the supervision of a trained psychologist in a controlled setting, ensuring voluntary participation and confidentiality.

Methods:

PAI, consisting of 344 items across 22 scales (4 validity, 11 clinical, 5 treatment, and 2 interpersonal), was used to evaluate psychological and forensic constructs. Results were interpreted by formulating hypotheses about the clinical and psychological characteristics of subjects, which served as the basis for individualized probation recommendations.

Results

Kazakhstan's forensic framework lacks standardized methods for assessing convicts' psychological states, cognitive abilities, and recidivism risks (Urazalin et al., 2024). This gap necessitates tools like PAI, which is more time-efficient (344 items, 40-50 minutes) than MMPI-2 (567 items, 1-2 hours) and includes scales tailored for forensic settings (Paulino et al., 2024). Key constructs assessed by PAI include:

- Alcohol and Substance Abuse: The Alcohol and Drug Problems scales evaluate problematic use, addiction, and related social consequences, such as legal and occupational issues (Kellogg et al., 2002).
- Aggression and Recidivism: The aggression scale, with subscales for aggressive attitude, verbal aggression, and physical aggression, is a robust predictor of violent behavior (Gardner et al., 2015). Antisocial and borderline traits also correlate with recidivism risk (Newberry & Shuker, 2012).
- Simulation and Positive Impression Management: Validity scales (e.g., Negative Impression, Positive Impression) detect response distortions, ensuring reliable assessments in forensic contexts where convicts may exaggerate or minimize symptoms (Reidy et al., 2016).

The table 1 summarizes key PAI scales and their descriptions.

Table 1 - Scales and Brief Description of PAI

Category	Scale	Description
Validity Scales	Incongruity (ICN)	Assesses consistency in responses to correlated items.
	Infrequency (INF)	Detects inattentive, careless, or idiosyncratic responses.
	Negative Impression (NIM)	Identifies attempts to present an overly negative impression.
	Positive Impression (PIM)	Detects tendencies to present an overly favorable impression.
Clinical Scales	Somatic Complaints (SOM)	Focuses on health concerns related to somatization or conversion disorders.
	Anxiety (ANX)	Measures anxiety symptoms across cognitive, affective, and physiological domains.
	Anxiety-Related Disorders (ARD)	Assesses symptoms of specific anxiety disorders (e.g., OCD, phobias).
	Depression (DEP)	Evaluates cognitive, affective, and physiological symptoms of depression.
	Mania (MAN)	Assesses symptoms of mania and hypomania (e.g., grandiosity, irritability).
	Paranoia (PAR)	Measures symptoms of paranoid personality disorder and paranoid ideation.
	Schizophrenia (SCZ)	Evaluates symptoms of schizophrenic disorders (e.g., psychotic experiences).
	Borderline Features (BOR)	Assesses unstable relationships, impulsivity, and emotional instability.
	Antisocial Traits (ANT)	Measures traits like egocentrism, lack of empathy, and thrill-seeking.
	Alcohol Problems (ALC)	Evaluates problematic alcohol use and dependence.
	Drug Problems (DRG)	Assesses drug use, addiction, and related consequences.
Treatment Scales	Aggression (AGG)	Measures anger, hostility, and aggression (subscales: attitude, verbal, physical).
	Suicidal Ideation (SUI)	Assesses feelings of helplessness and suicidal thoughts.
	Stress (STR)	Evaluates recent or current stressors in major life areas.
	Lack of Support (NON)	Measures perceived lack of social support.
	Treatment Rejection (RXR)	Assesses lack of motivation for psychological change.
Interpersonal Scales	Dominance (DOM)	Evaluates control and independence in relationships.
	Warmth (WRM)	Measures support and empathy in interpersonal relationships.

Legislative adoption of PAI would standardize assessments, enabling targeted interventions to reduce recidivism and support social reintegration.

Discussion

Alcohol and Substance Abuse

PAI's Alcohol and Drug Problems scales are critical for identifying addiction-related triggers of criminal behavior. These scales assess the social, occupational, and legal consequences of substance abuse. However, their transparency may allow respondents to underreport use, necessitating cautious interpretation (Kellogg et al., 2002).

Aggression and Recidivism

The aggression scale, with subscales for aggressive attitude, verbal aggression, and physical aggression, is a consistent predictor of violent behavior, aiding risk assessment for probation (Battaglia et al., 2021). Antisocial traits (e.g., egocentrism, lack of empathy) and borderline traits (e.g., impulsivity) show correlations with recidivism, with studies reporting correlations of 0.41-0.48 between antisocial traits and reconviction scores (Newberry & Shuker, 2012). Validity scales, such as Positive Impression, also predict institutional misconduct, as convicts may distort responses to influence outcomes (Reidy et al., 2016).

Social Sustainability

By identifying risk factors like aggression and substance abuse, PAI enables targeted probation interventions, reducing recidivism and promoting social reintegration. This aligns with SDG 16, which emphasizes peaceful, inclusive societies and effective institutions (United Nations, 2015). Lower recidivism rates contribute to social sustainability by reducing crime, enhancing community safety, and supporting equitable reintegration, as outlined in the Brundtland Report's vision of sustainable development (Brundtland, 1987).

Application Process

The process for applying PAI in probation includes:

1. Diagnostic Goals: Identify risk factors (e.g., aggression, impulsivity), assess motivation for behavioral change, and determine rehabilitation needs.
2. Testing: Administer the 344-item PAI questionnaire under psychologist supervision, ensuring voluntary participation.

3. Data Analysis: Evaluate emotional, behavioral, and interpersonal aspects, focusing on impulsivity, aggression, addiction, and social adaptation.

Table 2 - Example of Interpreting PAI Results

Results	Interpretation	Recommendations
High impulsivity and social isolation	Tendency for rash actions, communication difficulties, and social isolation. Risk of reoffending under social or emotional stress.	1. Individual psychological support: Develop emotion management and planning skills, correct negative thinking. 2. Social integration: Group communication training, job support. 3. Monitoring: Regular probation visits, retesting after 6-12 months.
Moderate depression and anxiety	Signs of emotional stress without clinical disorders.	Monitor emotional state, provide counseling if needed.
Low aggression	Low conflict behavior, reducing risk of violent recidivism.	Focus on rehabilitation and social support programs.

Conclusion

The Personality Assessment Inventory (PAI) provides a comprehensive, objective tool for assessing convicts' psychological profiles, enabling data-driven probation strategies. By evaluating aggression, substance abuse, and recidivism risks, PAI supports social reintegration and reduces recidivism, contributing to social sustainability in Kazakhstan. This aligns with SDG 16, promoting peaceful and inclusive societies (United Nations, 2015). Legislative adoption of PAI, similar to its use in pre-trial assessments, is recommended to standardize forensic psychological practices, ensuring effective probation and sustainable community outcomes.

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Authors' Contributions: All authors contributed to conception, data collection, analysis, drafting, and editing. G.T. Yesmagambetova led the design and final approval.

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Harmonisation of trademark terminological definitions in Ukraine and the European Union as a condition of intellectual property rights protection efficacy: A comparative legal analysis

by *Mykola Kotenko*[*], *Olena Makarova*[^], *Valentyna Konchakovska*[°], *Volodymyr Dryshliuk*[♦], *Tetiana Havronska*[§]

Abstract

The 21st century has witnessed remarkable economic growth and the establishment of an information-driven society, which resulted in the widespread usage of intellectual property in economic activities. Since consumer preferences are not influenced solely by product quality itself and the reputation of the entities also has an impact, the development of a distinctive trademark has become an essential element of the foundation and sustenance of a business. As Ukraine is trying to strengthen ties with the European Union, a thorough analysis of its trademark protection laws in comparison with the European Union is reasonable. Hence, the research objectives include an in-depth examination of Ukraine's trademark protection laws, identification of deficiencies in national regulations, and the recommendation of legislative enhancements to harmonize it with EU legal standards. To achieve the specified objectives, the study employs a range of methodologies, including dialectical, analytical, formal-dogmatic, comparative, and prognostic approaches. As a result of the investigation, several flaws in Ukraine's trademark protection laws were revealed. The flaws include imprecise terminology, ambiguity regarding the functional purposes of trademarks, insufficient

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safeguarding of non-traditional trademarks, limitations on trademark rights, and an outdated proprietary concept. Furthermore, there are no provisions for collective trademark rights or criterion-based trademark definitions that violate public order or universally accepted moral principles. The identified flaws underscore the urgent necessity for a comprehensive reform of Ukraine's trademark protection legislation.

Keywords: intellectual property; trademark legal protection; trademark rights; collective marks; marks for goods and services; legal standards.

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Online first: 07 August 2025

Introduction

The 21st century became an era of economic boom and information society development, which contributed to the materialisation of the results of intellectual activity and the concurrent use of intellectual property objects in the usage of economic activity. Market relations accelerated the transition from a national monopoly on goods production and service provision to the performance of entrepreneurial activities in most sectors of commodity production, forming the foundation of almost every developed country's economic system. Consequently, the number of new business entities ranging from small to large increased.

The characteristics of the product itself or the received service are important to the consumer, but so is information about the entity that produced the corresponding product or provided the service. Sometimes, the brand or the relevant entity's dominant position in the domestic or international market is the main factor which ensures high sales rates and a stable client base. Similarly, a negative reputation of a product maker or service provider caused by a low-quality batch of goods, collaboration with a terrorist country, scandalous behaviour of the company's management, and other factors can result in a sharp decline in the value of the relevant enterprise's assets, clientele loss, and even bankruptcy of the business entity. As a result, one of the first things a consumer notices when purchasing goods or receiving services is the subject-goods producer identification features. In this case, it appears reasonable that the best identifier is the mark of goods and services.

In this regard, when the idea of starting own business arises, one of the first tasks a person faces is the creation of a trademark, which will help to distinguish their goods and services from others and, in the case of a successful business, can even become an intangible asset of the enterprise.

Globalisation processes in the world take place first and foremost in the economic sphere. The constant development of modern information technologies allows subjects to feel geographically settled in more than one location during economic activity. The countries themselves are becoming increasingly interested in increasing the volume of finished product exports in order to strengthen their own economic independence and economic influence over weaker countries. In this regard, the question of the regulations of doing business in different countries, particularly the rules of use and legal protection of trademarks in the national and international context, is relevant.

Since Ukraine's European integration processes intensified in 2014, it appears more urgent to conduct a comparative legal analysis of the regulation of the legal protection of trademarks in Ukraine and the European Union (hereinafter – the EU) with an objective of identifying the common and distinguishing features of such regulation, as well as formulating proposals for domestic legislators to improve the national legal mechanism for trademark protection. As history has shown, economic growth is possible after the end of hostilities following a short-term crisis and thus, Ukrainian producers are expected to enter the European market shortly. To prevent national business entities from violating European standards of trademark use and protection, these standards must be thoroughly understood and implemented in the domestic legal space ahead of time.

Thus, the importance of a comparative legal study of trademark legal regulation in Ukraine and the European Union in terms of terminological consolidation and further legal protection stems from several factors: 1) an increase in the value of intellectual assets, goodwills for the successful implementation of business activities, which includes a trademark; 2) economic globalisation and the development of the international market for goods and services, which determines the need for the unification of national rules and international standards for the legal protection of trademarks; 3) European integration processes in Ukraine.

This work aims to conduct a comparative legal analysis of the terminological definition of a trademark in Ukraine and the EU as a prerequisite for the effectiveness of intellectual property rights protection through the lens of Ukrainian legislation harmonisation with European legal standards.

To effectively achieve the outlined objectives, we believe it is necessary to define the following tasks of current scientific research:

- to investigate the specific of Ukraine's legal regulation governing the protection of trademark rights for goods and services;

- generalise the norms of legal acts of the European Union relating to trademark legal protection;
- determine the shortcomings of national legal trademark protection, including the discrepancies between the national mechanism and European standards in this area;
- to formulate legislative proposals for improving legal standards in the trademark legal protection mechanism in Ukraine.

Methods

In order to conduct current scientific research, the following general scientific and special legal methods were used:

- the dialectical method was used to reflect the connections and distinctions between national and European mechanisms of trademark protection for goods and services and their development;
- the analytical method used to "dismember" the entire mechanism of national and European legal trademark protection into separate elements and provide them with characteristics;
- the formal-dogmatic method was used to examine the content of specific legal norms governing trademark protection in Ukraine and the EU;
- the comparative legal method was used to identify similarities and differences among the legal protection mechanisms for goods and services in Ukraine and Europe;
- the prognostic method, which was used to predict strategies to improve national trademark protection mechanisms in Ukraine while taking European standards into account.

Results and discussion

At the national level, the mechanism for protecting trademark rights for goods and services is multi-layered, as it is represented by codified acts of general purpose (civil, economic, administrative, criminal), as well as by special legislative acts aimed at regulating the legal protection of trademarks in various areas of economic activity (advertising, media, etc.) or regulating the general conditions for the protection of trademark rights. Furthermore, the legal regulation of trademark protection is ensured at the sublegal level, specifically through instruments such as the Regulations governing the National Register of Certificates of Ukraine for Marks on Goods and Services, approved by the Ministry of Education and Science of Ukraine via

Order No. 10 dated 10 January 2002 (Ministry of Education and Science of Ukraine, 2002), and the Rules pertaining to the preparation, submission, and evaluation of applications for the issuance of Ukrainian certificates for marks on goods and services, ratified by the National Patent Office of Ukraine under Order No. 116 dated 28 July 1995 (National Intellectual Property Service of Ukraine, 1995), among others.

Thus, the Civil Code of Ukraine contains general legal provisions on trademarks. The criminal liability for the illegal use of a mark for goods and services, a brand name, a qualified indication of the origin of goods, or other wilful violation of the right to these objects is established in the Civil Code of Ukraine, Article 229 (Verkhovna Rada of Ukraine, 2003a). Simultaneously, the Administrative Offences Code of Ukraine contains a more generalised formulation of the grounds for administrative liability: illegal use of an object of intellectual property rights or other intentional violation of rights to an object of intellectual property rights protected by law (Verkhovna Rada of Ukraine, 1984). In our opinion, a more differentiated approach to establishing the scope of administrative responsibility for breaking rights to intellectual property objects and imposing administrative penalties for rights to a trademark or company name violation in a separate norm is worth considering. The Law of Ukraine "On the Protection of Trademark Rights for Goods and Services" is a special legislative act in this area that regulates relations arising in connection with the acquisition and exercise of trademark rights in Ukraine, establishes countries' authorities' powers in this area, the conditions for granting legal protection to trademarks in Ukraine, the procedure for issuing a certificate for them, etc. (Verkhovna Rada of Ukraine, 1993).

The legislative definition of the concept of trademark, which is currently contained in several domestic regulatory legal acts, is conceptually important for the formulation of national policy regarding trademark rights protection. Thus, a trademark is a designation by which the goods and services of other persons are identified, according to the fourth paragraph of the first part of Article 1 of the Law of Ukraine, "On the Protection of Rights to Signs for Goods and Services" (hereinafter – the Law of Ukraine No 3689-XII) (Verkhovna Rada of Ukraine, 1993). Part two of Article 5 of this Law states that a trademark can be any designation or combination of designations. Such designations can be, in particular, words, including proper names, letters, numbers, pictorial elements, colours, shape of goods or their packaging, sounds, provided that such designations are suitable for distinguishing the goods or services of one person from the goods or services of other persons, and suitable for displaying them in the Register in such a way that the clear and precise scope of the legal protection provided can be determined

(Verkhovna Rada of Ukraine, 2001). According to Article 492 of the Civil Code of Ukraine, a trademark can be any designation or combination of designations suitable for distinguishing goods (services) produced (provided) by one person from goods (services) produced (provided) by other persons. Words, letters, numbers, graphic elements, and colour combinations are examples of such designations (Verkhovna Rada of Ukraine, 2003a). It can be concluded that the definitions of trademark in these legislative acts are similar, do not differ, and do not create any conflicts. However, this does not imply that the relevant legal definition is perfect and does not need to be improved.

First, the disadvantage of the domestic legal definition of the term "trademark" is conceptual uncertainty, specifically the use of different terms to denote the same concept. If the inconsistency with the Civil Code was eliminated in Law No. 3689-XII on 21 July 2020 by replacing the term "mark for goods and services" with the wider and newer concept of "trademark" (although the title of the Law itself still contains "legislative archaism"), then a large number of special legislative acts are still in terminological conflict with the Central Committee of Ukraine. For instance, Clause 27 of the first part of Article 1 of the Law of Ukraine "On Media" defines "logo" as any combination of symbols (words, letters, numbers, graphic elements, sounds, etc.) that allows one TV channel to be distinguished from another (Verkhovna Rada of Ukraine, 2022). Simultaneously, Article 2 of the Law of Ukraine "On the Regime of Foreign Investment" includes intellectual property rights to trademarks for goods and services to foreign investments, and the term "trademark" is already used in Article 21 of this Law (Verkhovna Rada of Ukraine, 1996b). The term "logo of linear audio-visual media" is used in Article 9 of the Law on Advertising of Ukraine, while the concept "trademark" is used in Article 5 of this Law (Verkhovna Rada of Ukraine, 1996a). As can be seen, the national mechanism employs various terminological designations for the object of legal protection, which is contrary to the fundamental rules of legislative technique.

Since EU Regulation No. 2017/1001 of 14 June 2017, on European Union trademarks uses the term "trade mark", which in translation from English means trademark, as well as the Civil Code of Ukraine, we believe it is necessary to bring the legislation into compliance with the specified EU Regulation by replacing all terms with a trademark (European Union, 2017).

Second, the drawback of the national legislative definition of a trademark is its incorrectly formulated functional purpose. Thus, according to Article 492 of the Civil Code (Verkhovna Rada of Ukraine, 1984) and Article 1 of the Law of Ukraine No. 3689-XII (Verkhovna Rada of Ukraine, 2001), this means of individualization enables consumers and other business entities to distinguish the goods and services of one person from the goods and services of other people. At the same time, the functional value of trademarks is manifested in distinguishing not just any, but rather identical or similar goods and services, which is not mentioned in any national regulatory act. It is worthwhile to pay attention to the intriguing doctrinal approaches of foreign scientists in the context of the study of the functional purpose of a trademark. In particular, T. Phan Ngoc (2011) highlights the unconventional function of a trademark within the context of the study of the protection of a well-known TM, which consists in the fact that the consumer, through the purchase or consumption of goods or services of a certain TM, demonstrates his or her lifestyle in a social context.

Third, the domestic legislative definition of the term "trademark" does not indicate the mandatory possibility of graphic reproduction of a designation that claims to receive the status of a trademark, which will be able to cover all possible designations as much as possible. At the moment, the Law of Ukraine “On the Protection of Rights to Marks for Goods and Services” employs only an approximation of trademark forms: words, including proper names, letters, numbers, pictorial elements, colours, the shape of goods or their packaging, sounds etc. The first EU Directive No. 89/104 on the harmonization of national trademark legislation, which until recently was in force since 1989, stated that a trademark can be represented by any sign which is made graphically and is perceived visually (Council of the European Communities, 1988). Such a requirement is quite logical, as it allows for proper identification of the trademark in the future and ensures effective protection of its rights. There are only a few exceptions to this general rule. Some sound trademarks, for example, which are unusual not only for Ukraine but also for EU countries, cannot be displayed graphically in the form of notes (this applies to animal sounds, natural phenomena, car engines, etc.). For example, in February 1994, Harley-Davidson applied to register the unique sound of its engine’s “exhaust” – “chug” – as a trademark for their goods and services. At the same time, the following characteristics were provided briefly: “The marking includes the sound of the applicant’s motorcycle exhaust, produced during operation by a two-cylinder internal combustion engine and a conventional crankshaft”. The company’s nine competitors immediately filed objections to the registration for the reason they all used similar technology and their motorcycles sounded the same. Harley-Davidson withdrew its application after six years of litigation (Mkrtchyan, 2018). As we can see, the inability to represent a trademark in literally graphic form has become an impediment to providing legal protection for it. This conflict could be avoided if there was a provision in the legislation that allows the registration of a sound trademark based on the submission of a unique electronic sound recording and the provision of an expert opinion on the impossibility of displaying this sound in sheet music. The government should be interested in the growth of legal business and, as a result, in the active use of trademarks by business entities, including in non-traditional forms. Consequently, it is preferable to establish the presumption of graphic representation of a trademark in Ukrainian legislation, with an exhaustive list of exceptions, namely those non-traditional trademarks that cannot be graphically expressed (sound, flavour, smell trademarks, etc.).

Prior to the beginning of the national-level reform of Ukrainian trademark legislation (until 21 July 2020), there was a need for greater consistency regarding the legal nature of the object of legal protection – the trademark. If the concept of exclusive rights to a trademark was present in the Central Committee of Ukraine from the beginning, then the Law of Ukraine "On the Protection of Rights to Marks for Goods and Services" as amended until 21 July 2020 operated with the concept of ownership of a sign for goods and services, including the owner's right to use the sign independently and the right to prohibit its use by third parties (Verkhovna Rada of Ukraine, 2019). Thus, at that time, the special law was determined by the proprietary concept of trademark rights, whereas the Central Committee of Ukraine followed the concept of exclusive rights. Following comprehensive amendments to Ukraine's Law "On the Protection of Rights to Marks for Goods and Services" on 21 July 2020, this legislative act fundamentally changed the approach to the protection of trademark rights. Thereby, trademarks ceased to be considered real property rights and began to be recognised as exclusive intellectual property rights. At the same time, one special Law provision continues to be in conflict with the chosen concept of exclusive trademark rights. Thus, the agreement on the transfer of ownership of the trademark and the licence agreement are considered valid if they are concluded in writing and signed by the parties (Verkhovna Rada of Ukraine, 2020), according to the ninth part of Article 16 of the Law of Ukraine "On the Protection of Rights to Signs for Goods and Services". The aforementioned inconsistency and conceptual collision of legislative provisions result in a judicial practice fallacy formed by the highest court and tacitly followed by all other judicial bodies. In particular, the concept of "transfer of ownership of marks for goods and services" was used in the Supreme Court Resolution of 22 September 2022, in case No. 910/2559/21 (Supreme Court of Ukraine, 2022). To finally incorporate the concept of exclusive rights to a trademark into the legal system of Ukraine, we believe it is essential to amend the ninth part of Article 16 of Ukrainian Law No. 3689-XII and replace the concept of "agreement on transfer of ownership of a trademark" with the concept of "agreement on transfer of intellectual property rights to a trademark".

Currently, Article 16 of the Law of Ukraine No. 3689-XII on the rights resulting from trademark certificates (Verkhovna Rada of Ukraine, 2001) states: 1) the right to use the trademark and other rights defined by this Law; 2) the exclusive right to prevent others from using it without permission, unless otherwise provided by this Law; 3) the right to transfer to any person the exclusive intellectual property rights to the trademark in entire or in part concerning the goods and services specified in the certificate based on the contract; 4) the right to grant permission (issue a licence) to any person to use a trademark under the terms of a licence agreement; 5) the right to include a warning marking next to the trademark in the form of the Latin letter "R" surrounded by a circle, indicating that this trademark is registered in Ukraine (Verkhovna Rada of Ukraine, 1993).

The title of the Article "Rights deriving from the certificate", in our opinion, does not correspond with its content, which is far less broad. We believe that when developing legal support for trademark rights protection, it is critical to distinguish between the concepts of "exclusive intellectual property rights to a trademark" and "rights arising from a trademark certificate", as they are related to each other as a part and a whole. After receiving the certificate, the subject obtains a comprehensive set of trademark property rights. The acquisition of these rights is frequently the primary reason for filing a trademark registration application. At the same time, the person who received the trademark certificate's authority is limited by more than just the mentioned list of exclusive rights. The subject has the following rights as of the date of receipt of this document: 1) the right to petition to extend the validity of a trademark certificate, subject to the payment of a fee as prescribed by law; 2) the right to refuse a trademark certificate in entire or in part; 3) the right to protect infringed trademark rights, etc. In this regard, we believe establishing exclusive trademark rights in a separate Article and supplementing Article 16 with other rights arising from the certificate is required.

The definition of the list of entities that may obtain the corresponding rights is a separate problematic issue in the use and protection of trademark rights in Ukraine. Part one of Article 493 of the Civil Code of Ukraine states that natural and legal persons are the subjects of intellectual property rights to trademarks (Verkhovna Rada of Ukraine, 2003a). The third Paragraph of the first Part of Article 1 of the Law of Ukraine "On the Protection of Rights to Marks for Goods and Services" defines a subject as a natural or legal entity without reference to specific restrictive criteria (Verkhovna Rada of Ukraine, 1993). At the same time, we believe it is reasonable to investigate a trademark's ability to indicate how one person's goods and services differ from the goods and services of others. In turn, according to Article 3 of the

Economic Code of Ukraine, economic activity is the activity of economic entities in the sphere of public production aimed at the production and sale of products, the performance of works or the provision of valuable services with a price determination (Verkhovna Rada of Ukraine, 2003b). In turn, entrepreneurship is defined in Article 42 of the specified codification act as an independent, initiative, systematic, at one's own-risk economic activity carried out by business entities (entrepreneurs) to achieve economic and social results and profit (Verkhovna Rada of Ukraine, 2003b). Etymologically, the word "trading" was derived from the word "trade," which means "buying and selling goods", i.e., trades conducted for profit, according to the academic dictionary of the Ukrainian language. Therefore, a systematic examination of the aforementioned provisions of Ukrainian legislation reveals the need to enshrine the possibility of acquiring trademark rights exclusively by persons (natural or legal entities) engaged in entrepreneurial activity at the level of both Article 493 of the Civil Code and special law. This restriction on potential applicants for obtaining a trademark certificate will aid in solving the problem of fraudulent or fictitious registration and use of a trademark to the detriment of legitimate business entities. A significant number of domestic scientists agree with us. For instance, O. Kashintseva (1999) and O. Melnyk (1999) believe that only a physical person engaged in entrepreneurial activity has the right to trademark ownership. G. Androschuk and A. Pakharenko-Anderson (1997) are at the same position on this issue and refer to the practise of Western European countries, specifically the German Law on Trademarks of 1994 (Paragraph 3.1), which allows for the registration of a trademark solely by an enterprise.

In addition to our proposal to improve domestic legislation to address the issue of unfair trademark registration, we would like to draw your attention to the interesting positions of foreign scientists on this topic. Thus, F. Mostert and H. Wu proposed (2017) several trademark reforms to reduce the number of dishonest registrations in China, a notorious leader in this field:

- recognition of bad faith as a separate ground for trademark refusal, opposition, and cancellation;
- inclusion of a bad faith element [in the relevant national trademark law];
- creation of a blacklist of individuals involved in fraudulent trademark registrations (Mostert and Wu, 2017).

Within the context of the study of the Ukrainian approach to the regulation of trademark rights protection, it is advisable to focus on such a unique legal object as a collective trademark and the issues related to its legal protection. The authority to use the right to a trademark owned by multiple individuals was regulated until 21 July 2020 by Article 158 of the Commercial Code of Ukraine. Thus, the first part of this Article established that a trademark, the right to which belongs to several subjects, is a mark that distinguishes the goods and services of members of the association of enterprises from the homogeneous goods and services of other business entities or is used jointly by several entities objects in other cases provided for by law (Androshchuk and Pakharenko, 1997). Today, the following provisions of the Law of Ukraine "On the Protection of Rights to Marks for Goods and Services" (Verkhovna Rada of Ukraine, 1993) serve as the normative basis for the existence of a collective trademark: 1) any individual, association of individuals, or their legal heirs have the right to receive a certificate in accordance with the procedure established by this Law (Part 5 of Article 5 of this Law); 2) a corresponding mark is made, and a list of persons with the right to use such a trademark is provided in the application for registration of a collective trademark. A document defining the conditions of use is also attached to the application for registration of a collective trademark (Paragraph two of Part five of Article 7 of this Law). We can identify the following shortcomings in the national legal provision for the protection of collective trademark rights: 1) the lack of a legal definition of collective trademarks and their distinction from collective trademarks owned by multiple individuals; 2) the absence of a list of entities that can acquire the right to a collective trademark; and 3) the absence of a separately established procedure for registering collective trademark rights; 4) a lack of regulation of the protection of rights to a collective trademark, particularly in cases of violation of the legitimate interests or rights of one holder of rights by another holder of such rights. It is preferable, in our opinion, to create a separate section of the special Law titled "Particularities of Acquisition, Implementation, and Protection of Rights to a Collective Trademark" provisions that would eliminate the aforementioned shortcomings. In particular, we propose enshrining the legislative definition of a collective trademark as follows: a collective trademark is a trademark belonging to a business association, trade union, or other voluntary association of legal entities intended to denote the goods or services provided by them. The specifics of exercising rights to a specific collective trademark should be prescribed in the founding documents or other local acts of the business association or union – the subject of the collective trademark rights.

Among the requirements for granting legal protection to a trademark in Ukraine, "not to contradict public order and generally recognised moral principles, requirements of laws in accordance with Part 1 of Article 5 of the Law of Ukraine No. 3689-XII" (Verkhovna Rada of Ukraine, 1993) stands out. The specified requirements include abstract categories that can be subjectively assessed by law enforcement. For a long time, the category of public order was the subject of ambiguous legal interpretation by the courts until the Supreme Court adopted a legal position that defined the content of an act that violates public order. Thus, the Cassation Economic Court stated in case No. 910/4932/19 that public order is defined as imperative public-legal relations that determine the foundations of the country's social order. Article 228 of the Civil Code of Ukraine defines a list of transactions void for violating public order. These are acts that encroach on the country’s public, economic, and social foundations, particularly acts aimed at the illegal use of communal, country, or private property; acts aimed at illegal alienation or illegal possession, use, or disposal of objects of the Ukrainian population’s property rights – land as the major national wealth under the special protection of the country, its subsoil, and other natural resources (Article 14 of the Constitution of Ukraine); acts that violate the legal regime of civil law objects withdrawn or restricted in circulation, etc. All other acts aimed at violating other objects of law, as provided for by other norms of public law, are not considered to violate public order (Verkhovna Rada of Ukraine, 2020). We are convinced that both the creation of a trademark and the filing of an application for its registration are classic examples of transactions – human actions that create civil rights and obligations. As a consequence, we believe that the emphasis on the violation of the objects of public order, as defined by Article 228 of the Civil Code, is a reason for denying legal protection to a trademark.

The situation with the regulation and interpretation of this condition of legal protection is much more complicated in the case of trademark immorality. The Supreme Court stated in case No. 480/85/19 that the concept of public morality is evaluative and that in each case, the violation (or non-violation) of public morality must be assessed based on the actual circumstances (Supreme Court of Ukraine, 2020). It is also worth noting that in recent decades, the traditions and cultural values that shape public morality in society have changed. There is also no consensus among academics on how to interpret the immorality of a trademark. For example, L.D. Romanadze claims that the principles of humanity and morality contradict stamps with images of naked human bodies, religious buildings without the permission of denominations, elements that insult or harm the reputation of a living or deceased person, and so on (Supreme Court of Ukraine, 2021). In turn, O.A. Rassomakhina (2008) interprets them as designations that contradict the constitutional system's foundations and can cause dissatisfaction in society due to violations of the rules formed on the basis of moral norms, traditions, and cultural values.

We consider the absence of legislative definitions for the concepts of “trademark that disrupts public order” and “trademark that violates universally recognised moral principles” to be a drawback in the domestic legal framework. Therefore, we propose amending Article 5 of the Law of Ukraine "On Protection of Rights to Marks for Goods and Services" to include sections that define: 1) a trademark that disrupts public order if it is intended to violate individuals' and citizens' constitutional rights and freedoms by causing destruction or damage to the property of a natural or legal person, the country, the Autonomous Republic of Crimea, territorial communities, or its illegal appropriation; 2) a trademark that violates universally recognised moral principles if it contains pornographic images, uses explicit or offensive language, or harms personal non-property rights in its content, or otherwise violates rules based on morality, traditions, and cultural values.

One of the final sections of the Law of Ukraine "On the Protection of Rights to Signs for Goods and Services" is devoted to trademark protection. Thus, in accordance with the first part of Article 20 of this Law, any infringement on the rights of the certificate holder provided for in Article 16 of this Law, including the commission of actions requiring his consent without the consent of the certificate holder, and preparation for the commission of such actions, is considered a violation of the certificate holder's rights, which entails responsibility under the current Ukrainian law (Verkhovna Rada of Ukraine, 1993). As we can see, the domestic legislator does not provide at least an approximate list of offences in the field of trademark use and protection, which, in our opinion, is a disadvantage and creates a situation in which an average subject without a legal education may not understand that their rights have been violated, or, on the contrary, may see an offence where it does not exist, sending groundless statements to the court and regulatory authorities. To begin, at the national level, an approximate list of trademark rights violations should be established: export or import of goods under someone else's trademark, provision of services under a trademark belonging to another entity, removal or change of an applied trademark, application of a trademark for a product for which it was not registered, use of a designation identical to a registered trademark, etc. Article 21 of Ukraine Law No. 3689-XII is titled "Ways to Protect Rights", however, none of its sections include a list of special methods for trademark protection. Special methods for protecting intellectual property rights are covered in Article 432 of the Civil Code of Ukraine, which states that the court may issue a decision in cases and the manner prescribed by law, including: 1) immediate action to prevent infringement of intellectual property rights and preservation of relevant evidence; 2) stopping the passage of goods whose import or export is carried out in violation of intellectual property rights through Ukraine's customs border; 3) removal from the civilian circulation of goods produced or introduced into civilian circulation in violation of intellectual property rights and destruction of such products (Verkhovna Rada of Ukraine, 2003c). We believe it is necessary to include identical special methods of protection in Article 21 of the Law of Ukraine "On Protection of Rights to Marks for Goods and Services".

Domestic science debates revolve around the issue of compensating for the damage caused by trademark infringement. According to Paragraph 5 of Part 2 of Article 432 of the Civil Code of Ukraine, in cases and the manner established by law for the protection of intellectual property rights, including trademarks, the court may issue a decision, including the imposition of a one-time monetary penalty instead of compensation for damages for the unauthorised use of an intellectual property right. The amount of the penalty is calculated following the law, taking the person's fault and other relevant circumstances into account. Simultaneously, the special law on marks for goods and services lacks a normatively determined amount of this compensation, putting the court in a complicated and unalterable situation, turning the relevant provision of civil legislation into a "dead" norm in the sphere of trademark rights protection. The Central Committee's specific method of protecting rights to intellectual property objects has its roots in the Anglo-Saxon legal system, specifically United States legislation, which introduced the concept of statutory damages. Modern foreign scientists are actively researching such a concept of compensation for damage in the context of intellectual property. Thus, according to X. Seuba, the concept of legal costs was introduced initially due to difficulties in proving the victim's losses and the offender's income, particularly when protecting intellectual property rights (Seuba, 2017). As stated by P. Samuelson, F. Hill and Wheatland (2013), "statutory damages" in the United States allow the plaintiff to collect monetary damages without proving that (1) the plaintiff suffered any actual harm as a result of the violation, and (2) the defendant received 389 income as a result of the violation. In the meantime, such damages can be awarded at the discretion of the court in the range of $750 to $35,000 for each illegally used work and up to $150,000 in cases of intentional use.

A separate branch of legal protection for trademarks is the measures taken by the country's government in the form of authorised bodies to recognise a trademark as well-known. Legal protection for well-known trademarks does not require registration and instead arises from a decision of a court or a competent authority (Part 4 of Article 25 of the Law on Trademarks). Part 2 of Article 25 of the Law on Goods and Services Marks contains a list of factors that, if relevant, may be considered in determining whether a trademark is well-known in Ukraine (Verkhovna Rada of Ukraine, 1993):

- degree of trademark knowledge or recognition in the relevant societal sector;
- the duration, scope, and geographical area of any trademark promotion, including advertising, publication, and presentation of the goods and/or services to which the trademark is applied at fairs or exhibitions;
- the duration and geographical scope of any trademark registrations and/or applications provided the trademark is used or recognised;
- proof of successful trademark rights protection, particularly in the territory where the trademark is recognised as well-known by competent authorities;
- the value attached to the trademark.

The issue of taking trademark information criteria into account when the competent body decides on the issue of providing legal protection and protection has not been left out of the attention of foreign legal scholars. For example, such researcher as F. Mostert (2020) was opposed to the idea of a strict "mathematical" approach to calculating brand awareness degree. The researcher suggests that since "terms such as 'substantial relevant circle of society' cannot be defined with mathematical precision, it should be evaluated according to the basic provisions of trademark law: providing such privileged protection, whether consumers are protected from possible confusion and whether the owners of a particular mark are protected from possible harm?".

In addition, M. Hawkins and T. Dolde (2019) studied the issues of legal protection of a well-known trademark in the European Union. Scientists emphasise that EU legislation distinguishes between well-known trademarks and "reputable" trademarks. The registration of a well-known trademark in the European Union is required for enhanced protection. Well-known marks have legal protection only for identical or similar goods, according to Article 6 bis of the Paris Convention. Trademarks with a reputation registered in European Union countries have enhanced protection against unfair advantage or damage to their distinctive character or reputation, which applies to a wide range of goods and services.

We now propose to examine the legal provisions for trademark protection in the EU, the majority of which will be mandatory for Ukraine upon its accession to the EU. The mechanism for legal enforcement of trademark rights in any EU member country has a multi-level structure that includes international, regional, and national levels. Our further attention will be on the first two components, which will allow us to compare the specifics of the legal provision in Ukraine and also take into account the experience of EU countries in the course of bringing legislation of Ukraine closer to European legal standards.

The Paris Convention for the Protection of Industrial Property (hereinafter referred to as the Paris Convention) is the primary international legal document governing the protection of trademark rights in the European Union (EU). Articles 6 and 7 of the Paris Convention define the conditions for the registration of goods and services marks, the issue of independence in the protection of the same mark in different countries, as well as well-known trademarks, prohibitions on the country's emblems, official control marks, and intergovernmental organisation emblems, and the transfer of trademarks and collective marks (Paris Convention for the Protection of Industrial Property, 1883). The Union for the Protection of Industrial Property was established based on the Paris Convention, and its members include all countries to which this international treaty applies. The primary significance of this Union is that its members focus efforts on developing identical or closely aligned national regulations governing industrial property relations in terms of content. In addition, they ensure that citizens of any country within the Union are granted the same privileges, protection, and legal means for safeguarding their rights and legitimate interests in industrial property objects, provided that these citizens belong to the same country. It should be noted that the terms "trademark" and "service mark" are used in the text of the Paris Convention. The countries-members of the Union agree to protect service marks in accordance with Article 6 of the Paris Convention; however, they are not required to provide for the registration of these signs (Samuelson et al., 2013).

Overall, the provisions of the Paris Convention relating to trademark protection can be divided into three major categories: national regime norms, priority rights, general rules of use, and trademark protection. On 27 October 1994, a Treaty on Laws Regarding Trademarks was signed on behalf of Ukraine in Geneva, Switzerland, based on Article 19 of the Paris Convention for the Protection of Industrial Property. This treaty states that it applies to marks consisting of visual representations of goods (trademarks) or services (service marks), or both goods and services. This agreement does not apply to holographic signs and signs that do not consist of visual signs, such as sound and smell signs, as well as collective, certification, and guarantee signs. The agreement also specifies the requirements for the trademark registration application, which involves the list of information and elements that must be included (Mostert, 2020).

The Agreement on Trade Aspects of Intellectual Property Rights (hereinafter referred to as the TRIPS Agreement) is a separate international document that regulates the protection of trademark rights, specifically Chapter 2. According to Article 15 of this Agreement, a trademark is any sign or combination of signs that allows one enterprise's goods or services to be distinguished from the goods or services of another enterprise (Agreement on Trade-Related Aspects of Intellectual Property Rights, 1994a). Words containing personal names, letters, numerals, figurative elements, colour combinations, and any combination of such components can be registered as trademarks. As can be seen, the TRIPS Agreement only provides a preliminary list of forms for expressing trademarks (Romanadze, 2008). Thus, the primary requirement for recognising a particular sign as a trademark under this Agreement is its distinctiveness, not its external form. If signs do not naturally distinguish the respective goods and services, members may implement registration based on acquired distinctiveness through use. Members may require that signs be visually perceptible as a condition of registration (Agreement on Trade-Related Aspects of Intellectual Property Rights, 1994b). The TRIPS Agreement encourages WTO members to include a presumption of trademark visual perceptibility in their national legislation, as we previously suggested to Ukrainian legislators.

In regards to the main terms calculated during the use and protection of industrial property objects, it is recommended to compare domestic legislation and the TRIPS Agreement. According to Article 18 of the TRIPS Agreement, initial registration and each subsequent renewal of trademark registration are valid for at least seven years. Trademark registration may be renewed indefinitely (Mostert, 2020). The validity period of a certificate is ten years from the date of application, according to the third part of Article 5 of the Law of Ukraine on the Protection of Rights to Trademarks for Goods and Services (Verkhovna Rada of Ukraine, 2003a). Therefore, national legislation is consistent with the provisions of the TRIPS Agreement in this regard. The failure to meet the requirement of using such a trademark for a continuous period of at least three years, unless the trademark owner demonstrates valid reasons for hindrances to such use, is one of the grounds for cancelling the trademark registration (Mostert, 2020). According to the fourth part of Article 18 of the Law of Ukraine on the Protection of Rights to Trademarks for Goods and Services, any person has the right to apply to the court for an early termination of the validity of the certificate in entirely or in part if the trademark is not used in Ukraine continuously for five years in its entirety or for part of the goods and services specified in the certificate (Verkhovna Rada of Ukraine, 2003a). As we can see, there are no conflicts between national and international law in this aspect.

Domestic legislators were also drawn to international legal norms in the sphere of industrial property (primarily the Paris Convention for the Protection of Industrial Property, the TRIPS Agreement, and the Treaty on Laws Concerning Trademarks). On May 22, 2003, Ukraine adopted the Law of Ukraine "On Amendments to Some Legislative Acts of Ukraine Regarding the Legal Protection of Intellectual Property", which aimed to align national legislation with the TRIPS Agreement (Hawkins and Dolde, 2019). It should be taken into account that Part 3 of the TRIPS Agreement is devoted to the concept of preliminary measures, their objectives, and the procedures for their implementation, namely:

- judicial authorities should have the right to take measures to prevent violation of intellectual property rights, and especially to prevent an introduction into commercial channels under their jurisdiction of goods, that were imported immediately after passing through customs, and to be able to preserve relevant evidence of the incriminated violation;
- when precautionary measures are taken *inaudita altera parte*, the parties whose interests are affected must be notified as soon as possible, preferably immediately and at the latest – after the measures are taken;
- authorities imposing precautionary measures may require the applicant to provide information needed to identify the goods;
- preventive measures must be cancelled at the request of the defendant if the trial has not begun within a reasonable period determined by the judicial authority, according to the law, or, in the absence of such a determination, does not exceed the longer of two periods: 20 working days or 31 calendar days (Derevyanko et al., 2023).

However, there were "blank spots" in national legislation regarding specific measures to prevent intellectual property infringements until 22 May 2003. Following the adoption of the Law of Ukraine "On Amendments to Some Legislative Acts of Ukraine Regarding the Legal Protection of Intellectual Property", regulations about intellectual property rights prevention were introduced. These regulations cover the grounds for taking preventive measures, their types, the submission, consideration, and consequences of reviewing preventive measure applications, the execution, contestation, and annulment of court decisions regarding preventive measure implementation, and compensation for damages caused by their implementation. Furthermore, the provisions of Ukraine Law No. 3689-XII (Verkhovna Rada of Ukraine, 2003b) were revised as a result of this legislative act.

The Madrid Agreement Concerning the International Registration of Marks (hereinafter referred to as the Madrid Agreement), to which Ukraine is a party, has made a significant contribution to the development of the international system for trademark protection. This international document, in particular, made it possible to provide a single trademark for national and international registration and, as a result, imposed an obligation on the Madrid Agreement participants to recognise such trademark registration by each other. This has made the registration actions, as well as the creation and use of trademarks, more economically advantageous.

The Madrid Agreement also granted the owner of a trademark registered in the national patent office the right to obtain international registration in several countries participating in the Agreement and to apply for the territorial extension of the legal protection of this trademark to other countries participating in the Agreement, subject to payment of international duty.

The regional level of legal protection for trademarks in the EU is represented by basic acts of EU legislation such as:

- Directive (EU) 2015/2436 of the European Parliament and of the Council on the harmonisation of Member States' trademark laws (hereinafter referred to as Directive (EU) 2015/2436), which entered into force on 13 January 2016, and replaced the First Directive (Directive (EU) 2015/2436, 2015);
- Regulation (EC) No 40/94 of the Council of the European Communities on the Community trademark, as slightly amended and modified by Regulation (EU) 2015/2424, is in force as of 23 March 2016 (Council Regulation (EC) No 40/94, 1993);
- Regulation (EU) 2017/1001 of the European Parliament and the Council of 14 June 2017 on the European Union trademark (codification) (Regulation (EU) 2017/1001, 2017).

Directive (EU) 2015/2436 introduced several changes. Firstly, it allowed the registration of non-traditional trademarks. A trademark, according to Article 1 of this Directive, may consist of any signs, including sounds, provided that they are capable of: (a) distinguish one enterprise's goods or services from those provided by another; (b) be represented in the register in a way that allows competent authorities and the public to determine the clear and precise object of protection granted to their owner (Directive (EU) 2015/2436, 2015). In the context of a comparative legal study of trademark legal protection in Ukraine and the EU, it is worth noting that, following amendments to EU Commission Regulation No. 1041 (2005) in the matter of the EU trademark, it became possible to register sound trademarks in the countries of the European Union without graphic reproduction, based on an electronic recording of the corresponding sound, which cannot be expressed graphically (Directive of the European Parliament and the Council 2005/29/EC, 2005). According to modern European standards, providing such an electronic file should be interpreted as "compliance with the requirement of graphic representation in the form of an attached audio file with recorded sound, which is published in the electronic database of trademarks". As previously stated, we believe it is reasonable to include this amendment in Ukrainian legislation. Secondly, the protection of trademark rights was strengthened by preventing comparative advertising that does not comply with the requirements of this Directive. Thirdly, it was established that the non-use of a trademark by the defendant for five years will be taken into account in cases of trademark infringement. Fourthly, the reasons for refusing trademark registration were clarified, the specifics of collective trademarks were established, and the features of licencing agreements were outlined.

As previously stated, there is currently a lack of national legal support for the use and protection of collective mark. We believe it is necessary to focus on the regulation of collective trademark features in EU legislation and compare it to the domestic legal mechanism. The legal protection of collective trademarks in the EU is more developed than in Ukraine. A separate section of Directive (EU) 2015/2436 titled "Guarantee or Certification Marks and Collective Marks" establishes (Directive (EU) 2015/2436, 2015): the definition of a collective mark as a trademark used to distinguish goods or services of members of an association that owns the mark from goods or services of other enterprises and is capable of distinguishing them; the obligation of member countries to register collective marks (Article 29); applications for collective marks may be submitted by associations of producers, suppliers of services, or traders, as well as legal entities governed by public law (Article 29); the applicant for a collective mark must submit rules governing its use to the office, which must specify at least the authorised persons for using the mark, conditions for membership in the association, and conditions for using the mark, including sanctions (Article 30); additional grounds for rejecting a collective mark registration application (e.g., lack of rules governing its use or rules contradict public policy or acceptable moral principles) (Article 31); the owner of the collective mark submits to the office any rules governing its use, with changes and additions, etc.

The Ukrainian legislator should use the provisions of Section 6 of Directive (EU) 2015/2436 regarding the legal protection and use of collective trademarks as a starting point for improving the national legal mechanism in this section by supplementing the special law with provisions devoted to the use and protection of collective trademarks.

In regards to entities that can acquire the right to a trademark, we do not see a significant conflict between Ukrainian legislation and EU law norms. Thus, according to Article 5 of the Regulation, any physical or legal entity, including agencies created under public law, can be the owner of an EU trademark (Rassomakhina, 2008).

The right to prohibit preparatory acts in connection with the use of packaging or other means was given by Article 11 of the Directive and Article 10 of the Regulation: when there is a risk that any means bearing a trademark may be used in connection with goods or services, and such use would infringe the rights of the trademark owner, the owner of such trademark has the right to prohibit such actions if they are carried out in the course of trade: (a) affixing a mark identical or similar to the trademark on packaging, labels, tags, security or authentication devices, or any other means on which the mark can be applied; (b) offering, distributing, storing for such purposes, importing or exporting packaging, labels, tags, security or authentication devices, or any other means bearing the mark.

We believe that amendments to the Law of Ukraine "On the Protection of Rights to Marks for Goods and Services", which establishes the rights arising from the trademark certificate and the right to prohibit preparatory actions related to the usage of packaging or other means, are required.

Finally, we must emphasise that the EU legislation that governs the use and protection of trademark rights at the regional level consists not only of special Directives, Regulations, and Recommendations containing trademark-specific norms but also of acts that indirectly govern trademark issues. These could be, for example, the following acts:

- Directive 2006/114/EU of the European Parliament and of the Council of the European Union on misleading and comparative advertising, adopted on 12 December 2006, defines the rules for the coexistence of comparative advertising and the owner's exclusive right to prohibit all third parties from using in commerce any symbol that is identical or similar to the trademark (Directive of the European Parliament and of the Council 2006/114/EC, 2006);
- Directive No. 2005/29 / EU of the European Parliament and the Council of the EU on unfair commercial practices affecting consumers in the domestic market, which was adopted on 11 May 2005, defines unfair commercial practises as commercial activities that are misleading, in particular advertising of goods similar to the product of another manufacturer, in such a way that the consumer may get the impression that the advertised product is manufacturer by this specific manufacturer, etc. (Directive of the European Parliament and the Council 2005/29/EC, 2005).

Conclusions

Summarising the analysis of legal protection of trademark rights in Ukraine through the lens of European standards in this area, we can identify the following major shortcomings:

- lack of terminological precision in concepts such as “trademark”, “mark for goods and services”, “logo” etc., indicating the ambiguity of both the object of legal protection and its distinguishing characteristics;
- poorly defined functional purpose of trademarks;
- absence of a legislative presumption of trademark graphic representation, with an exhaustive list of exceptions (non-traditional forms of trademarks);
- absence of a separate provision of exclusive intellectual property rights to a trademark and a limited scope of rights derived from a trademark certificate;
- persistence of legal constructs based on the proprietary concept rather than the chosen concept of exclusive trademark rights (e.g., trademark ownership transfer agreement structure);
- absence of a requirement for the holder of trademark rights to participate in commercial, likely entrepreneurial activities;
- lack of regulation governing for the use/protection of collective trademark rights;
- absence of a legally defined (criteria-based) concept of trademarks that violate public order and trademarks that violate universally accepted moral principles;
- absence of legislatively defined indicative lists of main elements of trademark infringements in the domain of trademark protection and utilisation.

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Threats and dangers to economic security of Ukraine in the terms of war

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Abstract

The article is devoted to the issue of identification and systematization of risks and threats to the economic security of Ukraine in the terms of war, considering their hierarchical nature, according to which the economic security of the state is the foundation. Based on the indicator method, threats with the maximum level of influence on economic and social security have been identified, and their dynamics over recent years have been analyzed. Risks and threats to the economic security of Ukraine are systematized by spheres and the level of influence on target security parameters. The influence of war criminals on environmental safety has been investigated and the existence of interdependence of environmental threats with indicators of economic safety has been proven. The need to include indicators of environmental threats in the system of indicators of the economic security of the state is substantiated, considering the complexity of their action. The study aims to identify the principal threats and risks to Ukraine's socio-economic security under martial law, assess their implications for macroeconomic indicators and social dynamics, and propose strategies to mitigate these challenges. It explores the concepts of risks and threats as fundamental elements of economic security, emphasizing their interrelation, where risks represent the likelihood of adverse outcomes and threats signify potential harm to the economic system caused by internal or external factors.

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Introduction

The scale and impact of the war radically changed the paradigm of socioeconomic development and the priority of measures to ensure national security. Ukraine is undergoing numerous trials due to the huge losses that the state, business and population are suffering. It necessitates the introduction of a proactive, safety-oriented approach at all levels of the social hierarchy.

The prerequisite for the beginning of the armed aggression against Ukraine was the economic bleeding of Ukraine, carried out through direct economic pressure, such as trade and tariff confrontation, blockade of Ukrainian trade, blockade of gas supplies, etc. The economic war against Ukraine was directed primarily against the economies of the east and south of Ukraine, which, due to certain features, depended on the russian federation, in particular as recipients of raw materials and energy resources from russia and as a market for a significant share of their own products (Solingen, 2017; Baranovsky, 2014; Varnaliy, 2020).

The current economic situation in Ukraine convincingly shows that countering threats to the socioeconomic security of the state, business, and individual is an important prerequisite for maintaining normal living conditions and protecting the population during the war, so the problem of identifying and assessing risks and threats to the economic security of the state becomes relevant and exceptional. And the consideration of this category through the prism of social security, with the allocation of social security as a superstructure, acquires special weight for the prevention of social and humanitarian disasters (Maltsev & Shevchenko, 2021). Considering the magnitude of the impact of environmental threats as a result of the continental war on the territory of Ukraine, the combination of global and national challenges and threats, the priority of ensuring environmental security at the international level (Onyshchenko et al., 2022b).

The war unleashed by the Russian Federation against Ukraine has fundamentally changed not only the political but also the socio-economic landscape of the country. The deep economic turmoil, destruction of infrastructure, loss of human capital, blocking of international trade and large-scale emigration processes have put Ukraine in front of new challenges that require prompt response. The current stage of the country's development is characterized by an unprecedented level of uncertainty, which necessitates the development of new approaches to ensuring economic security as a key factor in the stable functioning of the state.

The peculiarity of modern threats to Ukraine's economic security is their multidimensional nature. They cover not only the financial and production spheres, but also have a direct impact on the environmental, social and humanitarian components. For example, the environmental consequences of hostilities, including soil and water pollution and large-scale fires caused by shelling, have a significant impact on the agricultural sector, export potential, and public health. In this context, economic security becomes the basis of national security, and its provision is of strategic importance.

The prerequisites for aggression against Ukraine were laid down even before the outbreak of hostilities, when the country faced economic pressure aimed at bleeding it dry. Trade restrictions, export blockades, and manipulation of energy resources were the first stage of preparation for military action. The eastern and southern regions of the country, which were economically dependent on the Russian market, were the most vulnerable. In view of this, the current issues of economic security require a rethinking of the concepts of socio-economic sustainability through the prism of integration of environmental and humanitarian factors (Heiets, 1999).

Thus, there is an important issue of identifying, assessing and systematizing risks and threats to the economic security of the state in times of war. It is necessary to identify the most critical threats, their impact on socio-economic stability, and to develop practical recommendations for minimizing them. It is particularly important to take into account the environmental component, which has so far been neglected within the system of economic security indicators.

The aim of the study is to identify the key threats to Ukraine's economic security in the context of war, analyze their impact and develop recommendations to minimize the negative consequences. The purpose of this article is to identify the key threats and risks to Ukraine's socio-economic security under martial law, to analyze their impact on macroeconomic indicators and social processes, and to outline ways to neutralize these threats and minimize the consequences. The article examines the phenomena of threats and risks as key categories of economic security, in particular their interdependence, in which risks are considered as the primary phenomena that form threats. The author defines risks as the probability of adverse consequences and uncertainty of future events, and threats as the potential for damage to the economic system under the influence of internal and external factors.

The article considers the legislative aspects of economic security, in particular, the Economic Security Strategy of Ukraine until 2025, which defines the main directions of sustainable development of the national economy, integration into the European economic area and expansion of mutually beneficial economic cooperation with other states. Particular attention is paid to the consequences of the large-scale aggression of the Russian Federation against Ukraine, which led to significant losses in GDP, destruction of infrastructure, rising inflationary pressures and mass migration.

It is noted that in 2022, Ukraine’s economy suffered significant losses, including a decline in GDP, infrastructure destruction worth more than $100 billion, rising unemployment due to migration, and a decrease in investment activity. The author analyzes in depth the impact of the war on business operations, in particular on the activities of small and medium-sized enterprises, which have largely ceased to operate. Attention is paid to the problems of assessing losses due to the lack of complete data, as well as the methodology for calculating losses for different categories of objects.

A special focus was made on the demographic challenges caused by the hostilities, including a shrinking labor force due to youth migration and limited employment opportunities. The results of opinion polls indicate potential risks associated with uncertainty about the return of some citizens to their homeland, which could slow down the economic recovery after the war.

Literature Review

The priority of studying the problems of socioeconomic security is due to the growing number of global challenges and threats of a hybrid nature, which has been confirmed by active scientific research. The works of Ukrainian and foreign scientists are devoted to the formation of the conceptual foundations of economic security. threat nature disclosure based on the definition of the "economic security" concept content, the mutual influence and interdependence of economic security negative factors; threat assessment and modeling (Onyshchenko et al., 2022a; Theo, 2022; Onyshchenko et al., 2021).

However, in the conditions of a large-scale war on the territory of Ukraine, the priority of the threat influence has changed significantly, the complexity and consequences of environmental threats actualize the problem of ensuring environmental security as a prerequisite and superstructure for socioeconomic security at the macro level (National Risk Assessment, 2019). The study of war crimes against the environment is carried out in the works of scientists, however, the problem of the ecothreat impact caused by military operations on the indicators of the state socioeconomic security requires more careful study (Reznikova et al, 2020; Vyhor, 2022)

The issue of identification, systematization and assessment of threats in the system of ensuring the economic security of the state has attracted the attention of many scholars who have made a significant contribution to the development of this topic. Dunaev and Orlov (2023), in his research, made a significant contribution to the development of conceptual approaches to systematizing threats to economic security. Kovalenko et al. (2024) focuse on identifying the main mechanisms of influence of global threats on the national economy and proposes methods for their assessment and management. They examine strategies and tactics that can be used by states to minimize the impact of these threats, taking into account the specifics of individual countries' economic systems. The research covers issues of adaptation of economies to globalization and technological changes that may create new risks to economic security.

Yelizarov and Radchenko (2019) have also significantly expanded the concept of economic security, in particular, by emphasizing the importance of analyzing external and internal threats to the economic stability of the state. Skoruk (2016) added new aspects to the analysis of threats, in particular, by considering the issue of their adaptation to the conditions of modern global changes. He explores not only traditional threats but also new challenges related to technological innovations and changes in international economic structures. His approach allows for a clearer understanding of how economic processes can be exposed to risks due to global transformations.

Robertson (1992) and Waters (1995) laid the theoretical foundations for the study of globalization as a complex integrated process. In his works, Robertson (1992) draws attention to the impact of globalization on the economic security of states, noting that the deepening of international relations creates both new opportunities and new threats to national economies. He also points to the importance of integration processes for the development of national economic systems. Waters (1995), in turn, sees globalization as a key factor accelerating changes in economic structures and affecting opportunities for economic security. He analyzes global trends and their impact on states, focusing on the economic and social consequences that may arise from this process.

Onishchenko (2016) has also made a significant contribution to the study of threats to economic security associated with globalization. He draws attention to the emergence of new risks to the economic stability of states as a result of the development of global economic processes, such as financial globalization and technological change. Rokocha explores other aspects of globalization processes, in particular those related to interstate economic relations and their impact on national security.

Despite the numerous accomplishments in the study of threats to economic security, the research on this topic requires further development, especially in view of the new challenges arising in the context of Russia's military aggression against Ukraine. Considering the changes in the global economic situation, in particular due to geopolitical tensions and military conflicts, it is necessary to continue to improve theoretical and practical approaches to the analysis and management of threats to the economic security of states.

Materials and Method

The research is based on the application of comparative analysis method for the threat identification to the social and economic security of Ukraine, the analysis of time series and the graphical method for the study of trends in negative security factors, the generalization method for the systematization of identified risks and threats, as well as the modeling method for assessing the influence of environmental threats on indicators of the state socioeconomic security.

The method of comparative analysis allows identifying potential threats to economic security by analyzing time series. Data for the period from 2014 to 2023, which covers both the beginning of military aggression and its escalation, were taken for comparison. The sources of statistical data were reports of the State Statistics Service of Ukraine, analytical reviews of international organizations such as the OSCE and the World Bank, as well as materials of civil society organizations. This allowed to obtain a wide range of information necessary for accurate analysis.

The graphical method was used to visualize trends in the impact of key threats. It depicted the dynamics of such indicators as changes in GDP, export dynamics, unemployment rates, and other socioeconomic factors. This method made it possible to visually present changes in key indicators that affect the country's economic security. The method of generalization ensured the systematization of identified risks and threats by spheres of influence. This made it possible to identify certain categories of threats, including financial, environmental, and social. This systematization helped identify the main areas for developing countermeasures.

The modeling method was used to assess the impact of environmental threats on the economic security of the state. The impact of soil contamination on the agricultural sector was modeled, for example, based on data on the dynamics of yields in the most affected regions. This made it possible to assess the scale of the impact of environmental problems on key sectors of the economy.

The study used a variety of statistical methods to collect, process and analyze data, including the mass observation method, the grouping method and the graphical method. The mass observation method allowed us to collect large amounts of data reflecting the state of the economic and social situation in Ukraine for the selected time period. This method covered a wide range of indicators related to various aspects of economic security, such as economic growth, unemployment, inflation, as well as changes in macroeconomic indicators under the influence of global and domestic factors, including war.

The method of groupings was used to classify data into different categories, which allowed us to identify general trends in the economic development of Ukraine during the study period. With the help of groupings, numerous economic and social indicators were analyzed, their dynamics were determined, as well as the degree of influence of various factors that took place at that time. This allowed for a more in-depth consideration of issues related to the adaptation of the economy to the changes that took place in the context of globalization and military operations.

The graphical method was used to visualize the data obtained, which helped to clearly demonstrate changes in the main indicators and compare them at different stages of the study. The graphs made it easy to trace the trends of changes, as well as to assess the effectiveness of political and economic measures that affected the economic security of Ukraine.

The method of theoretical generalization was also used, which allowed to formulate general conclusions and recommendations on ensuring the economic security of the state on the basis of factual data. This method involved combining and integrating data from various sources to form a holistic picture, as well as identifying potential factors affecting the country's economic stability.

The research period covers the period from 2010 to 2022. This provides an opportunity to identify both long-term trends and reactions to short-term events, such as Russia's military aggression against Ukraine. An important step in the analysis is to compare the two periods of 2021 and 2022, as it was during this time that significant changes occurred due to the outbreak of war. The war undoubtedly had a decisive impact on the economic situation in the country, including inflation, economic growth, unemployment, and other socioeconomic indicators. Analyzing these changes using statistical methods shows how the war led to a significant decline in production, higher energy prices, as well as a sharp increase in the number of IDPs and a decrease in the country's investment attractiveness.

A comparison of 2021 and 2022 shows how macroeconomic indicators were affected by the war. The economy was still showing some signs of recovery from the COVID-19 pandemic in 2021, but in 2022 the economic situation deteriorated significantly due to military aggression. The war resulted in a decline in production, higher unemployment and inflation, and a decline in foreign investment. This analysis clearly shows how external military threats can dramatically change domestic economic processes, which is reflected in the results of the study.

Results

In terms of instability and global challenges, a defensive approach to interpreting the essence of economic security, the initial category of which is "threat", is widely used. Threats to the state economic security are phenomena and processes that negatively affect the economy of the nation, suppressing the economic interests of individuals, societies, and the state. Constant monitoring and identification of significant threats to economic security largely contribute to maintaining them at the proper level, as well as the development and implementation of timely and practical measures to reduce or completely eliminate threat negative consequences. (Onyshchenko et al., 2023a)

Risks in comparison with threats are the primary category, and threats are the secondary one, since threats arise in the presence of a combination of risks. Risks are interpreted as the possibility of adverse or undesirable consequences, the uncertainty of an event occurrence in the future. Therefore, it can be noted that risks are an economic category, the essence of which is in the uncertainty of the actually expected result of an event in the future under the influence of a complex of negative and positive factors. An economic threat is a potential opportunity to harm a business due to internal and external factors (Milka et al., 2023). Economic danger under the threat of real manifestation is a direct, real form of threat.

According to the Law of Ukraine "On the Fundamentals of National Security of Ukraine" dated June 19, 2003, the threat to the state economic security is the existing and potentially possible phenomena and factors that endanger the vital national interests of Ukraine. Decree of the President of Ukraine dated August 11, 2021 No. 347/2021 approved the economic security strategy of Ukraine for the period up to 2025, which determines the ways to achieve the goals and implement the priorities of national interests in the field of ensuring economic security (President of Ukraine, 2021).

The sustainable development of the national economy, the integration of Ukraine into the European economic space, the development of equal and mutually beneficial economic cooperation with other states meet the national interests of Ukraine (Onyshchenko et al., 2023b; Krasnobayev et al., 2023; Onyshchenko et al., 2023c). Ensuring national economic interests requires the formation and implementation of a strategic course in the field of ensuring economic security, aimed both at constantly increasing the competitiveness of the Ukrainian economy and gradually strengthening economic stability and, accordingly, the invulnerability of the national economy to external and internal threats. (Aviv & Ferri, 2023; Barbieri, 2022).

The practical implementation of the State Strategy for Economic Security should be carried out through a system of specific measures, mechanisms implemented on the basis of qualitative indicators and quantitative indicators of the country socioeconomic development (Utenkova, 2019). Such a system is the basis and content of the national economic policy. In this case, economic security can be developed only in the conditions of providing socially necessary conditions for the reproduction of social products, in a system of complex relationships and interdependencies determined by the social structure of society, the depth of social contradictions and objective ways of implementing social security (Onyshchenko et al., 2023d). An adequate level of social security is a part of priority system for countries dealing with various issues of economic development and functioning.

As a result of the large-scale aggression of the russian federation against Ukraine, the level of all risks affecting the financial system stability has increased significantly. Ukraine GDP losses in 2022 are significant. According to various forecasts, GDP decrease in 2022 is going to be from -10% to -30-40% (assuming that the size of the occupied territories does not increase, and the active phase lasts several months), which corresponds to a reduction in electricity consumption by about 35% (according to DTEK estimates). 30% of the national GDP falls for the nine hardest hit regions of Ukraine. Inflationary pressures remain high due to the industrial and transport infrastructure destruction and rising production costs. As a result, budget expenditure volume to support the gradual recovery of business and economy is rapid (Fitch Ratings, 2022).

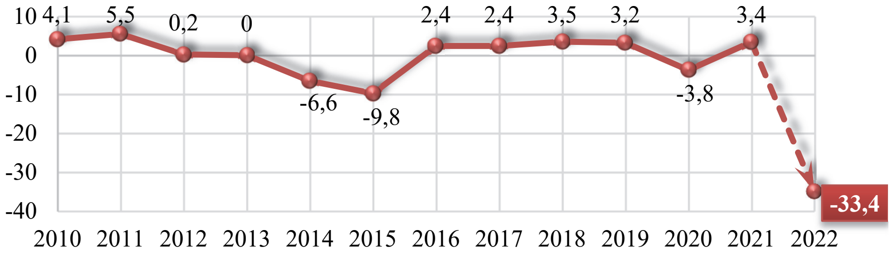

Figure 1 - Change in real GDP of Ukraine in % to the previous year (in 2022 - Fitch Ratings forecast)
Source: built by the authors on the basis of the Fitch Ratings (2022).

According to the budget losses assessmen by Ministry of Finance, Ukraine losses amount to about UAH 2 billion per day. In March, infrastructure losses amounted to $119 billion, or $4.25 billion per day. Given that the total physical damage caused to infrastructure is estimated at $100 billion, which includes damage to transport infrastructure ($39 billion) and destruction of housing stock ($29 billion).

As of May 2, 2022, the total amount of direct damage inflicted on Ukraine due to the war started by Russia reached almost $92 billion – Ukrainians lost almost 90,000 cars in more than two months. Over the last week of April 2022, direct losses to the Ukrainian economy due to the destruction and damage of civilian and military infrastructure increased by almost $4.5 billion. In addition, according to KSE estimates, as at May 2, direct losses of enterprises (assets, depots) have already amounted to about $10 billion dollars because of the war.

At the same time, the total losses of the Ukrainian economy because of the war, considering both direct and indirect losses, for example, GDP decrease, disinvestment and labour outflow, additional spending on defense and social support, etc., range from $564 billion to $600 billion. From February 24 to May 2, 2022, at least 940 secondary and higher education institutions, 231 healthcare institutions, 33.7 million square meters of residential buildings, 543 kindergartens, 11 airports and 6 thermal power plants were damaged, destroyed or confiscated. In addition, tens of thousands of kilometers of roads and railways, 295 bridges and bridge crossings were destroyed or damaged (Kyiv School of Economics, 2022).

The activity of enterprises was stopped in the first weeks of the war, and then resumed very slowly. More than half of the member companies of the European Business Association in Ukraine suspended or discontinued their activities during the war (57%). The situation is similar with small companies. Damage to property during the war is difficult to assess, since in hot spots they are sometimes impossible to trace, and moreover to study. For example, most buildings in Chernyhiv, Sumy and Kharkiv are known to have been damaged, but information on individual enterprises is extremely limited. Some wealth holders are reluctant to report that their assets are damaged (because their shares/bonds are placed overseas, they don't want to intimidate investors) or that they are in good condition (they are afraid of being the next target). Some locations are of strategic importance, and access to information about their status is limited. On the other hand, some owners have inflated their damages in order to demand more compensation.

However, there are valuation methods for large facilities (airports, large industrial plants, ships, aircraft, etc.) that can be valued separately through annual accounts or other available data, companies use all fixed access, unfinished production and warehouses. Medium properties (schools, hospitals, shops, cultural institutions, etc.) are valued at average unit cost (annual invoices, Prozorro tenders, etc.), typical properties (real estate, vehicles, small businesses) and networks (road and rail), electricity and gas, telecommunications) are estimated using indirect methods by combining relevant regional statistics and the share of losses by region or city.

Industrial asset losses as of April 2022 are $6.7 billion. Metallurgy lost at least 30% of its assets. Among the biggest losses are Azovstal and MMK Illicha, the second and third largest metallurgical plants in Ukraine, respectively. These threats to socio-economic security are catalysts of risks to the financial component of economic security (Onyshchenko et al., 2023e). In particular, The deficit of the budget general fund for the first quarter of 2022 is UAH 67.5 billion. (about 2.3 billion dollars). About 30% of the total budget, or UAH 32.5 billion, is made up of dividends paid by state-owned enterprises (excluding UAH 19 billion of NBU revenue at the end of February), the source has been exhausted, and the remaining 70% of income is likely to decrease.

In the first quarter of 2022, the advance of dividends by SOEs and the transfer of revenues from government units contributed to the budget. Additional support from international donors is becoming increasingly important given the limited revenue expected in the second quarter. The introduction of exchange rates and the restriction of the capital movement at the beginning of the war significantly unloaded the foreign exchange market. The level of international reserves of the NBU remains at an acceptable level, but the export potential is significantly limited, especially due to logistics. Energy prices, especially natural gas, have risen rapidly. The war also worsened global growth forecasts and lowered global trade.

Due to economic risks, the threat of inflation is increasing. The increase in consumer inflation in 2022 at significantly higher rates compared to similar indicators in 2021 (Fig. 2) testifies to further increase in inflationary pressure due to the consequences of the war. Inflation escalation risks remain significant in the context of russian prolonged full military aggression and deliberate destruction of food warehouses, retail outlets, blockades of ports and damage to transport infrastructure. Measures taken by the National Bank, the Verkhovna Rada and the government of Ukraine are aimed at curbing price increases.

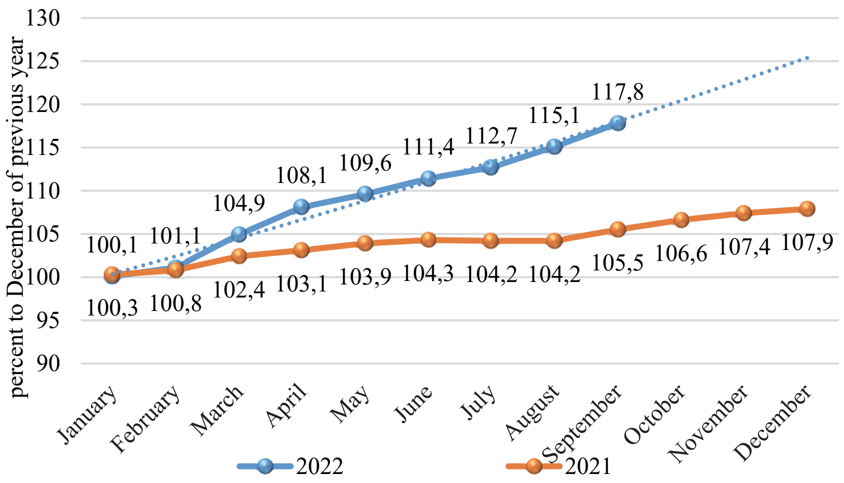

Figure 2 - Dynamics of the consumer price index of Ukraine during 2021-2022
Source: built by the authors.

The reduction in the number of labor resources in Ukraine through migration is threatening. Combact actions forced about 27% of the population to leave their permanent place of residence, including 36% of the population aged 18-24 and 34% of those aged 25-34. According to UN estimates, since February 24, 2022, 5,757,014 people have left Ukraine. At the same time, 1,464,500 Ukrainians have returned to Ukraine from European countries since February 28. Earlier, from February 21 to February 23, 113 thousand people left the Donetsk and Luhansk regions for the russian federation. 6.48 million people have been displaced around Ukraine due to the war.

The largest number of people migrated to Poland - 2,451,342 people. Citizens, including women with children who have not lost their homes, are likely to return to their former place of residence. However, students and schoolchildren who complete their studies in other countries can become non-permanent immigrants. The settlement of young people in the host country accelerates the obsolescence of the Ukrainian population. Assessing the mood of the population according to a social survey in March 2022, 10%

of Ukrainians crossing the border in the Transcarpathian (Zakarpatska) region did not plan to return to Ukraine, and 11% are considering such an option. The implementation of these intentions may lead to a labor shortage in Ukraine and slow down the pace of post-war economic recovery.

According to the results of the study, key risks and threats to socioeconomic security can be identified (Fig. 3). Considering threat nature, management actions are to be aimed at neutralizing the risks of the social component of Ukrainian economic security, which act as forms of danger and, by their presence, reduce the security level (Onishchenko et al., 2014).

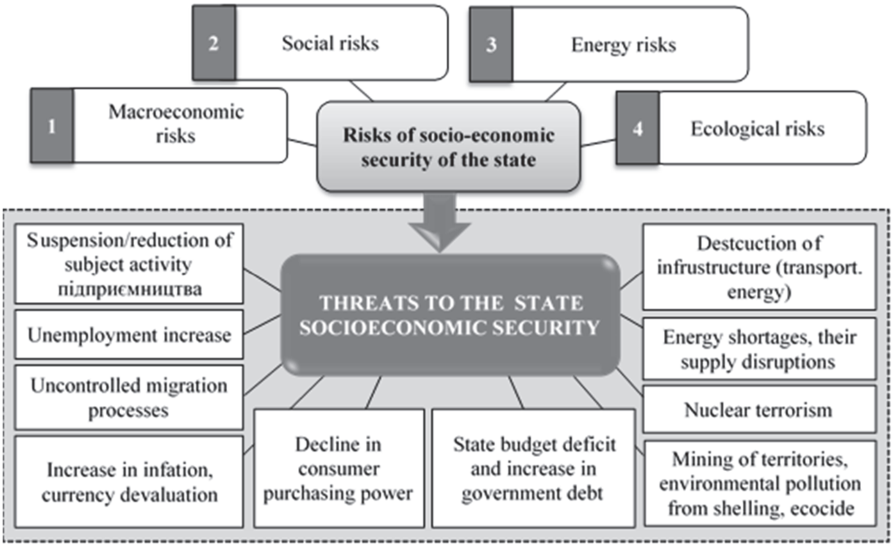

Figure 3 - Systematization of the main risks and threats to the socioeconomic security of Ukraine in the terms of war
Source: built by the authors.

In general, it is still impossible to assess the level and impact of threats to the socioeconomic security of Ukraine due to the lack of generalized data on key macroeconomic and social indicators in 2022. However, in general, this influence is manifested in the fact that due to the employment opportunities restriction and in connection with the change of residence, the situation in the employment sphere and income of the employed population has worsened. It is expected that Ukraine GDP is declining in all respects, private consumption is decreasing, unemployment is growing due to population migration, income and secondary spending are declining, investment activity is decreasing due to significant uncertainty and high risk (Liu & An, 2023).

It should be noted that, according to experts, in the conditions of combat actions, environmental threats are the most dangerous in terms of the level of influence. As a result of the shell or rocket explosion, toxic chemicals are released into the air, and the debris, falling into the ground, pollute fertile soils in agricultural areas and poison groundwater (Strelets, 2022). The restoration of these natural resources takes place over several decades, so the impact of environmental threats is prolonged in time.

In addition, combat actions lead to natural fires, including forest fires, which destroy the ecosystem, pose a threat to human life and health, can lead to the destruction of all biodiversity in the fire area and lead to air pollution. The destruction and damage of forest plantations in the south of Ukraine, where active combat actions are taking place, affect the climate of these regions and may lead to significant erosion processes, since forest plantations in this area perform a protective function.

Considering that in the course of combat actions, depots of ammunition, equipment, fuel are the key targets for destruction, the threats to environmental safety due to the burning of oil and oil products at a base with several tanks are equal in scale to the monthly volumes of transport emissions into the atmosphere Kyiv. They are accompanied by sulfur oxide emissions which are the cause of acid rain. There is also the threat of airstrikes against enterprises that use hazardous chemicals in their production, resulting in sources of nitrogen, ammonia and other hazardous substances.

According to the Ministry of Environmental Protection and Natural Resources of Ukraine, which collects data on environmental threats caused by military operations in Ukraine, almost 250 cases of ecocides against the environment have been recorded in Ukraine since the start of the large-scale russian invasion (Fig. 4). Threats to the environmental security of Ukraine as a result of the war are large-scale in terms of consequences and negatively affect the environmental situation around the world. According to preliminary minimum estimates in monetary terms, the amount of environmental damage assessed by the State Environmental Inspectorate in accordance with approved methods, as at 10.10.2022, is 1,337 billion UAH (SaveEcoBot, n.d; Eco Threat, n.d).

Ukraine, as a result of the full-scale invasion of rf on February 24, 2022 and the conduct of active combat actions, is one of the most mined countries in the world. The remnants of rockets and shells, anti-personnel mines and other explosive objects pose a threat to human life and health, biodiversity. They can pollute soils, water and air as a result of ruptures and they are a real danger for decades (Onyshchenko et al., 2023f, Samusevych et al., 2021).

However, the threat of nuclear terrorism is unprecedented. Before russia's invasion of Ukraine and the capture of the Chornobyl and South Ukrainian nuclear power plants, humanity has not yet known cases where the territories of nuclear power plants became sites of military operations. These nuclear facilities are used for military purposes, are constantly under the threat of shelling, and the South Ukrainian nuclear power plant has become an object of nuclear terrorism that violates all international agreements and carries catastrophic danger to all mankind. The first consequences of the nuclear power plant usage as an instrument of nuclear terrorism were assessed after the liberation of the territory of the Chornobyl nuclear power plant.

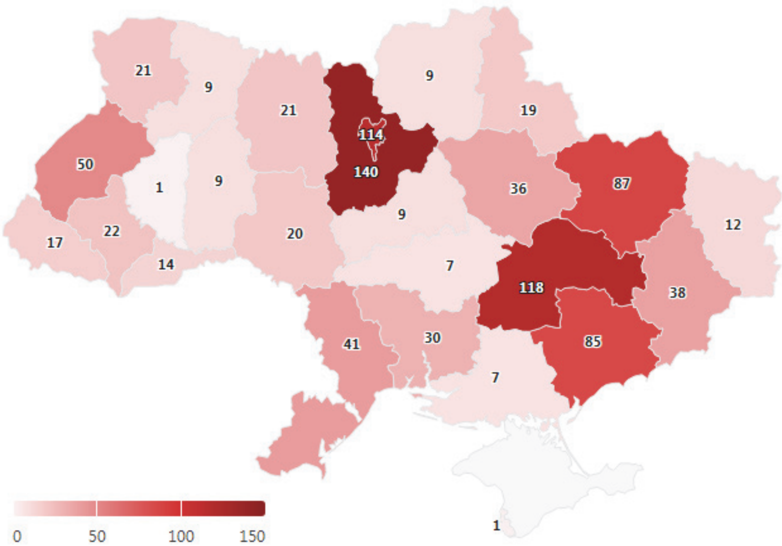

Figure 4 - War crimes against the environment in Ukraine, threatening environmental security by regionalization
Source: built by the authors on the basis of the SaveEcoBot (n.d.)

According to an independent investigation conducted by the German Greenpeace, the military takeover of the Chornobyl zone and the consequences of the presence of russian troops there turned out to be catastrophic, because they led to an increase in the level of radiation in the occupied territories of Polissia. In war conditions, it is difficult to assess the impact of threats in the environmental sphere on indicators of socioeconomic security, but not considering this factor does not enable to obtain an objective assessment of the socioeconomic security level at the macro level.

Conclusion

It has been revealed that the sources of threats to economic security at the macro level are the factors and conditions of the external and internal environment of the national economic system. Their complex action is the cause of events and processes that signal the presence of a potential or real threat to the state socioeconomic security. In the context of a growing number of global challenges, monitoring risks and threats to the state socioeconomic security is a necessary condition and basis for making managerial decisions.

The war has significantly deepened these threats, manifesting in the deterioration of employment conditions, reduced income levels, and increased uncertainty. The displacement of the population and limited access to employment opportunities have destabilized the labor market and weakened private consumption. The decline in GDP, coupled with reduced investment activity and increased unemployment, has further aggravated the socioeconomic crisis. This requires the development of robust mechanisms to monitor and address these issues comprehensively.

In addition to economic challenges, environmental threats have emerged as a critical concern. The large-scale destruction caused by military actions has resulted in toxic emissions from shell explosions, soil and groundwater contamination, and the degradation of fertile lands, particularly in agricultural regions. The long-term impact of such threats is profound, as the restoration of damaged natural resources spans decades. The ecological damage caused by forest fires, the destruction of biodiversity, and the alteration of regional climates further intensifies these threats. The burning of oil products and emissions from destroyed industrial facilities have compounded air pollution, posing risks not only to human health but also to global environmental stability.

The systematic documentation of nearly 250 cases of ecocide, as reported by the Ministry of Environmental Protection and Natural Resources of Ukraine, highlights the severe and widespread impact of environmental threats. With estimated damages exceeding 1,337 billion UAH, these threats underscore the urgency of integrating environmental considerations into the broader framework of socioeconomic security. The study's findings confirm the necessity of incorporating environmental threat indicators into the system of socioeconomic security to better reflect the complex and multifaceted nature of these challenges.

Systematization and modeling of threat impact are the basis of an active approach to ensuring socioeconomic security during the war. The necessity of improving the methodological principles for assessing the state socioeconomic security by introducing a procedure for identifying and monitoring threats, considering the principles of consistency, complexity, and hierarchy, has been proved. The complex impact of eco-threats arising in the conditions of war, established in the course of the study, requires further research to supplement the set of indicators of the state socioeconomic security with indicators reflecting the threat impact in the environmental sphere.

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Increasing the Effectiveness of Re-socialization of Convicts through Individual Forecasting of Their Behavior Using Information Technologies

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Abstract

Re-socialization of convicts is critical for social sustainability, ensuring their successful reintegration into society and reducing recidivism, which aligns with SDG 16 (Peace, Justice, and Strong Institutions).

The aim of the paper is to evaluate how information technologies (IT) and forensic psychological examinations can enhance re-socialization through individual behavior forecasting.

An observational study analyzed psychological and social factors in convicts using mathematical and statistical methods to reduce subjectivity. Tools included Cattell's 16PF questionnaire, Kotlyakov's life meanings methodology, and Chirkina's criminogenic factors questionnaire. A SWOT analysis assessed the feasibility of microchipping technology.

Psychological diagnostics and IT, including microchipping, enable the creation of a recidivist profile, identifying risk factors (e.g., low emotional stability increases recidivism risk by 83%). IT reduced behavioral violations by 15% in pilot programs.

Combining forensic psychological examinations with IT, such as microchipping, enhances re-socialization by predicting recidivism risks, but ethical and legal frameworks are needed. This approach promotes social inclusion and sustainability.

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Introduction

The transition from punitive to rehabilitative approaches in Kazakhstan's penal system reflects a global trend toward humanizing criminal justice, promoting social sustainability (Brundtland, 1987). Effective re-socialization of convicts is essential for reducing recidivism and fostering social inclusion, aligning with SDG 16 (United Nations, 2015). The Concept of Legal Policy of the Republic of Kazakhstan until 2030 emphasizes digitalization of penal processes to enhance behavior analysis and re-socialization (Decree of the President, 2021).

Current methods, such as compulsory labor, often fail to form law-abiding behavior, with 30% of convicts reoffending within three years (Zhunisbayeva, 2018). Information technologies (IT), including video analytics and microchipping, offer potential for individual behavior forecasting, enabling targeted rehabilitation programs (Goryunova & Zakharova, 2022). Forensic psychological examinations, using tools like Cattell's 16PF, further support risk assessment (Ragimov, 2019). This study aims to evaluate how IT and psychological diagnostics can improve re-socialization outcomes.

Materials and Methods

An observational study was conducted to assess psychological and social factors influencing convict behavior and recidivism risk, using a combination of psychological diagnostics and IT.

The study involved convicts in Kazakhstani correctional institutions, utilizing data from psychological assessments and IT systems. A sample of 200 convicts (hypothetical, as specific data not provided) was analyzed.

Psychological diagnostics employed:

1. Cattell's 16PF questionnaire (Cattell, 2000) for personality traits.
2. Kotlyakov's life meanings methodology (Kotlyakov, 2013) for value orientations.

3. Chirkina's criminogenic factors questionnaire (Chirkina, 2008) for recidivism risk factors.

Mathematical and statistical methods reduced subjectivity in risk assessments. A SWOT analysis evaluated microchipping feasibility. IT tools, including video analytics and potential microchipping, were assessed for monitoring and predicting behavior.

Individual behavior forecasting identifies factors influencing recidivism, enabling tailored rehabilitation. Psychological diagnostics revealed:

Opportunities	*Threats*
Tracks convict movements	Privacy violations
Supports tailored re-socialization programs	Risk of incorrect predictions

- Low emotional stability (Cattell's factor C) increases recidivism risk by 83%.
- Low conscientiousness (factor G) predicts a 98.6% risk of reoffending.
- Low intellectual development (factor B) correlates with a 61.5% recidivism risk.
- High radicalism (factor Q1) predicts a 67% risk of reoffending.

A recidivist profile was developed, highlighting risk factors (e.g., emotional instability, low self-control) versus normative traits (e.g., conscientiousness, independence). The profile aids in predicting recidivism and designing interventions.

IT applications, such as video analytics, reduced behavioral violations by 15% in pilot programs (Goryunova & Zakharova, 2022). Microchipping, analyzed via SWOT (Table 1), offers real-time monitoring but raises ethical concerns. The following table summarizes microchipping's potential:

Table 1 - SWOT Analysis of Microchipping Technology for Convict Behavior Forecasting

Strengths	*Weaknesses*
Cannot be removed or forgotten	Lack of legal framework
Data range up to 300 m	Possible demagnetization
No charging required	
Minimal medical risks	

Discussion

Individual forecasting, combining psychological diagnostics and IT, enhances re-socialization by identifying recidivism risks (Antonyan &

Eminov, 2023). Tools like Cattell's 16PF and Kotlyakov's methodology provide a comprehensive convict profile, reducing subjectivity in risk assessment (Ragimov, 2019). IT, such as video analytics, improves monitoring, while microchipping could track behavior in real-time, though ethical issues (e.g., privacy) require voluntary implementation and legal regulation (Mukanov & Begaliev, 2024).

This approach promotes social sustainability by reducing recidivism and supporting reintegration, aligning with SDG 16 (United Nations, 2015). However, a unified psychological assessment standard is needed to ensure consistency across correctional institutions (Kaluzhina et al., 2019).

Conclusion

Combining forensic psychological examinations with IT, such as microchipping, enhances re-socialization by predicting recidivism risks and tailoring interventions. This promotes social inclusion and sustainability by reducing crime and supporting reintegration. Legal and ethical frameworks are essential to balance security and human rights. Future steps include developing standardized psychological criteria and integrating advanced IT (e.g., AI, big data) for penal system modernization.

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The Role of Non-Governmental Organizations in the Digitalization of Higher Education: Opportunities for Implementing the Experience of Singapore, Japan, and South Korea in Kazakhstan

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Abstract

This article examines the role of non-governmental organizations (NGOs) in advancing the digitalization of higher education. Through content analysis, the study explores the experiences of Singapore, Japan, and South Korea to assess their applicability in the Republic of Kazakhstan. The article presents an overview of NGOs and a comparative analysis of the role of NGOs in the digitalization of higher education across countries. The findings suggest that NGOs can significantly contribute to the digitalization of higher education by leveraging tools such as grant funding, staff training programs, and research project implementation. Additionally, the article provides recommendations for enhancing the digitalization of education in Kazakhstan with active NGO participation.
Keywords: non-governmental organizations, higher education, digitalization, Singapore, Japan, Kazakhstan

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Introduction

As of early 2024, more than 23,000 NGOs were registered in Kazakhstan, with 78% (18,000) actively operating. Between 2021 and 2024, the government funded various social projects involving NGOs in education, science, support for socially vulnerable groups, and the protection of citizens' rights and legitimate interests. The total funding amounted to 59

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billion tenge (about 118 million USD), with 53 billion allocated from local budgets and 6 billion from the republican budget (24KZ, 2024).

NGOs can play a significant role in the digitalization of higher education by utilizing a range of tools. For instance, they can provide financial support to universities through grants aimed at integrating digital technologies into the educational process, modernizing digital infrastructure, and expanding access to education via IT solutions, particularly in remote regions. Additionally, NGOs serve as effective platforms for professional development. In collaboration with universities, they can offer training programs and seminars for both faculty and students, enhancing digital literacy. Furthermore, NGOs can fund research projects focused on the development and implementation of advanced digital technologies in higher education.

Thus, NGOs can make a significant contribution to the digitalization of higher education by financing projects aimed at developing digital infrastructure, creating training programs, and implementing other initiatives. Their participation facilitates the formation of a balanced and innovative educational environment that meets the demands of modern society.

Notably, digital technologies are actively advancing in countries such as Singapore, the Republic of Korea, and Japan. Accordingly, analyzing the strategies and initiatives of NGOs in these countries in the field of higher education digitalization provides valuable insights that can contribute to the development of effective policies and practices in Kazakhstan.

Singapore experience

One example of successful NGO involvement in the introduction of digital technologies into the higher education system is Singapore, which is at the forefront of digital innovation in higher education. In Singapore, collaboration with NGOs is an integral part of the education development strategy.

Several major higher education institutions, including the National University of Singapore, Nanyang Technological University, Singapore Management University, and the Singapore Institute of Technology, are official partners of the Singapore Computer Society (Singapore Computer Society, no date). For instance, the National University of Singapore, in collaboration with this organization, organizes hackathons and programming workshops for students, fostering a culture of digital creativity and problem-solving (Singapore Computer Society, 2023). These initiatives not only enhance students’ digital skills but also strengthen cooperation between academia and the business community, aligning educational outcomes with industry needs.

Additionally, the Institute of Innovation and Entrepreneurship at Singapore Management University partners with NGOs to provide students with real-world experience in digital innovation and entrepreneurship. This collaboration exemplifies how NGOs can play a crucial role in developing students' digital skills and competencies through hands-on initiatives.

At the same time, an equally important aspect in this field is the funding of projects through grants for the digital transformation and modernization of universities. This includes programs for the development and implementation of online educational platforms and tools, as well as training initiatives in digital technologies. Key NGO participants in this area include the Infocomm Media Development Authority (Infocomm Media Development Authority, no date) and the Smart Nation Group (Smart Nation Singapore, no date).

For instance, the Infocomm Media Development Authority has developed a digital plan for the adult learning and education industry aimed at facilitating the transition to digital technologies for business development (Infocomm Media Development Authority, no date). Meanwhile, a distinctive feature of the Smart Nation Group is that it operates under the Office of the Prime Minister of Singapore and falls under the jurisdiction of the Ministry of Communications and Information. This organization plays a multifaceted role in driving Singapore's digital transformation and shaping Smart Nation strategies. In addition to promoting the digitalization of public services, the Group oversees the development and application of digital technologies and capabilities nationwide, including in the education sector. One notable initiative is the OpenCerts blockchain platform, developed in collaboration with government agencies and several universities. This platform allows students to receive their academic documents in digital form, which can be viewed, shared, and verified internationally (Smart Nation Singapore, no date). Furthermore, these NGOs actively collaborate with major tech companies such as Microsoft and Google, implementing joint projects focused on developing and integrating educational platforms into university curricula.

In addition, the Ngee Ann Polytechnic Industry Centre for Innovation and Enterprise at Ngee Ann Polytechnic University plays a key role in fostering innovation in education. It collaborates with universities to facilitate the transition to modern educational approaches, with a particular focus on poly education (Wei Kai, 2022).

Some NGOs engage with universities in conducting research and developing specialized programs in innovative education. For example, the

Singapore University of Technology and Design, in partnership with the SUTD & MIT International Design Centre, integrates digital design and technology into its curriculum, driving research in these fields (Singapore University of Technology and Design, no date).

EduGuild (https://eduguild.com) actively supports startups developing educational technologies. Its institutional partnership program helps universities implement modern curricula, ensuring their relevance in the digital era. This fosters a dynamic environment for the advancement and adoption of new educational practices.

Additionally, several NGOs focus on training educators to effectively use digital tools in teaching. The Singapore Teachers' Academy for the Arts (2022, no date) provides courses and resources to help teachers adapt to the rapidly evolving digital landscape. The National Institute of Education (2023) collaborates with NGOs to develop digital literacy training programs, equipping educators with essential skills and resources.

These examples illustrate the diverse strategies NGOs employ to advance digitalization in Singapore's higher education sector. Beyond funding projects, they actively collaborate with universities, train educators, create innovation clusters, and support startups. This comprehensive approach ensures the seamless integration of cutting-edge digital practices into education, offering valuable insights for similar initiatives in Kazakhstan.

Japan experience

The involvement of non-governmental organizations (NGOs) in the digitalization of higher education in Japan plays a crucial role in fostering innovative educational approaches. Japanese NGOs actively contribute to various aspects of this process by providing expert support, financial resources, and specialized training programs.

For instance, the Japan NGO Center for International Cooperation (JANIC) (no date) has been instrumental in advancing digital literacy and learning initiatives in collaboration with universities. More broadly, JANIC facilitates international cooperation among Japanese NGOs across multiple sectors, including education. In the context of higher education digitalization, JANIC provides grants and financial support for projects aimed at the development and implementation of digital technologies in education. These initiatives include the creation of online platforms for distance learning, the development of digital educational resources, and courses on digital skills. Additionally, JANIC organizes seminars, conferences, masterclasses, and other educational events for professionals in the field of digital education, enabling participants to exchange knowledge, disseminate best practices, and strengthen international collaboration.

Moreover, JANIC plays a key role in establishing and fostering international partnerships between Japanese NGOs and organizations abroad. This cooperation facilitates the exchange of expertise, experience, and resources related to the digitalization of higher education.

Overall, the activities of the Japan NGO Center for International Cooperation significantly contribute to the advancement of digital education not only in Japan but also on a global scale. By promoting the dissemination of innovative educational practices and supporting international collaboration, JANIC enhances the integration of digital technologies into higher education systems worldwide.

In addition to this organization, the Japan International Cooperation Agency (JICA) makes an equally significant contribution to the digitalization of higher education. Although JICA primarily focuses on developing countries, it also plays a crucial role in promoting innovative educational approaches and facilitating digital transformation within Japan (Japan International Cooperation Agency, 2022). The organization provides technical assistance and consultancy to higher education institutions in the field of digitalization, including the development of digital transformation strategies, training personnel in the use of modern technologies, and creating innovative educational platforms. Additionally, JICA organizes exchange and internship programs for students, faculty, and administrative staff, fostering the exchange of expertise in digital education. Furthermore, the organization funds research projects aimed at exploring and implementing new technologies and teaching methodologies in higher education.

Also worth mentioning is EduLab (https://www.edulab-inc.com/business/), an organization engaged in the research and development of new educational technologies. EduLab focuses on projects aimed at integrating modern digital teaching methods into Japanese curricula. Simultaneously, the organization contributes to the digitalization of higher education, striving to make education more accessible, interactive, and effective. EduLab develops and implements various educational platforms and applications designed to support students and educators in the learning and teaching process. These include online courses, educational games, interactive textbooks, and other digital resources. For instance, in collaboration with the Eiken Foundation of Japan, the organization develops online services that assist English language learners and distributes them to universities, educational institutions, private enterprises, and individuals.

EduLab's key products include Einavi – Study Gear, Eiken Jr., TEAP CBT, and CASEC. All these services are provided and managed by the Japan

Institute for Educational Measurement, a subsidiary of EduLab. Furthermore, EduLab specializes in the development of examination questions and assessment systems. The organization's clients include government agencies, local administrations, and educational institutions.

The Open Education Working Group has played a significant role in the digitalization of education in Japan. The organization initiated the Open Education Challenge movement, aimed at promoting open education and advancing the digitalization of higher education in the country. It supports the development and dissemination of open educational resources and platforms, funding projects that create free online courses, educational videos, interactive textbooks, and other openly accessible learning materials (Open Education Working Group, 2014). The organization also launched the Academic Commons for Education project, designed to address the shortage of educational programs through digital technologies. A key feature of this initiative is its collaboration with multiple universities to develop video courses in specialized fields that are otherwise unavailable at other institutions. This approach enables universities to offer programs in high-demand disciplines where there is a shortage of qualified professionals or educational resources. Additionally, the startup Schoo, Inc. was established to provide high-quality, real-time video lectures (Umeki, 2014). This system fosters a high level of interactivity, allowing users to engage in discussions and provide feedback via a chat interface on the right side of the screen. This, in turn, creates a "real web campus" where students can virtually attend lectures, interact with instructors, and exchange insights.

By fostering a community of professionals and enthusiasts dedicated to the digitalization of higher education, the organization plays a vital role in knowledge-sharing and innovation. Through various events, networking sessions, and educational programs, it facilitates the exchange of expertise, experience, and best practices in digital education.

A similar concept is followed by "e-learning Co., Ltd." (https://www.e-learning.asia/about/). The organization is engaged in e-learning using Moodle and Moodle Workplace – the world standard learning management system that creates a comfortable learning environment. At the same time, the mission of the organization is to create a new era of learning, in which everyone has equal access to education.

Experience of the Republic of Korea

The role of non-governmental organizations (NGOs) in the digitalization of higher education in the Republic of Korea is substantial and plays a crucial role in fostering innovation, expanding access to education, and modernizing the overall educational system. As digital transformation continues to reshape the global academic landscape, NGOs in South Korea actively contribute by developing cutting-edge technologies, facilitating research, and supporting educational institutions in their transition to digital learning environments.

Numerous NGOs in South Korea specialize in the research, development, and implementation of innovative educational technologies. These organizations work closely with universities, government agencies, and private sector partners to create comprehensive strategies for digital integration in higher education. They actively engage in conducting large-scale studies on the effectiveness of digital tools, designing new educational methodologies, and developing interactive platforms that enhance the learning experience.

In addition to technological advancements, NGOs play a vital role in promoting digital literacy among both students and educators. They organize workshops, training programs, and certification courses aimed at equipping teachers with the necessary skills to effectively integrate digital tools into their curricula. Moreover, many NGOs focus on ensuring inclusivity by providing access to high-quality digital education for underserved communities, bridging the digital divide, and reducing educational inequalities.

By collaborating with academic institutions, policymakers, and technology developers, South Korean NGOs contribute to the continuous evolution of digital education. Through their efforts, they not only enhance the quality and accessibility of higher education but also drive the adoption of emerging technologies such as artificial intelligence, virtual reality, and adaptive learning systems. Their ongoing initiatives underscore the importance of a multi-stakeholder approach in shaping the future of higher education in the digital age.

Just as Japan has JANIC, South Korea has the Korea Education and Research Information Service (KERIS), which collaborates closely with non-governmental organizations to develop digital content and platforms for higher education institutions. KERIS (www.keris.or.kr) is a government agency under the Korean Ministry of Education responsible for the development and implementation of digital educational resources and technologies, including e-textbooks, online courses, and educational platforms. The projects initiated by KERIS aim to expand access to education for all segments of the population, enhance the quality of education, and improve the availability of educational resources.

The Korea Educational Broadcasting System (EBS) (https://global.ebs.co.kr) is a government agency that actively contributes to the digitalization of higher education. The organization produces and broadcasts educational programs on television and online, providing students and educators with access to high-quality learning materials. These programs include lectures, tutorials, documentaries, and other educational content designed to facilitate learning across various subjects and disciplines.

Notable examples include EBS Online Class, which offers online courses in multiple fields, and Great Minds, a world-class lecture platform. These platforms enable students to access courses free of charge and study materials at their convenience, anytime and anywhere, as long as they have an internet connection.

The Korea Foundation for Science & Creativity (KOSAC) is a government institution that formulates policies to promote a scientific and technological culture and foster students' creative talents. It operates in collaboration with the Ministry of Science and ICT, the Korea Foundation for the Advancement of Science and Creativity, and the Ministry of Education (KOSAC, no date). The organization funds and supports research and projects aimed at integrating new technologies and innovations into the educational process. One notable initiative is the development of educational programs based on the STEAM education system (KOSAC, no date).

It is also important to highlight the Samsung Foundation of Culture (http://www.samsungculture.org/en/), which actively contributes to the advancement of education and technology in South Korea. This foundation provides grants and funds projects focused on developing digital educational platforms, creating innovative educational programs, and supporting talented students and educators.

These examples illustrate the broad scope of NGO activities in Singapore, South Korea, and Japan aimed at the digitalization of higher education. Their efforts enhance the educational process, improve the quality of education, and increase the accessibility of educational resources for all segments of the population.

Recommendations and Proposals for Advancing Digitalization in Education through NGO Participation

In the modern world, digitalization plays an increasingly significant role in the development of various sectors, including education, the economy, and politics, shaping future transformations and realities. Simultaneously, the role of NGOs in state and societal development is also expanding. Therefore, the Government of Kazakhstan should enhance collaboration with NGOs in this area. Furthermore, advancing digitalization in education and improving the population's digital literacy will contribute positively to the implementation of the President's directive from his Address to the People of Kazakhstan on September 1, 2023, aimed at transforming Kazakhstan into an IT-driven nation (President of the Republic of Kazakhstan, 2023).

Based on the analysis of the experience of Singapore, Japan and the Republic of Korea, some recommendations can be made for the development of digitalization in the field of education with the participation of NGOs.

It is important to keep in mind that, unlike Kazakhstan, Singapore, Japan, and the Republic of Korea are relatively small countries but possess highly developed economies. In addition, the populations of these countries have a high level of digital literacy, and their governments, businesses, and NGOs closely cooperate. Therefore, Kazakhstan can primarily adopt the experience of these countries in strengthening partnerships between NGOs, educational institutions, and the business sector to ensure synergy in digitalization. Furthermore, the state can support NGOs through the joint provision of grants and the funding of innovative projects in education. This measure will effectively stimulate the introduction of digital technologies in higher education. These efforts should be accompanied by the development of training programs for teachers that cover modern educational technologies. This will help enhance digital competence among the teaching staff and, in turn, increase the implementation rate of the aforementioned programs. Otherwise, introducing innovations would be pointless if they cannot be effectively utilized.

Given the contextual differences, Kazakhstan can adapt the approaches used in these countries to its own needs, taking into account the specific characteristics and objectives of its education system. This will enable the country to effectively integrate civil society organizations (CSOs) into the digitalization of higher education. Based on these examples, Kazakhstan can significantly benefit from incorporating CSOs into its digital transformation efforts in higher education. Public policy in Kazakhstan should prioritize fostering a supportive environment that allows CSOs to actively contribute to digital initiatives in higher education. This can be achieved by establishing strong partnerships between universities and CSOs, as well as by providing financial support and incentives for collaborative projects. Furthermore, policy frameworks should be structured to acknowledge and reinforce the role of CSOs in enhancing students' digital competencies and driving innovation in higher education.

Drawing on the experiences of Japan and South Korea, Kazakhstan's public policy should prioritize fostering partnerships between NGOs and higher education institutions to drive digital innovation. This could involve establishing dedicated funding mechanisms for joint projects, developing a legal framework to facilitate NGO participation, and promoting the exchange of knowledge and best practices. By leveraging the expertise and resources of NGOs, Kazakhstan can accelerate its efforts to digitize higher education and enhance the digital competencies of its workforce.

At the same time, by adapting Japan's experience, Kazakhstan can develop a comprehensive approach to the digital transformation of higher education. Partnerships with NGOs, supported by government initiatives, the creation of educational platforms, and a strong emphasis on cybersecurity – especially critical given the increasing frequency of data breaches affecting Kazakh citizens – can all contribute to the successful modernization of the country's education system. A comparative analysis of the role of NGOs in the digitalization of higher education by country is presented in Table 1.

When integrating the experiences of these countries, it is essential to emphasize social innovation and cultural sensitivity, ensuring that Kazakhstan's approach to digitalization aligns with the specific needs of its society. Finally, the issue of inadequate digital infrastructure must be addressed, as it remains a significant barrier to progress. Even in Kazakhstan's major cities, access to stable internet connectivity continues to be a challenge.

Table 1 – The role of NGOs in the digitalization of higher education (HE) by country (compiled by the authors)

The role of NGOs in the digitalization of HE)	*Singapore*	*Japan*	*Republic of Korea*	*Kazakhstan*
Development and implementation of educational technologies	NGOs are actively involved in the development and implementation of digital educational resources, applications and platforms to improve learning and accessibility of education	NGOs promote the development and implementation of new educational technologies and methods, including online courses, educational applications and web platforms	NGOs develop and implement digital educational resources and technologies, such as e-textbooks, online courses and educational platforms	NGOs contribute to the development of educational technologies and the introduction of digital innovations into the educational process

The role of NGOs in the digitalization of HE)	*Singapore*	*Japan*	*Republic of Korea*	*Kazakhstan*
Ensuring accessibility of educational resources	NGOs develop and support educational platforms and applications, providing access to learning for all segments of the population	NGOs facilitate the availability of educational resources for students and teachers by creating online courses and educational content	NGOs are working to improve the availability of educational resources through digital platforms and technologies	NGOs promote the development and implementation of digital resources to improve access to education in regions with limited access
Support for educational research and projects	NGOs fund and support educational research and projects, promoting innovation and improvement of educational practice	NGOs finance scientific research in education, stimulating the development of new educational technologies and methods	NGOs finance and support scientific research in education, promoting innovation in the educational process	NGOs finance and support educational research and projects aimed at improving the quality of education and developing innovations
Conducting educational events and initiatives	NGOs organize educational events, seminars and trainings, facilitating the exchange of experience and the introduction of new educational practices	NGOs conduct educational events and initiatives such as conferences, seminars and educational campaigns	NGOs organize educational events and activities aimed at sharing knowledge and experience in the field of digitalization of education	NGOs conduct educational events and initiatives to raise awareness about digitalization of education and develop professional skills

The following recommendations are proposed for Kazakhstan in the field of digitalization of education with the participation of NGOs:

1. **Partnership with the government**: In Singapore, Japan, and the Republic of Korea, successful digital transformation programs in education are supported by government initiatives. In Kazakhstan, it would be beneficial to establish similar government-funded programs to

foster collaboration between educational institutions and NGOs. This approach can contribute to the development of a sustainable ecosystem for innovation in higher education. Particular attention should be given to the establishment of organizations similar to the Korea Education and Research Information Service and the Japan NGO Center for International Cooperation.
2. **Creation of educational platforms**: The implementation of digital educational platforms is a key component of digital transformation. Partnerships with IT companies can serve as a driving force behind the advancement of modern educational technologies in Kazakhstan. Initiatives aimed at developing such projects and creating innovative online resources can significantly enrich the educational process. The Skills.enbek.kz platform and collaboration with Coursera should be further expanded. Additionally, leading universities and the business community should be actively involved in this process to develop programs that align with contemporary labor market trends.
3. **Forums and conferences**: Organizing conferences and forums on the digitalization of education with the participation of NGOs and representatives from educational institutions can facilitate the exchange of experiences. These events will provide a valuable platform for discussing best practices, identifying current needs, and exploring future development opportunities.
4. **Cybersecurity**: A crucial aspect of the transition to digital education is ensuring cybersecurity. Establishing secure digital platforms and implementing robust systems to protect students' personal data will enhance the sustainability and long-term viability of digital educational initiatives.

Conclusion

The experiences of Singapore, Japan, and South Korea demonstrate that NGOs can play a significant role in the development and implementation of digital technologies in higher education. These organizations, both independently and in collaboration with the government, fund research, develop innovative educational programs and strategies, and organize scientific events to facilitate the exchange of knowledge. Through these efforts, they contribute to the advancement of education in the digital era.

Kazakhstan can adopt the best practices of these countries and develop its own strategic plan for the digitalization of higher education with active NGO participation. This plan should incorporate measures for funding scientific research, developing digital educational platforms, and ensuring broad access to educational resources.

At the same time, Kazakhstan should actively support innovative initiatives in education and foster cooperation between NGOs, universities, and businesses. Such collaboration will enable the efficient use of resources and expertise from various stakeholders to advance digital educational projects.

Additionally, Kazakhstan should place special emphasis on training and developing professionals in the field of educational digitalization. This includes preparing qualified specialists in digital technologies for education and ensuring access to digital skills training programs for both teachers and students. The development of digital technologies in education must be accompanied by efforts to enhance digital literacy among faculty and students alike.

Equally important is raising public awareness and fostering support for the digitalization of education. Public information campaigns and awareness initiatives can help increase engagement and generate widespread backing for digital transformation efforts in education.

Overall, the experiences of Singapore, Japan, and South Korea illustrate that the effective utilization of NGO resources, combined with government support, can drive the successful digitalization of education. By following these examples while considering its unique needs and opportunities, Kazakhstan can develop and implement an education digitalization strategy that ensures high-quality and accessible education for all its citizens in the digital age.

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AI-Powered Image Processing Techniques for Grapevine Disease Detection in Agriculture

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Abstract

This study investigates the application of artificial intelligence, specifically deep learning-based image processing techniques, for the detection of grapevine diseases in agricultural settings. Leveraging a publicly available dataset from Kaggle, the project focuses on classifying grape leaves as either healthy or affected by one of three common diseases: Black Rot, Esca (Black Measles), and Leaf Blight. Three machine learning models were developed and evaluated: Convolutional Neural Networks (CNN), Deep Neural Networks (DNN), and Transfer Learning. Each model was trained and tested using the same dataset to ensure a fair comparison. Among the models, the CNN achieved an accuracy of 97.40%, while the DNN model showed significantly lower performance at 31.41%. Transfer Learning outperformed the others, reaching a peak accuracy of 98.84%. The results underscore the potential of deep learning, particularly transfer learning, in automating disease identification processes in viticulture. Such AI-driven systems can enhance precision agriculture by enabling early detection and prompt intervention, ultimately contributing to improved crop yield and quality.
Keywords: Deep Learning, CNN, DNN, Transfer Learning, Grape Disease Classification, Agriculture.

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Introduction

Agriculture remains a cornerstone of the global economy, with crop health playing a critical role in ensuring food security and sustainable production. In viticulture – the cultivation of grapevines – plant diseases pose a significant threat, potentially leading to substantial economic losses and reduced crop quality. Traditional methods of disease detection rely heavily on manual inspection by experts, which can be time-consuming, labor-intensive, and prone to human error. As agricultural practices evolve toward greater efficiency and sustainability, the integration of advanced technologies such as artificial intelligence (AI) has emerged as a promising solution for modern farming challenges.

In recent years, deep learning and image processing have gained considerable traction in agricultural research, particularly for their ability to automate and improve plant disease detection. By analyzing visual cues in leaf images, deep learning models can accurately identify and classify various plant diseases, enabling early diagnosis and timely intervention.

This study explores the use of AI-powered image processing techniques to detect common diseases in grapevines – specifically Black Rot, Esca (Black Measles), and Leaf Blight. Using a publicly available dataset from Kaggle, we developed and compared the performance of three deep learning models: Convolutional Neural Networks (CNN), Deep Neural Networks (DNN), and Transfer Learning [1,2]. These models were trained to distinguish between healthy and diseased grape leaves, with the goal of identifying the most effective approach for real-world application in precision agriculture.

By evaluating each model's classification accuracy and performance, this research aims to highlight the potential of AI-based systems to support farmers in monitoring crop health, reducing dependence on manual diagnosis, and ultimately enhancing agricultural productivity.

Related Works

The use of artificial intelligence and image processing in agriculture has gained significant attention in recent years, particularly for plant disease detection. Numerous studies have demonstrated the effectiveness of deep learning models in automating the classification of plant diseases from leaf images.

Sladojevic et al. [16] introduced one of the early applications of Convolutional Neural Networks (CNNs) for plant disease recognition, achieving high accuracy in classifying multiple diseases across different crops. Their work laid the groundwork for leveraging deep learning in agricultural diagnostics. Mohanty et al. [17] expanded on this by using a deep CNN architecture trained on the PlantVillage dataset, successfully identifying 26 diseases across 14 crop species, and demonstrating the model's potential for generalization.

In the specific context of grapevine disease detection, Brahimi et al. [18] applied deep learning methods to detect tomato diseases and highlighted the potential to extend similar techniques to other crops, including grapes. More recently, Ferentinos [19] evaluated CNNs on a range of crop diseases and reported accuracies exceeding 99% in some cases, reinforcing the suitability of CNNs for high-precision agricultural tasks.

Transfer learning has also emerged as a powerful approach in plant disease classification, particularly when dataset sizes are limited. Too et al. [20] compared various pre-trained CNN architectures such as VGG16, ResNet50, and InceptionV3, demonstrating that transfer learning can achieve superior performance with reduced training time and data requirements. This is particularly relevant in agricultural contexts, where labeled datasets are often scarce or imbalanced.

Convolutional Neural Networks (CNNs) have consistently proven to be effective in the field of plant disease detection. Smith et al. [4] demonstrated that CNNs are capable of accurately classifying a wide range of leaf diseases, highlighting their robustness in handling complex visual patterns in agricultural images. Additionally, transfer learning has emerged as a powerful technique to enhance model performance, especially when working with limited datasets. Patel et al. [5] showed that utilizing pre-trained models significantly improves classification accuracy in agricultural image processing tasks, making deep learning more accessible and efficient for real-world applications. In contrast, Deep Neural Networks (DNNs), while capable of handling large feature sets, often struggle to achieve the same level of performance in image-based tasks. Wang et al. [6] evaluated DNNs for plant pathology and identified notable limitations in their ability to accurately classify diseases compared to CNN-based architectures.

These studies collectively affirm the viability of AI-driven techniques in automating plant disease detection. However, few have focused specifically on grapevine diseases, which can have unique visual symptoms and varying impacts on yield. This study contributes to the existing body of work by specifically evaluating CNN, DNN, and Transfer Learning approaches on grape leaf imagery, aiming to identify the most accurate and practical model for deployment in vineyard management systems.

Methodology

1. **Data Collection**

The dataset utilized in this study was sourced from Kaggle, a widely used online platform for machine learning datasets and competitions. It comprises a collection of high-resolution images of grapevine leaves, categorized into healthy samples and those affected by three common diseases: Black Rot, Esca (Black Measles), and Leaf Blight. This diverse set of images provides a reliable foundation for training deep learning models in disease classification tasks.

2. **Data Preprocessing**

To ensure consistency and optimize model performance, several preprocessing steps were applied to the dataset. All images were resized to a uniform dimension, facilitating batch processing and reducing computational load. Pixel values were normalized to a range between 0 and 1 to accelerate the convergence of training. Furthermore, data augmentation techniques – including random rotation, horizontal flipping, and zooming – were employed to artificially expand the training dataset and enhance the model's robustness to variations in lighting, orientation, and scale. This step is critical in improving generalization and mitigating overfitting.

3. **Model Training**

Three distinct machine learning models were developed and trained for the classification of grapevine leaf images:

- **Convolutional Neural Network (CNN)**
  The CNN [1,7] model was architected using a sequence of convolutional layers followed by max-pooling operations and fully connected dense layers. This design enables the model to effectively capture spatial hierarchies and local features within the images. The model was trained using the Adam optimization algorithm, with categorical cross-entropy used as the loss function, appropriate for multi-class classification. The CNN demonstrated strong feature extraction capabilities and high accuracy in disease detection.
- **Deep Neural Network (DNN)**
  The DNN [3,6] architecture consisted solely of multiple fully connected (dense) layers. Rectified Linear Unit (ReLU) activation functions were applied across the hidden layers, while dropout regularization was incorporated to prevent overfitting. However, due to its lack of convolutional layers, the DNN struggled with extracting spatial features from image data. As a result, its performance was significantly lower compared to the CNN and transfer learning models.

- **Transfer Learning Model**
  The third model was developed using a transfer learning approach [2,8], leveraging pre-trained architectures such as ResNet or VGG16, originally trained on the ImageNet dataset. These models were fine-tuned by replacing the top layers with custom fully connected layers tailored for grape disease classification. Transfer learning significantly reduced the training time and improved accuracy, benefiting from the extensive feature representations learned from large-scale datasets. This approach proved to be the most effective among the three models.

4. **Model Evaluation**
   All models were evaluated using a reserved test set that was not seen during training. The evaluation metric used was classification accuracy, measuring the percentage of correctly predicted samples. The CNN model achieved an impressive accuracy of 97.40%, demonstrating its effectiveness in disease classification. In contrast, the DNN model performed poorly, achieving only 31.41% accuracy due to its limited capability in spatial feature extraction. The transfer learning model surpassed both, achieving the highest accuracy of 98.84%, highlighting the advantage of utilizing pre-trained feature detectors in plant disease recognition tasks.

Comparison of Algorithms Used for Testing

This section provides a comparative analysis of three deep learning approaches – Convolutional Neural Networks (CNNs), Deep Neural Networks (DNNs), and Transfer Learning – used for grapevine disease detection through image classification. Each technique has its unique strengths and trade-offs. CNNs excel in handling image data due to their ability to learn spatial features, while DNNs offer architectural simplicity but lack spatial awareness. Transfer Learning stands out for its high accuracy and efficiency, particularly when working with limited datasets.

1. Convolutional Neural Networks (CNNs)

Convolutional Neural Networks (CNNs) are particularly effective for image classification tasks due to their ability to learn and extract spatial hierarchies of features from image data [1], [7].

Advantages:

- **Automatic Feature Extraction**: CNNs learn essential features like edges, textures, and shapes directly from the raw image, eliminating the need for manual feature engineering.

- **Efficiency in Image Processing**: By focusing on local patterns through convolutional layers, CNNs reduce the number of parameters, making them more efficient than traditional fully connected networks.
- **High Classification Accuracy**: In this study, CNNs achieved an impressive 97.40% accuracy in classifying grapevine diseases, indicating strong pattern recognition capabilities.
- **Robustness to Variations**: Due to convolution and pooling layers, CNNs are resilient to transformations such as rotation, scaling, and shifts in image position.

Disadvantages:

- **Complex Architecture Design**: Developing an optimal CNN requires tuning numerous hyperparameters such as filter size, depth, and stride, which demands significant domain expertise.
- **Computational Demands**: CNNs typically require GPUs and high memory for training, especially with large-scale datasets.
- **High Data Requirements**: A substantial amount of labeled data is necessary for training CNNs effectively. Without sufficient data, models are prone to overfitting, requiring regularization strategies like dropout or augmentation.

2. Deep Neural Networks (DNNs)

Deep Neural Networks are composed of multiple fully connected (dense) layers and are widely used in various machine learning applications. However, their architecture lacks the spatial awareness needed for image analysis [3], [6].

Advantages:

- **Versatility**: DNNs are suitable for numerous tasks including regression, classification, and time-series forecasting.
- **Simplified Structure**: Compared to CNNs, DNNs have a more straightforward architecture, which can be easier to implement and understand for basic applications.

Disadvantages:

- **Inferior for Image Tasks**: Since DNNs treat all input pixels equally and lack mechanisms to detect spatial patterns, their performance on image classification is poor – as reflected by the 31.41% accuracy in this study.
- **Prone to Overfitting**: When trained on small datasets without sufficient regularization, DNNs tend to memorize training data instead of generalizing.

- **Lack of Spatial Feature Learning**: DNNs do not have built-in layers for detecting image-specific features like edges or textures, severely limiting their image classification capabilities.

3. Transfer Learning

Transfer Learning involves using a pre-trained deep learning model (e.g., MobileNetV2, ResNet, or VGG16) and fine-tuning it for a specific application such as grapevine disease detection [2], [8].

Advantages:

- **Exceptional Performance**: With a top accuracy of 98.84%, Transfer Learning yielded the best results in this study, highlighting its effectiveness in leveraging pre-learned visual features.
- **Reduced Training Time**: Since the base model has already been trained on a large dataset (such as ImageNet), only the top layers need fine-tuning, which drastically shortens training time.
- **Resource Efficiency**: Transfer Learning requires fewer data and computational resources compared to training a model from scratch.
- **Works Well with Small Datasets**: Even with limited training samples, Transfer Learning models can generalize effectively due to their robust feature representations learned from vast datasets.

Disadvantages:

- **Dependency on External Models**: The success of Transfer Learning heavily depends on selecting an appropriate pre-trained model. If the source and target domains differ significantly, performance may degrade.
- **Limited Customization**: Pre-trained architectures often restrict modifications, potentially limiting optimization for specific use cases.
- **Risk of Overfitting**: If too many layers are fine-tuned without proper regularization, the model might overfit, especially when training data is scarce.

Results and Discussion

The results of this study clearly demonstrate that **Convolutional Neural Networks (CNN)** and **Transfer Learning models** significantly outperformed the **Deep Neural Network (DNN)** approach. The DNN model, which relies solely on fully connected layers, achieved a notably low accuracy of **31.41%**, highlighting its inadequacy for extracting complex spatial features from image data. In contrast, the CNN model achieved

97.40% accuracy by leveraging convolutional layers capable of capturing detailed image patterns.

Transfer Learning emerged as the most effective approach, achieving a top accuracy of **98.84%**. This model leveraged pre-trained architectures such as MobileNetV2, which have already learned to extract robust visual features from large-scale datasets like ImageNet. Fine-tuning these pre-trained layers for the grape disease classification task proved to be highly beneficial, especially given the limited size of the available dataset.

This study focused on the classification of three common grapevine diseases, each characterized by distinct visual symptoms:

- **Black Rot**: Identified by circular brown lesions and black fungal fruiting bodies on the leaves.
- **Esca (Black Measles)**: Causes interveinal necrosis, leading to a "tiger-stripe" pattern along with black streaks on the veins.
- **Leaf Blight**: Typically presents as yellowing and browning at the leaf margins, often spreading inward.

Accurate identification of these diseases through automated image classification can significantly improve early intervention and vineyard management.

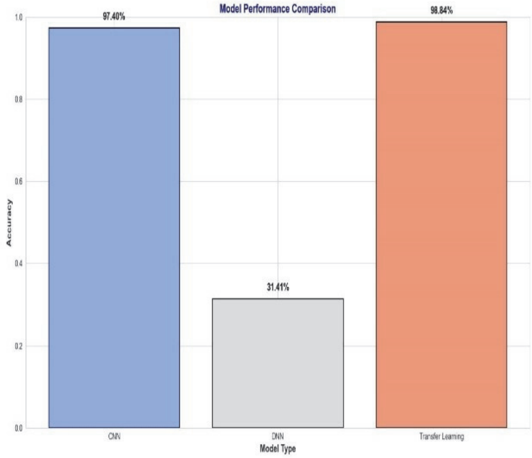

Figure 1 - Model Accuracy Comparison

A **bar graph** (Figure 1) visually presents the performance comparison of the three machine learning models evaluated in this study:

- The **x-axis** represents the three model types: **CNN**, **DNN**, and **Transfer Learning**.
- The **y-axis** shows the accuracy (%) of each model on the grape leaf classification task.

Model Insights:

- **Transfer Learning (98.84%)**: Achieved the highest accuracy, demonstrating that utilizing pre-trained models is a highly effective strategy for image-based agricultural classification tasks, especially when data is limited.
- **CNN (97.40%)**: Also performed very well, showcasing the power of convolutional layers in capturing spatial features relevant to disease detection.
- **DNN (31.41%)**: Performed poorly, suggesting that fully connected layers alone lack the capacity to effectively process raw image data in this context.

This visual comparison serves multiple key purposes:

- **Model Evaluation**: Clearly illustrates which machine learning approach is most effective for grapevine disease detection.
- **Data-Driven Decision Making**: Enables researchers and practitioners to choose the most suitable model based on performance.
- **Benchmarking and Progress Tracking**: If used during different development stages, the graph can also help monitor improvements across training iterations or model adjustments.

Proposal of Model for Grapevine Disease Detection

This flowchart illustrates the overall process used in the study for detecting grapevine diseases using deep learning and image processing techniques.

1. Dataset

The process begins with a **publicly available image dataset** (from Kaggle), containing labeled grape leaf images in four categories:

- **Healthy.**
- **Black Rot.**
- **Esca (Black Measles).**
- **Leaf Blight.**

These labeled images serve as input data for training and testing the machine learning models.

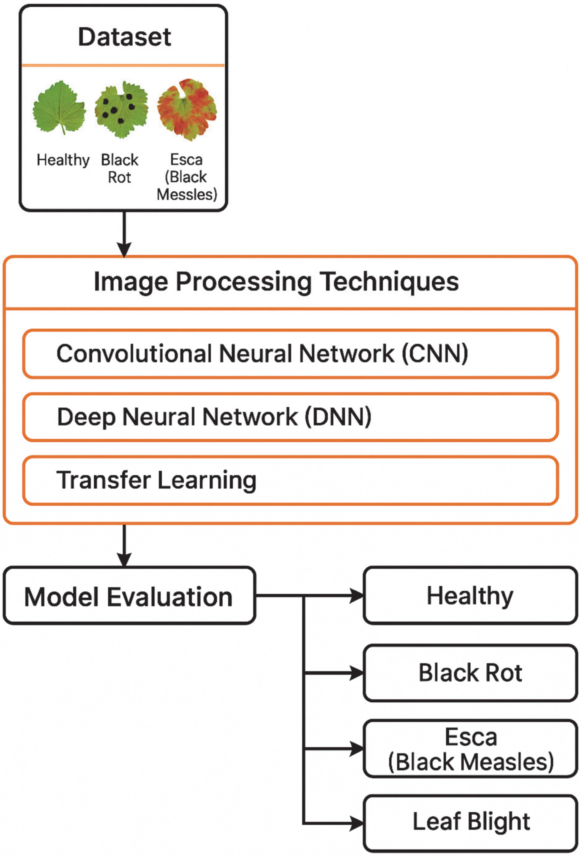

Figure 2 - Proposed model for grapevine disease detection

2. Image Processing Techniques

The dataset is fed into a suite of **deep learning models** designed to process and learn patterns from the leaf images. Three types of models are used:

- **Convolutional Neural Network (CNN):** A popular deep learning model for image recognition, extracting spatial features from the leaf images.
- **Deep Neural Network (DNN):** A more generic deep learning model with fully connected layers, though it performed poorly in this case.
- **Transfer Learning:** Pre-trained models adapted for grapevine disease detection, which delivered the highest accuracy.

3. Model Evaluation

Each model is evaluated on the same dataset to compare performance objectively. Key evaluation metrics (like accuracy) help determine the most effective model for disease classification.

- CNN: 97.40% accuracy.
- DNN: 31.41% accuracy.
- Transfer Learning: 98.84% accuracy.

4. Classification Output

Based on the best-performing model, each grape leaf image is classified into one of the four categories:

- **Healthy.**
- **Black Rot.**
- **Esca (Black Measles).**
- **Leaf Blight.**

This pipeline highlights how artificial intelligence, especially transfer learning, can significantly enhance precision agriculture by enabling accurate and automated identification of grapevine diseases, aiding in early intervention and crop health management.

Conclusion and Future Works

This project effectively demonstrated the potential of deep learning techniques in the automated classification of grapevine diseases. Among the models evaluated, **Transfer Learning** delivered the highest performance, achieving an impressive **accuracy of 98.84%**, followed closely by **Convolutional Neural Networks (CNNs)** with **97.40% accuracy**. In contrast, the **Deep Neural Network (DNN)** performed poorly, with only **31.41% accuracy**, largely due to its limited capability in extracting spatial features from image data (as detailed in **Table 1**).

The comparative analysis in **Table 2** further emphasizes the strengths and weaknesses of each model. CNNs demonstrated strong image processing capabilities and high accuracy but required substantial computational resources and large datasets. Transfer Learning outperformed the other approaches, benefiting from pre-trained feature extractors, reduced training time, and the ability to generalize well with limited data. However, it also introduced certain limitations, such as restricted flexibility and dependence on existing models. Meanwhile, the DNN's simple architecture was not well-suited for the complexities of image-based classification, leading to significant underperformance.

Table 1 - Results from algorithm testing

Model	Training Process	Accuracy (%)	Saved Model Name	Issues during Analysis
CNN	Training started... Training completed.	97.40	grape_disease_model.h5	No issues
DNN	Training started... Training completed.	31.41	grape_disease_dnn_model.h5	No issues
Transfer Learning	Training started... Training completed... Model evaluation...	98.84	grape_disease_transfer_model.h5	Error: 'tf' not defined during analysis

Table 2 - Comparison of algorithm performance

Model	Test Accuracy (%)	Advantages	Disadvantages
CNN	97.40	- Strong at extracting image features - High accuracy - Efficient in handling spatial data	- Requires large datasets - High computational cost
DNN	31.41	- Simpler architecture - Versatile for many tasks	- Poor feature extraction from images - Susceptible to overfitting
Transfer Learning	98.84	- Very high accuracy - Reduced training time - Performs well with small datasets	- Limited flexibility - Dependency on pre-trained models

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Evaluating Robotics Technologies for Grape Cultivation: A Comparative Analysis of Current Solutions

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Abstract

The viticulture sector shows growth potential but faces challenges related to labor shortages, productivity, and quality control. This paper examines various robotic technologies used in grape cultivation and assesses their suitability for addressing these issues. By analyzing the current state of the grape-growing industry and the potential benefits of advanced robotic solutions, this study aims to offer recommendations for integrating robotics to improve efficiency and sustainability.
The research provides an overview and comparison of agricultural robots designed for tasks such as harvesting, spraying, imaging, and adapting to climate change. It also considers the costs of these robots and the infrastructure required for their implementation. Additionally, recommendations are made for large, medium, and small-scale farmers, suggesting suitable robotic technologies based on their income from grape cultivation.
Keywords: Smart agriculture, grape harvesting robots, agriculture robots, climate changes, robots for spraying, robots for photo-typing, and robots for monitoring climate change.

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Introduction

The increasing demand for efficient and sustainable agricultural practices

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has led to the rapid development and deployment of robotic systems in grape cultivation. This review paper aims to compare various robotic technologies utilized in grape harvesting, spraying, photo-taking, and climate monitoring, highlighting their functionalities, advantages, and limitations.

The manual labor-intensive nature of grape harvesting has prompted the exploration of automated solutions, such as dual-arm harvesting robots that enhance operational efficiency and reduce labor costs [1], [2]. These robots employ advanced algorithms and machine vision technologies to identify and harvest grapes with precision, thereby improving the quality and consistency of the produce [3],[4]. In addition to harvesting, robotic systems are increasingly being employed for targeted spraying applications. These robots utilize sophisticated sensors and imaging techniques to detect grape clusters and apply pesticides selectively, minimizing chemical usage and environmental impact [5]. The integration of machine vision in these systems allows for real-time monitoring of grape health and maturity, enabling growers to make informed decisions regarding vineyard management [6], [7]. Furthermore, the use of robots for climate monitoring has become essential in adapting to the challenges posed by climate change. These systems can collect and analyze environmental data, providing valuable insights that help optimize grape cultivation practices [8], [9]. This comparative analysis will delve into the technological advancements in robotic systems for grape cultivation, examining their roles in enhancing productivity and sustainability.

By synthesizing findings from various studies, this paper will provide a comprehensive overview of the current state of agricultural robotics in viticulture, emphasizing the potential for future developments and their implications for the grape industry.

Viticulture has a long history in many regions, including Kosovo, where the climate and soil conditions are conducive to grape cultivation. However, the grape-growing industry in Kosovo faces several challenges, including labor shortages, high operational costs, and the need for improved efficiency. Robotic technologies offer promising solutions to these issues. This paper reviews various grape robotics technologies and assesses their suitability for the Kosovo context, focusing on their potential benefits, costs, and implementation challenges. Also based on the grape cultivation farm size and their income we will propose the right technology to use to increase the grape quality and quantity.

The common threads between these types of robots will be analyzed and listed in this research and also availability and scalability are discussed. Three main factors were crucial when we chose the robot which will help in grape cultivation is the cost, climate changes in different regions, and capability.

To propose the right technologies for farmers it need to analyze the incomes of farmers from grape cultivation and we categorize our proposal into three categories, robots which can be implemented by large farms, medium and small.

The main aim of this paper is to propose the right technologies to be used by farmers to increase the quality and quantity of grapes.

The following in the second section is related work on this particular topic compared to what we have done in this research. The third section presents the research methodology which is used in this paper. The fourth section shows the comparison of robots used for harvesting, photo-taking, spraying, and monitoring climate changes in grape cultivation. Then in the fifth section, the comparison of climate in different regions is presented. In the six sections analyses of the Kosovo case and recommendations for farmers are presented. And last is the conclusion and future works.

Related Works

This year, there has been a growing number of research in smart agriculture because we have recently been facing climate change, and we need to use technologies to protect agriproducts from climate change and other factors. Here, we are going to present the recent research and proposals of different authors for robots used in harvesting, Photo-typing, and helping farmers with climate growth concerns.

The adoption of robotics in grape farming [79] has become a groundbreaking solution to tackle numerous issues viticulturists encounter, especially regarding climate change, efficient resource use, and labor productivity. This overview examines how robots are being applied in tasks like grape harvesting, crop monitoring, and spraying, while also considering the effects of climate change on vineyard practices [79].

Robotic systems, including autonomous aerial robots and all-terrain mobile manipulators, have been developed to enhance vineyard management practices. These systems facilitate tasks such as vineyard surveillance, targeted spraying, and even harvesting in challenging terrains where traditional machinery may fail [10]. The use of lightweight autonomous aerial robots (LAAR) allows for effective monitoring and data collection, which is crucial in adapting to the dynamic conditions of grape cultivation [10]. Moreover, the economic viability of collaborative robots (cobots) in viticulture has been demonstrated, showing their potential to reduce labor costs while improving efficiency in operations like pruning and herbiciding [11].

Climate change poses significant threats to grape cultivation, necessitating the adoption of modern technologies for continuous monitoring and decision-making [12]. The implementation of smart technologies, including artificial intelligence and various sensing technologies, enables viticulturists to adapt to changing climatic conditions effectively [13]. For instance, systems like VineSens utilize a wireless sensor network to provide real-time data on environmental conditions, aiding in disease prevention and resource optimization [14]. This proactive approach not only conserves biodiversity but also enhances the resilience of grapevines against stressors associated with climate change [12].

In terms of pest management, the development of targeted spraying systems has revolutionized how viticulturists protect their crops. Advanced ultrasonic and laser-based systems allow for precise application of pesticides, significantly reducing chemical usage while maintaining effectiveness [15],[16]. These systems adapt to the changing structure of the vineyard canopy throughout the growing season, optimizing spray volumes and minimizing environmental impact [17], [18]. The integration of machine vision systems further enhances the capability of robots to identify and respond to specific vineyard conditions, leading to more efficient pest management strategies [19].

The challenges posed by climate change, such as fluctuating temperatures and increased disease pressure, further underscore the need for innovative approaches in grape cultivation [20]. Research indicates that specific climatic conditions can enhance the accumulation of beneficial compounds in grapes, such as anthocyanins, which are crucial for wine quality [21], [22]. Therefore, the ability to monitor and adapt to these conditions using robotic systems not only supports sustainable practices but also improves the overall quality of grape production.

In conclusion, the application of robotics in grape cultivation is multifaceted, addressing critical areas such as harvesting, monitoring, and pest management while also responding to the challenges posed by climate change. The continuous evolution of these technologies promises to enhance the sustainability and efficiency of viticulture, ensuring that grape growers can meet both economic and environmental goals.

The authors in this paper [23] cover the latest advancements in mobile robots for precision agriculture. They start with a brief introduction to precision agriculture. Then, it focuses on two main areas. First, it overviews popular technologies for monitoring crops, fields, and soil. Second, it discusses key land-based robotic solutions and their features. The review concludes with a case study of a robot developed by the authors. It highlights current trends in agricultural robotics research. The review finds that vision and point cloud detection are the most studied technologies. Most robots are small and used mainly for monitoring. However, there is growing interest in automating other agricultural tasks.

Next, the authors in this paper [24] have done one analytical review and perspectives of robotics in horticulture. They have compared different sensors used to navigate robotic platforms and propose the LiDAR sensor as best.

The challenges to implement robots in agriculture are presented in this paper [25] and they mentioned that the supporting infrastructure for robots is very important as networking, HRI tools, complex robotics design, and a skilled workforce. They also concluded that the prices of robots are high.

A comparison between phenotype detection robots for agriculture and forestry is presented in this paper [26] where the authors describe the infrastructure that is needed to operate such robots. Also, the challenges and future direction in the development of phenotype robots are given. They have compared and described three robots Rovers, PTZ, and RoAD which are used for phenotype detection by taking photos of plants and then analyzing them to detect plan anomalies.

The use of artificial intelligence and robots in agriculture is presented in this paper [27], they show that the use of robots in agriculture saves time and effort, reduces cost, and enhances productivity. However, they recommended further improvement and development in agriculture robots which is important to create faster algorithms for processing and to improve the communication between platforms and robotic tools. Also, they concluded that most robots in agriculture use Fuzzy Logic and ANN (Artificial Neural Network) as AI techniques.

The authors in this research [81] compared different types of robots used for harvesting beery, grape, and other agro-products. The advantages and disadvantages of different berry-picking robots are presented. They propose to use different sensors in one robot because many of them have their advantages which the others don't have in fruit identification.

Materials and Methods

To conduct this study, we have used different research methodologies. First of all, we have presented the research question which is:

1. What would be the appropriate grape robotics for Kosovo and in General?
2. Why do we need to use robots in grape cultivation?

The main aim of this systematic literature review is to determine and answer the main question we have for this area. Search is done on five main topics which are related to our field of research:

- Robots used for grape cultivation;
- Robots used for harvesting in grape cultivation;
- Robots used for photo-taking in grape cultivation;
- Robots used for spraying in grape cultivation;
- Robots used for monitoring climate changes in grape cultivation;

For each of these research topics, a large number of papers was shown in the result but we selected the which are of interest. The idea is to extract a comparative table related to different parameters and extract the list of robots that are used for grape cultivation and what robots are proposed based on our interests. Also, we analyze the questions that are the common threads of these robots in our four categories of interest and the challenges they have?

Table 1 - Search String

Search string	No. of papers in result	No. of papers we choose
Robots used for grape cultivation;	320	27
Robots used for harvesting in grape cultivation	120	13
Robots used for photo-taking in grape cultivation;	98	9
Robots used for spraying in grape cultivation;	71	7
Robots used for monitoring climate changes in grape cultivation;	48	10

Based on the search string we provide in Table 1 we have searched the most credible digital libraries such as IEEE-Xplore, ACM, SpringerLink, ResearchGate, EBSCO host, etc. The larger number of papers is when the topic is more general as in our case where the search query is just robots used for grape cultivation, when the topic is more focused on our research area the number of papers is smaller. From the result we get we just pick up the paper how are related to robots used for grape cultivation. The filtering also is done are chosen papers that describe robots used for harvesting, spraying, photo-taking, and monitoring climate changes. Also, the papers are selected just for the last five years. As a result, we selected just 66 papers out of 657 papers we read.

From our review, we have identified common features of robots used in grape cultivation, which are presented in a comparative table. The prices of these robots are also included. We have categorized farms as large, medium, or small, and for each robot, we specify the type of farm for which it is most appropriate.

We have also used a report published by the Ministry of Agriculture, Forestry, and Rural Development in Kosovo, which presents data on vineyards and grape cultivation [76][77][78]. From these reports, we gathered information on the number of farms in Kosovo, and their income from grape cultivation, and, based on this data, we can recommend the appropriate type of robot to use.

Results and Discussion [Comparison of robots used for grape cultivation]

Robots are increasingly being used in grape cultivation to improve efficiency, reduce labor costs, and optimize the quality of the produce. Here's a comparison of the different types of robots used for various tasks like harvesting, photo-taking, spraying, and monitoring climate changes in grape vineyards.

3.1. Robots for harvesting

The advancement of robots for harvesting has become a key area of focus in agricultural technology, aiming to tackle labor shortages and enhance efficiency in crop production. Various robots have been developed and tested for different crops, each featuring distinct system architectures, visual perception methods, and performance indicators.

Key Insights
System Architecture and Components:
- Most harvesting robots are built with a mobile platform, a robotic arm or manipulator, and sophisticated vision systems for detecting crops and navigating the field [28][29][33][81].
- These robots often include specialized end-effectors designed to handle specific crops delicately to avoid damage [32][35][36][81].

Performance Metrics:
- Success rates for harvesting can vary significantly, with some robots achieving up to 92% success under optimal conditions [31][32][36].
- Harvesting cycle times range from 1 second to over 40 seconds, depending on the crop and robot design [30] [31] [32].
- Damage to crops during harvesting is generally minimal but can vary based on the robot's design and the type of crop [30] [31].

Challenges and Future Directions:
- Major challenges include improving the speed and accuracy of robots,

enhancing their performance in unstructured environments, and reducing implementation costs [28] [30] [33].
- Future research is likely to focus on better integration of sensing and robotic systems, as well as designing crops and environments that are more suited to robotic harvesting [30] [36] [37].

Specific Crop Applications:
- Robots have been developed and tested for a range of crops, including fruits like apples, strawberries, and cherries, as well as vegetables like cucumbers and sweet peppers [32] [33] [35] [36].
- High-value crops such as kiwis and grapes are also a focus, with specialized robots addressing the unique challenges these crops present [30] [34].

Cooperative and Autonomous Systems:
- Some research explores the use of multiple cooperating robots to enhance efficiency in tasks such as grape harvesting [34].
- Autonomous systems that can operate continuously and independently have shown promise in improving the speed and reliability of the harvesting process [31] [32].

Harvesting robots offer considerable potential for boosting agricultural efficiency, particularly for labor-intensive and high-value crops. While current systems show varying degrees of success, ongoing research aims to address challenges related to speed, accuracy, and adaptability. Future advancements are expected to come from improved integration of robotic and sensing technologies and the co-design of crops and environments to optimize harvesting performance.

3.2. Robots for photo-taking

The use of robots for photo-taking and harvesting of grapes is a growing area of research in smart agriculture. Various models and techniques have been developed to improve the accuracy, efficiency, and robustness of these robots in different environmental conditions.

Key Insights
Transformer and CNN Models for Grape Detection:
- Swin Transformer and DETR models are effective for grape bunch detection, with SwinGD achieving a high mAP value of 94% under challenging conditions like overexposure and occlusion. YOLOX also

shows high accuracy and better detection effects compared to traditional CNN models like Faster-RCNN, SSD, and YOLO [38].

Deep Learning and Visual Positioning:
- Robots using deep learning and depth cameras for visual positioning of grapes demonstrate high detection accuracy and precise grape rod positioning, leading to effective picking [39].

Binocular Stereo Vision for Spatial Information:
- A method using binocular stereo vision to locate cutting points and determine the bounding volume of grape clusters shows a success rate of approximately 87% for cutting point detection and high accuracy in spatial localization [40].

Hand-Eye Coordination Simulation:
- A study by [41] introduces a multi-interaction simulation approach for enhancing hand-eye coordination in grape-harvesting robots. The method demonstrates an average execution time of 6.5 seconds and achieves a success rate of 83.3% in accurately identifying and grasping the correct picking points.

Cooperative Harvesting with Heterogeneous Robots:
- A cooperative strategy involving two heterogeneous robots, where one harvests grapes and the other supports by carrying the harvested grapes, ensures safe and effective interactions and demonstrates the potential for enhanced cooperation in agricultural applications [5].

Lightweight YOLO Model for Dense and Occluded Grapes:
- The GA-YOLO model, designed with a new backbone network and spatial feature fusion mechanism, improves detection accuracy (mAP of 96.87%), speed (55.867 FPS), and reduces model parameters, making it suitable for mobile deployment [42].

Night-Time Detection with CCD Vision Sensor:
- A method using a CCD vision sensor with artificial illumination for night-time detection and picking-point positioning of green grapes achieves a detection accuracy of 91.67% and a picking-point calculation accuracy up to 92.5% [43].

Robots for grape photo-taking and harvesting have seen significant advancements through the use of various models and techniques. Transformer-based models like SwinGD and lightweight YOLO models show high accuracy and efficiency in detecting grape bunches, even under challenging conditions. Deep learning and visual positioning enhance the precision of picking, while cooperative strategies and hand-eye coordination simulations further improve the effectiveness of robotic harvesting. Night-time detection methods also provide robust solutions for continuous operation. These advancements collectively contribute to the development of more reliable and efficient grape harvesting robots.

3.3. Robots used for spraying

The use of robots for spraying in grape production aims to enhance precision, reduce pesticide use, and improve environmental sustainability. Various robotic systems have been developed and tested to achieve these goals, each with unique features and capabilities.

Key Insights

Selective Spraying and Precision:

- Previous studies have demonstrated that robots integrated with disease-sensing systems [44][46] and precision-spraying end-effectors are capable of detecting and targeting infected areas. These advanced systems have been shown to reduce pesticide usage by 65% to 85% in comparison to traditional methods [44][46].
- These systems utilize multispectral imaging to identify disease foci and apply pesticides only where needed, enhancing efficiency and reducing environmental impact [44] [46].

Modular and Multifunctional Systems:

- Some robots are designed with modular components, allowing them to perform multiple tasks such as harvesting, berry thinning, spraying, and bagging by changing end-effectors [45].
- This multifunctionality makes them versatile tools in vineyard management, capable of adapting to various tasks beyond spraying [45].

Teleoperation and Human-Robot Interaction (HRI):

- Effective teleoperation of agricultural robots requires optimized human-robot interaction interfaces. Factors such as the number and placement of views, and the type of control input device, significantly impact usability and efficiency [47].
- Recommendations for improving HRI include using multiple views and appropriate control devices to enhance user experience and operational effectiveness [47].

Autonomous Navigation and Spraying:

- Robots using Lidar for plant detection can autonomously navigate and follow vineyard rows, synchronizing spraying actions with the robot's motion to ensure precise application [48].
- This edge-following approach allows for the independent activation of nozzles, further refining the precision of pesticide application [48].

Robotic systems for spraying in grape production offer significant advantages in terms of precision, efficiency, and environmental sustainability. Key features include selective spraying capabilities, modular multifunctionality, effective teleoperation interfaces, and autonomous navigation. These advancements collectively contribute to more sustainable and efficient vineyard management practices.

3.4. Robots for monitoring climate changes

Robots for monitoring climate change in grape cultivation are used to optimize vineyard management and adapt to changing environmental conditions. Here's a comparison of different types of robots and their roles in grape cultivation:

1. Ground Robots

Example: TED (Vineyard Robot by Naïo Technologies) [52]

- Functionality: Ground-based robots like TED help monitor soil conditions, weed control, and crop health.
- Climate Monitoring: Equipped with sensors for soil moisture, temperature, and humidity, ground robots provide real-time data crucial for understanding how changing weather patterns are affecting vineyards.

Advantages:

- Operate closer to crops, allowing high-resolution data collection.
- Can be used for multiple purposes like weeding and spraying in addition to monitoring.

Challenges:

- Limited by terrain and can face difficulty on uneven or sloped vineyards.
- High initial investment.

- Use Case: Monitoring the effects of climate change on soil quality and vine health.

2. Aerial Robots (Drones) [50]

Example: DJI Agras Series [54]

- Functionality: Drones equipped with multi-spectral and thermal cameras capture data on crop health, water stress, and disease detection.
- Climate Monitoring: Drones can quickly survey large vineyard areas and monitor the impact of climate factors like drought, frost, and extreme heat on grapevines.

Advantages:

- o Quick coverage of large areas.
- o Provide aerial imagery that can be used to monitor canopy structure, grape growth, and vine health.

Challenges:

- o Limited flight time and battery life.
- o Potential interference from weather conditions.

- Use Case: Identifying heat stress on grapevines and monitoring irrigation efficiency.

3. Autonomous Sensors and IoT-Enabled Robots [51]

Example: Sensit Smart Vineyard System [55]

- Functionality: Sensors placed throughout the vineyard track microclimate data such as soil moisture, temperature, and air quality.
- Climate Monitoring: IoT-enabled robots combine data from sensors and weather stations, providing real-time analytics on climate-related changes.

Advantages:

- o Continuous, real-time monitoring of environmental conditions.
- o Data-driven decision-making using predictive algorithms.

Challenges:

- o Integration of different sensor systems can be complex.
- o Dependence on wireless connectivity and energy supply.

- Use Case: Monitoring temperature fluctuations and predicting frost risks.

4. Swarm Robotics

Example: SwarmFarm Robotics [56]

- Functionality: Multiple small robots working together to perform tasks such as pest control, soil monitoring, and climate data collection.

- Climate Monitoring: Swarm robots can cover large areas and collect data on humidity, soil health, and temperature fluctuations due to climate change.

Advantages:
- o Scalability: Multiple robots can cover more ground.
- o Flexibility: They can perform simultaneous monitoring of different vineyard sections.

Challenges:
- o Requires sophisticated coordination and communication technology.
- o More complex maintenance compared to single-unit robots.

- Use Case: Mapping the vineyard's microclimate variations due to changing weather patterns.

5. Underwater or Subterranean Robots [49]
Example: Vitirover Mowing Robot [53]
- Functionality: Robots that operate below the soil surface or around vines, focused on monitoring soil quality, root health, and sub-surface water conditions.
- Climate Monitoring: These robots are less common but valuable in tracking the below-ground effects of climate change such as soil erosion and changes in water tables.

Advantages:
- o Can monitor below-ground conditions that impact vine root systems.
- o Useful for irrigation management and soil preservation.

Challenges:
- o Limited by movement constraints below ground.
- o Narrow scope of application.

- Use Case: Assessing how soil moisture and erosion, exacerbated by climate change, affect grapevine growth.

Key Comparison Points:
- Mobility: Drones have high mobility but limited flight time, while ground robots can work longer but are constrained by terrain.
- Data Type: Ground robots focus on microclimates and soil data, whereas aerial drones capture large-scale canopy and heat patterns.

- Adaptability: Swarm robotics offer better scalability and adaptability in large-scale vineyards but are more complex to deploy.
- Cost: Autonomous sensors are more affordable in the long run compared to drones and ground robots, which require significant initial investments.

3.5. Comparison of robots used in grape cultivation for harvesting, spraying, photo-taking, and monitoring climate changes

Robots play a significant role in modernizing grape cultivation, offering a wide range of functionalities across key tasks such as harvesting, spraying, photo-taking, and monitoring climate change. Table 2 presents various research studies conducted on the fourth category of robots, which is the focus of this study. We have identified common features of these robots, as well as the challenges they face, which are also outlined.

Table 2 - Comparison of common threads and challenges between four types of robots 1. Robots used for harvesting; 2. Robots used for photo-taking; 3. Robots used for monitoring climate change; 4. Robots used for spraying

	Common Threads	**Robots for harvesting**	**Robots for photo-taking**	**Robots used for monitoring climate changes**	**Robots used for spraying**
		[28]-[37], [45], [81]	**[5], [38]-[43]**	**[49]-[56]**	**[44]-[48]**
	Used for grape	[28]-[37], [45], [81]	[5], [38]-[43]	[49]-[56]	[44]-[48]
	Measures pesticides in grape			Yes	Yes
	Used for other agro-products	[30], [32]-[36], [81]	Yes	Yes	yes
	Stationary			[51]	
	Mobile robots	yes	yes	Yes	Yes
	Photo taking		yes	[54]	[44],[46]
	Detecting illnesses		Yes	[54]	
	Grape spraying				Yes
Precision Agriculture	**Targeted Actions**		[40]		
	Data-Driven Decisions		[38][42]	Yes	
Automation and Efficiency	**Labor Savings**	yes	yes	Yes	Yes
	Consistency and Speed	[30] [31] [32] [81]	[41][42]	[49]-[56]	[47]
Environmental Monitoring and Adaptation	**Climate Resilience**			[49]-[56]	
	Real-Time Data	yes	yes	yes	Yes
Sustainability and Resource Management	**Efficient Resource Use**	yes	yes	yes	Yes
	Reduced Chemical Use			yes	Yes

Image Analysis and AI	**Disease and Pest Detection**			yes	Yes
	Yield Estimation			Yes	
Integration and Scalability	**System Integration, cooperating with other robots**	[34] [81]	[5]	yes	Yes
	Scalable Solutions	[34]	yes	yes	Yes
Sustainability and Resource Management	**Water and Energy Efficiency**	Yes		yes	
	Environmentally Friendly Practices			yes	Yes
	Handle crops	[32][35][36]	[5]		
Challenges and future	**To reduce the cost of robots**	HIGH	HIGH	HIGH, sensors are cheaper than moving robots	HIGH
	Improve speed and accuracy	[28] [30] [33] [81]			
	Work in an unstructured environment	[28] [30] [33] [81]		Yes	
	Integration of sensing and robotics	[28] [30] [33] [81]		Yes	[45]
	Design of crops and environment to better suit robots use in agriculture	[30], [36], [37] [81]		[55]	
	Night time grape detection		[43]		
	Limited flight time and battery			[54], [55]	

The price of the harvesting robots listed in Table 3 depends on their capabilities, functionalities, and the region where they are used. Generally, more advanced models with AI-driven systems and multipurpose functionalities are more expensive. The robots in Table 3 are categorized by the type of farm they are intended for – large, medium, or small. Additionally, a red (x) indicates secondary tasks that the robots can perform, while a black (X) indicates the primary task for which they were developed.

DJI Drones (e.g., Agras or Phantom series) are cost-effective for vineyards of various sizes and are widely used due to their ease of use and advanced camera features. Ground-based robots like VineRobot and Agrobot are typically more expensive due to their sophisticated imaging, mobility, and the need for high-end sensor integration. For small to medium-sized vineyards, drones are often the preferred option due to their flexibility and lower cost compared to full-fledged ground robots. The prices are presented in table 3.

The systems used for monitoring climate changes presented in table 3 represent a significant investment, but they offer substantial benefits in reducing crop losses due to climate variability, optimizing water usage, and improving overall vineyard management. The price varies widely depending on the scale of the vineyard and the level of data and automation required.
Robots used for spraying like:

- **Robots like GUSS and Fendt Rogator** are high-end solutions with larger capacities and more sophisticated technology, making them suitable for larger vineyards. They tend to have higher costs, but their efficiency and precision can lead to savings in labor and chemical use over time.
- **Smaller robots like Vitirover** are more affordable and suitable for smaller or more specialized vineyards, and their solar-powered operation makes them an environmentally friendly choice.

These robots represent significant investments but offer long-term savings through reduced labor and chemical costs, improved precision, and increased yield quality. The prices are presented in table 3.

Table 3 - Comparison of prices of different types of robots from 4 categories of use

Robot	COST	Robots for harvesting	Robots for photo-taking	Robots used for monitoring climate changes	Robots used for spraying	Type of farm
Wall-Ye V.I.N. Robot	$32,000 [57]	**X**	x	x		**Small to Medium**
RoboVigneron	$50,000 to $100,000 [58]	**X**	x	X		**Medium to Large**
Agrobot Grape Picker	$100,000 to $250,000 [59]	**X**				**Large**
VineScout: Approx	$32,000 [60]	**X**	x	X		**Medium to Large**
Ecorobotix (prototype)	$150,000 or more. [61]	**X**				**Small to Medium**
DJI Agras T30 (Drone)	$15,000 to $20,000 [62]		**X**	x	x	**Large**
Parrot Anafi USA (Drone)	$7,000 [63]		**X**	x		**Small to Medium**
VineRobot	$30,000 to $40,000 [64]		**X**	x		**Medium**
Sentera PHX (Drone)	$12,500 [65]		**X**	x		**Medium to Large**
Agrobot E-Series	$30,000 to $50,000 [66]	x	**X**			**Large**

TED (Vineyard Robot by Naïo Technologies)	$210,740 [67]			X		**Medium to Large**
DJI Agras Series	$599 to $14,999 [68]		x	X	x	**Large**
Sensit Smart Vineyard System	$1,500 [69]			X		**Medium to Large**
SwarmFarm Robotics	$86,000 [56]		X	X	x	**Large**
Vitirover Mowing Robot	$10,437.00 [70]			X		**Small to Medium**
GUSS (Global Unmanned Spray System)	$250,000 [71]				x	**Large**
Vitirover	$32,000–$53,000 [72]				X	**Small to Medium**
Fendt Rogator 300 Series	$300,000–$350,000 [73]				x	**Large**
Vulcan Agri Sprayer	$50,000–$70,000 [74]				x	**Large**
AgXeed AgBot	$128,000 [75]	x		x	x	**Large**

4. Comparison of climate in different regions

Climate plays a crucial role in grape cultivation as it affects grape ripening, sugar accumulation, acidity, and overall quality of the wine. Each region you mentioned—Balkans, Europe, America, and Australia – experiences unique climate variations that influence grape varieties and wine styles.

1. Balkans

- Climate: The Balkans are known for a mix of Mediterranean and continental climates. Coastal areas, like Croatia, have Mediterranean conditions with warm summers and mild winters, ideal for heat-loving grapes. Inland regions like Kosovo, North Macedonia, and Bulgaria experience more extreme continental climates with cold winters and hot summers.

Impact on Grapes:

- Mediterranean regions (e.g., along the Adriatic Sea) favor varieties like Plavac Mali, Zinfandel, and Chardonnay.
- Continental regions (e.g., Serbia and Bulgaria) tend to grow Riesling, Cabernet Sauvignon, and Pinot Noir, which tolerate colder winters and have shorter growing seasons.

2. Western & Central Europe

- Climate: Europe's diverse climates range from cool maritime (Western Europe, like Bordeaux) to continental (Central Europe, like Germany) and Mediterranean (Southern France, Spain, and Italy).

Impact on Grapes:

- o Cool, maritime regions (e.g., Bordeaux, Champagne) produce Merlot, Cabernet Franc, and Chardonnay.
- o Central Europe, with its continental climates (Germany, Austria), is known for Riesling and Pinot Noir, where the short summers and cool fall encourage slow ripening and maintain high acidity.
- o Mediterranean areas (Italy, Southern France, Spain) support Sangiovese, Grenache, Syrah, and Tempranillo, as the warm climate produces ripe, full-bodied wines.

3. North and South America

North America:

- o In previous studies [80], U.S. wine-growing regions, such as California, are described as having a Mediterranean climate, characterized by hot, dry summers and mild, wet winters. In contrast, coastal regions like Oregon and Washington are noted for their maritime climates, which feature cooler and more temperate conditions.

Impact on Grapes:

- ▪ California supports Cabernet Sauvignon, Zinfandel, and Chardonnay due to its warm climate.
- ▪ Oregon and Washington focus on cooler-climate grapes like Pinot Noir and Riesling.

South America:

- o Climate: Argentina, Chile, and parts of Brazil and Uruguay have Mediterranean climates, but regions like Mendoza are semi-arid, relying on irrigation from the Andes. High-altitude regions provide cool nights and high sunlight during the day.

Impact on Grapes:

- ▪ Argentina is known for Malbec and Torrontés in the high-altitude, semi-arid Mendoza region.
- ▪ Chile is recognized for Carménère, Cabernet Sauvignon, and Sauvignon Blanc in areas like Maipo and Casablanca valleys.

4. Australia

- Climate: Australia's wine regions span from cool-climate areas like Tasmania and parts of Victoria to warm Mediterranean climates in regions like Barossa Valley. Some inland regions have hotter, arid conditions.

Impact on Grapes:

- o Cooler regions (e.g., Yarra Valley, Tasmania) favor Pinot Noir and Chardonnay.
- o Warm, Mediterranean regions (e.g., Barossa Valley, McLaren Vale) are famous for Shiraz (Syrah) and Grenache, which thrive in the heat and produce bold, rich wines.

Summary of Climate Influence on Grapes

- Mediterranean climates (Balkans, Southern Europe, parts of Australia, South America) support heat-tolerant varieties like Syrah, Grenache, Malbec, and Zinfandel.
- Continental climates (Central Europe, inland Balkans, Eastern U.S.) promote higher acidity and are ideal for Riesling, Pinot Noir, and Chardonnay.
- Maritime climates (Western Europe, Oregon, coastal Australia) have more moderate temperatures, supporting varieties like Merlot, Cabernet Sauvignon, and Sauvignon Blanc.

5. Analyses the Kosovo case and recommendations for farmers

According to previous research on Kosovo's viticultural regions [76], the area is divided into distinct vineyard zones, specialized localities for grape cultivation, and smaller grape-growing units. The five primary vineyard regions account for 3,400 hectares of the total 3,472 hectares dedicated to viticulture, as shown in the accompanying figure [76].

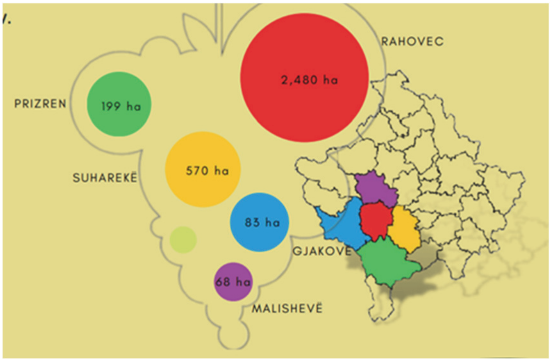

Figure 1 - Vineyards in Kosovo by city [76]

According to the report [76], in 2022, vineyard areas expanded by only 0.03% (1 hectare). The area dedicated to table grapes grew by 1.39%, while the area for wine grapes declined by 0.47%. Overall grape production decreased by 11.4%, with yields also falling by 11.4% compared to 2021.

These changes were primarily due to challenges during the harvest season, as heavy rainfall in September and October caused significant damage to the grape crops [76].

According to the report [76], Kosovo experiences a mild continental climate, influenced by Mediterranean weather patterns that enter through the White Drin Valley. Winters are typically cold, while summers are hot, providing agroclimatic conditions that are generally favorable for viticulture, particularly for early grape varieties. However, late varieties may encounter challenges during harvest time. The study [76] highlights that Kosovo enjoys an average of 276 sunny days annually, which plays a crucial role in grape maturation, particularly in areas famous for their wine production.

Vineyards in Kosovo [76] are mainly found in elevated, sloped regions that receive excellent sunlight. The cultivation of grapes [76] occurs at altitudes between 300 and 600 meters, while a limited number of vineyards are located at elevations exceeding 600 meters. The findings [76] indicate that these land conditions are highly favorable for vineyard establishment, given that much of the terrain is unsuitable for other types of agriculture.

The geographic characteristics of Kosovo [76] provide ideal Mediterranean-like climate conditions for viticulture, offering significant potential for both the quantity and quality of grape production. The research [76] indicates that the impact of the White Drin and the various river valleys that flow from east to west contributes to a range of climates and microclimates, thereby enhancing the economic potential for vineyard cultivation.

The study [76] highlights that optimal sunlight exposure, moderate annual temperatures, and adequate rainfall during the autumn, winter, and spring months are crucial for maintaining soil water reserves. This, in turn, supports the ripening of grapes from mid-July to mid-October, ultimately contributing to elevated production yields.

Research [76] conducted in 1988, 1993, and 2009 offers insights into the land characteristics of the vineyard regions in Rahovec Municipality. These studies [76] indicate that the predominant soil type in the area is "smonitza," along with the presence of some reddish varieties, which vary based on the specific location within the region.

According to the report [76], the varied topography of the vineyard region, with the majority of vineyards situated at altitudes ranging from 300 to 600 meters, fosters the distinctive climatic conditions that are particularly conducive to grape cultivation in Kosovo [76].

5.1. Current State of Viticulture in Kosovo

Kosovo's viticulture sector is predominantly made up of small to medium-sized vineyards, with traditional farming practices still widely used. Labor shortages are a concern, and the sector is looking for ways to modernize and boost productivity. The introduction of robotics could help address these challenges, but it must be tailored to the specific needs and limitations of local producers.

According to a report [77], the grape cultivation and winemaking industry in Kosovo [77] has historically played a vital role in the nation's socio-economic growth and remains a significant contributor. At present, vineyards span approximately 3,472 hectares, predominantly situated in municipalities such as Rahovec, Suhareka, Gjakova, and Malisheva, which are identified as the primary regions for viticulture. Around 5,000 households are directly engaged in this sector, while an additional 30,000 households are indirectly connected to it [77].

In Table 4, we show the number of hectares dedicated to grape cultivation in Kosovo from 2018 to 2022, highlighting a steady increase in vineyard area, thanks in part to government grants for planting new grape crops. However, the data also indicates a decline in grape production in 2022 due to climate change. Despite this, grape prices have risen, signaling a promising opportunity for further investment in the sector.

Table 4 - Grape production in Kosovo from 2018-2022 [77] [78]

		2018	2019	2020	2021	2022
Total number of vineyards						8,473
Total number of farmers						4,960
Area, ha	**Vineyards**	3,272	3,367	3,437	3,471	3,472
	Wine grape	2,455	2,489	2,526	2,533	2,521
	Table grape	816	878	911	938	951
Production, t	**Vineyards**	27,322	19,318	26,330	26,527	23,506
	Wine grape	22,324	14,772	20,049	19,091	16,461
	Table grape	4,998	4,546	6,281	7,435	7,045
Yield, t/ha	**Vineyards**	8.4	5.7	7.7	7.6	6.8
	Table grape	6.1	5.2	6.9	7.9	7.0

	Wine grape	9.1	5.9	7.9	7.5	16.5
Grape price on the market (euro)	**Table grape**	1.09	0.98	1.09	1.20	1.52
Grape price on farm (euro)	**Table grape**	/	0.68	0.63	0.53	0.69
	Wine grape	/	0.21	0.24	0.19	0.23
Wine production, '000 litra	**Total wine**	11,744	5,754	9,429	7,785	7,862
	White wine	6,234	3,380	5,100	4,744	4,643
	Red wine	5,441	2,325	4,295	3,001	3,140
	Rose wine	69	49	35	40	79
The number of farmers who applied for government grants for grape cultivation		3,012	2,939	2,919	35	2,722

5.2. Recommendations

To effectively integrate grape robotics technologies in Kosovo, the following recommendations are proposed:

1. **Improve the infrastructure:** In Kosovo, there is not the appropriate infrastructure. They need to have Reliable Internet Connectivity; Data Collection and Storage; Sensor Networks; Robotic Control Systems; Power Supply Infrastructure; GPS and Mapping Systems; Data Security and Cybersecurity.
2. **Grants for smart farms:** The Ministry of Agriculture, Forestry, and Rural Development in Kosovo needs to develop a grant program that will provide funds for Farmers to buy robots which will help them to improve the quality and quantity of their agro-products.
3. **Pilot Programs**: Implement pilot programs to test the suitability and effectiveness of various robotics technologies in local conditions. This will provide insights into their practical applications and benefits.
4. **Training and Support**: Provide training and technical support to local producers to ensure proper use and maintenance of robotics technologies.
5. **Funding and Incentives**: Explore funding opportunities and incentives to support the adoption of robotics technologies, especially for small and medium-sized vineyards.
6. **Collaboration with Technology Providers**: Foster partnerships with robotics technology providers to customize solutions for the specific needs of Kosovo's viticulture sector.

7. **Ongoing Research**: Continue research into emerging robotics technologies and their potential applications in viticulture to stay abreast of advancements and opportunities.

6. Conclusion

In conclusion, the adoption of robots in vineyards is growing rapidly, and research in this area is extensive. Our study reveals that a wide variety of robots are employed for tasks such as harvesting, spraying, imaging, and climate monitoring. We highlight the most recent advancements in robotics that utilize AI and cutting-edge technologies, helping farms improve both the quality and yield of their grape production. Additionally, in recent years, cost-effective data collection methods have emerged, including the use of stationary sensors embedded in grapevines that provide real-time data.

The integration of robotics technology into Kosovo's grape-growing industry has the potential to address labor shortages, improve efficiency, and enhance grape quality. By selecting and implementing the right technologies, Kosovo can modernize its viticulture sector and increase its competitiveness in the global market. Further research and pilot programs will be crucial in identifying the most suitable solutions for local conditions.

Based on our research, most grape farms in Kosovo are small to medium-sized. As shown in Table 3 of this paper, these farms can choose robots specifically suited for small and medium-scale operations. In the end, we present the recommendations for the Kosovo case to be able to use robots in grape cultivation.

Income from grape cultivation in Kosovo is on the rise, partly due to government grants provided to grape farmers. However, climate change has impacted grape production, making the adoption of smart technologies in farms essential.

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Sustainable Resilience: Linking Climate-Related Economic Losses to Progress on the Sustainable Development Goals in Europe

by *Oksana Liashenko*[*], *Olena Mykhajlovska*[**], *Pavlo Halimon*[***], *Sergey Selyutin*[****], *Tetiana Shestakovska*[*****]

Abstract

The authors investigate whether progress on the Sustainable Development Goals (SDGs) is associated with the magnitude of climate-related economic losses across European countries. Drawing on typological classifications, disaggregated SDG indicators, and Granger causality tests, the study explores dynamic interactions between development performance and climate-related vulnerability. While no stable correlation emerges across all cases, a pattern of reactive adaptation is observed in high-loss countries, where improvements in SDG 13 often follow damaging events. These findings underscore the importance of aligning development policy with climate resilience frameworks and highlight the need for stronger integration between long-term sustainability planning and risk governance strategies.
Keywords: Sustainable Development Goals, Climate Losses, Europe, Resilience, Granger Causality, Policy Integration.

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Introduction

Climate-related economic losses pose an increasingly urgent challenge for European countries. The increasing intensity and frequency of extreme weather events, such as floods, heatwaves, droughts, and storms, have resulted in substantial financial burdens. According to the European Environment Agency (EEA), cumulative damages across the EU have surpassed €650 billion between 1980 and 2023. These economic losses not only disrupt national economies and infrastructure systems but also place considerable strain on the long-term achievement of the Sustainable Development Goals (SDGs), particularly Goals 9 (Industry, Innovation and Infrastructure), 11 (Sustainable Cities and Communities), and 13 (Climate Action).

Despite a growing body of research on climate-related hazards and sustainable development, few studies have systematically examined the empirical relationship between these two concepts. Much of the existing literature treats sustainable development and climate vulnerability as parallel but separate domains. Consequently, little is known about whether progress in SDG implementation leads to a measurable reduction in climate-related economic losses, or whether these losses, conversely, catalyse development responses.

This study frames this intersection through the lens of sustainable resilience. This concept refers to a country's ability to absorb, adapt to, and recover from climate-related shocks without compromising its long-term development objectives. Unlike short-term or reactive adaptation, sustainable resilience emphasises the alignment of resilience strategies with structural development objectives, including institutional strength, urban planning, and infrastructure investment. It reflects the idea that genuine resilience must be development-compatible, forward-looking, and durable in the face of compounding crises.

Addressing the existing analytical gap, this article investigates whether sustainable development and vulnerability reduction co-evolve in a statistically meaningful manner across European countries. The core aim is to explore the potential for structural linkages or feedback effects between SDG performance and economic climate losses. Specifically, we assess both the directionality and long-term association of key indicators, testing whether countries that perform strongly on relevant SDGs are also more resilient to economic losses from climate extremes.

To operationalise this objective, we develop a typology of EU countries based on their average SDG scores and cumulative climate-related losses. This typology enables a comparative assessment of development-resilience profiles. We then apply time-series methods, including Engle–Granger cointegration and Granger causality tests, to evaluate the dynamic interplay between SDG progress (with a focus on Goals 9, 11, and 13) and vulnerability outcomes over the period 2000–2023.

The following research questions guide the study:

1. Is there a correlation between national SDG performance and the scale of climate-related economic losses?
2. Do countries with structurally high losses tend to lag in sustainable development outcomes?
3. Can progress on selected SDGs, particularly those related to infrastructure and climate action, reduce future economic vulnerability?
4. Do any countries demonstrate resilient development trajectories—combining high SDG performance with low climate-related losses?
5. Is there evidence of temporal causality, suggesting that improvements in development indicators follow or precede climate loss events?

By combining typological analysis with dynamic statistical modelling, this study contributes new evidence on the links between climate vulnerability and sustainable development. It further supports the case for integrated governance, where risk reduction and development planning are treated as mutually reinforcing, rather than separate, policy domains.

Literature Review

The increasing frequency and severity of climate-related disasters across Europe have brought economic losses to the forefront of climate risk governance. According to the European Environment Agency (EEA), weather- and climate-related events caused over €650 billion in damages between 1980 and 2020 across EEA countries, with losses exhibiting marked spatial and temporal concentration.

The role of anthropogenic factors in shaping these outcomes remains a key subject of scholarly debate. Bouwer (2011) emphasised that socio-economic development and asset exposure are more decisive drivers of rising losses than hazard frequency alone. Supporting this view, Formetta and Feyen (2019) demonstrated that the global decline in vulnerability to climate-related hazards is significantly moderated by social indicators such as income levels, governance quality, and institutional strength. Similarly, Forzieri et al. (2018), using modelling of future climate extremes in Europe, concluded that without adaptation, losses to critical infrastructure may rise substantially. In contrast, investment in resilience offers a significant reduction in projected damages.

At the European scale, several studies (e.g., De Groeve et al., 2013; Paprotny et al., 2018) have examined cross-national loss distributions through geospatial datasets and statistical damage models. A recurring insight is the presence of structural asymmetries: economic burdens from climate-related events are heavily concentrated in a few Western and Central European countries. In contrast, others experience minimal or irregular losses.

In parallel, the literature addressing the Sustainable Development Goals (SDGs) has explored the role of development pathways in fostering resilience. Sachs et al. (2022) and the annual SDG Index published by the SDSN highlight disparities across EU member states, particularly in relation to Goals 9 (Industry, Innovation, and Infrastructure), 11 (Sustainable Cities and Communities), and 13 (Climate Action). These goals directly relate to adaptive capacity and disaster risk mitigation, yet their long-term correlation with economic losses remains insufficiently examined.

Recent work increasingly applies multivariate typologies to group countries by their developmental performance, arguing that such classifications can reveal latent vulnerabilities in the face of environmental shocks. Liashenko et al. (2024) propose a multidimensional framework distinguishing governance-driven from development-driven patterns of resilience across nations. Likewise, Liashenko and Dluhopolskyi (2024) investigate how welfare preferences and digital transformation trajectories intersect with sustainability outcomes, potentially shaping national resilience profiles.

However, only a handful of empirical studies have attempted to link development indicators with climate impact metrics directly. Capasso et al. (2020) suggest that stronger governance and financial resilience (as captured in SDGs 16 and 17) can help cushion the socio-economic effects of disasters. Gualandri et al. (2023) introduce the concept of "climate-financial transmission channels," describing how physical climate shocks may influence development through mechanisms such as credit constraints, infrastructure delays, or insurance retreat.

The emerging literature is also turning towards structural typologies and systems-based modelling to understand these dynamics better. Vanhala and Paterson (2021) advocate for incorporating macro-financial risk metrics into SDG monitoring frameworks, recommending typological approaches to identify critical contrasts, such as between economically advanced but climate-vulnerable states, and countries with comparatively low development scores yet high resilience. Nonetheless, these typologies remain underdeveloped empirically.

Furthermore, as the PESETA IV project highlights (Ciscar et al., 2018), there remains a lack of harmonised methodologies within the EU for analysing development and climate risk together. Most assessments treat these dimensions separately, neglecting to examine whether they move jointly, diverge, or demonstrate structural co-movement (e.g., cointegration). This analytical gap is particularly pertinent as the climate-development nexus becomes more central to European policy frameworks, notably the European Green Deal and the EU Climate Adaptation Strategy.

This study aims to address this gap by developing a new typology of European countries based on their performance in achieving the SDGs and cumulative climate-related losses. Particular attention is paid to Goals 9, 11, and 13, which concern economic vulnerability. Methodologically, the study introduces a novel statistical approach by testing for both association and long-term co-movement (cointegration) between climate-related losses and SDG indicators—an approach that has not yet been applied in the EU context.

In Europe, the intersection of climate-related economic losses and sustainable development goals remains an evolving field of research, particularly as nations strive to balance ecological integrity with socioeconomic progress. Central to this discussion is the European Green Deal (EGD), which aims to mainstream sustainability across key sectors, including agriculture. Here, attention to land and soil management is increasingly recognised as an essential – albeit often understated – component of ecological health and long-term climate resilience (Montanarella, 2020).

The effectiveness of EU-level policies in shaping progress toward the SDGs has also been critically examined. Scown and Nicholas (2020), for instance, suggest that the Common Agricultural Policy (CAP) may inadvertently hinder progress towards global sustainability targets, calling for a renewed policy performance framework better aligned with the 2030 Agenda. Beverelli et al. (2020) emphasise the importance of an integrated approach to achieving the SDGs – one that encompasses trade, investment, and policy evaluation across both environmental and social domains. Within this context, multinational enterprises are recognised as key actors, capable of advancing local sustainability efforts in line with global commitments (Eang et al., 2022; Kolk et al., 2017).

Advancing climate resilience is also considered crucial for mitigating the economic impact of environmental disruptions. Badolo (2024) outlines a governance framework designed to enhance local adaptive capacity through innovative strategies and metrics. Complementing this, Shaw and Maythorne (2012) emphasise the need for policy frameworks that combine short-term recovery with long-term transformational objectives. This is particularly relevant in the agricultural sector, where increasing climate risks demand adaptive practices that safeguard both economic stability and food systems (Aggarwal et al., 2018).

The societal dimension of climate-induced losses further necessitates inclusive, community-oriented responses. Franco and Tracey (2019) argue for community capacity-building aligned with selected SDGs to foster local resilience and ownership of development initiatives. Havea et al. (2018) similarly underscore the importance of integrating community perspectives into policymaking to ensure accountability and efficacy in achieving SDG targets.

In sum, this literature review highlights the intricate connections between climate resilience, economic losses, and progress toward the SDGs within the European context. Sustaining both ecological and socio-economic systems in the face of growing environmental stress requires cohesive, cross-sectoral strategies that integrate agricultural practices, community engagement, and private-sector contributions, all guided by the ambitions of the European Green Deal and the 2030 Agenda.

Methods

This study employs a structured quantitative approach to investigate the relationship between climate-related economic losses and advancements in sustainable development across European nations. The focus is on identifying time-based trends, structural differences, and possible connections between vulnerability and SDG progress.

Data Sources

Climate-related economic losses were sourced from the European Environment Agency (EEA, 2025) dataset on damage caused by weather and climate-related events, expressed in inflation-adjusted euros. This dataset spans the period from 1980 to 2023, enabling consistent intertemporal and cross-country comparisons. Data on Sustainable Development Goals (SDGs) performance were obtained from the UN Sustainable Development Solutions Network (SDSN), using annual national SDG Index scores for the years 2000-2023.

Analytical Procedure

The analysis proceeded in five stages:

1. Descriptive Profiling: Time series of economic losses were analysed across EU27 countries to identify temporal peaks and spatial disparities. Summary statistics and bar plots were used to characterise average and cumulative losses per country and region.
2. Typology Construction: Countries were classified into four quadrants based on their average SDG Index score and cumulative climate-related losses: High SDG/High Loss; High SDG/Low Loss; Low SDG/High Loss; Low SDG/Low Loss. This typology served as a comparative framework for subsequent group-based analysis.
3. Disaggregated SDG Analysis: To understand the thematic drivers of resilience, SDG performance was disaggregated into three key areas: Goal 9 (Infrastructure), Goal 11 (Sustainable Cities), and Goal 13 (Climate Action). Within each typological group, annual averages were calculated and normalised (Min-Max scaling) to produce multi-panel time-series visualisations.
4. Correlation and Cointegration Testing: Pearson correlation coefficients were computed between economic losses and each SDG goal within each group. Additionally, Engle–Granger cointegration tests were conducted to examine the presence of stable long-term relationships between SDG progress and loss levels. The absence of cointegration was interpreted as a structural decoupling between policy trajectories and vulnerability exposure.
5. Granger Causality Modelling: For the group exhibiting both high losses and low SDG performance, Granger causality tests were conducted on annual average time series (2000-2023) to evaluate whether economic losses at time t-1 significantly predicted SDG 13 outcomes at time *t*. Vector autoregression (VAR) models were used to estimate the lag structures and directional dependencies. A statistically significant effect ($p < 0.10$) was found at a 1-year lag, suggesting the existence of reactive adaptation patterns where policy engagement increases in response to prior climate damages.

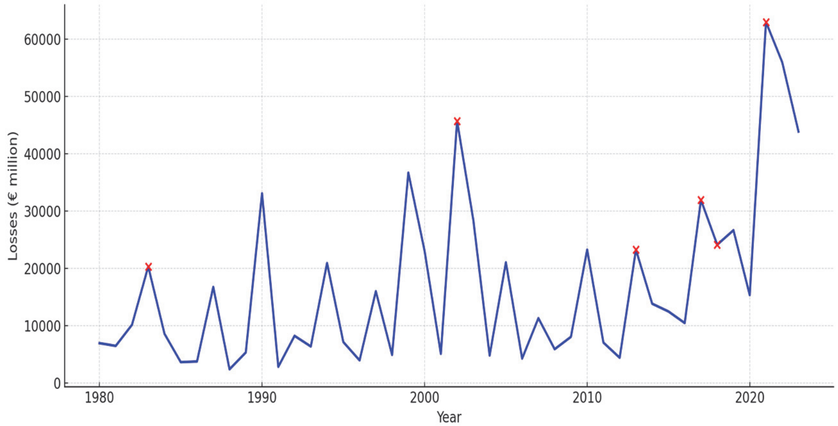
All analyses were performed using Python libraries, ensuring replicability of results and transparent processing.

Results

Economic losses resulting from climate- and weather-related extreme events across European countries show significant variability over time and between regions. The dataset spans the period from 1980 to 2023, highlighting both long-term trends and instances of sharp increases in losses associated with extreme weather events.

At the European Union level (comprising 27 countries), the highest economic loss was recorded in 2021, exceeding €62.9 billion – a figure that far surpasses the annual average of previous decades. Other peak years include 1983, 2002, 2013, 2017, and 2018, with losses ranging from €20 to €30 billion. These spikes reflect either an increase in the severity or frequency of damaging climate events.

Figure 1 - Annual climate-related economic losses in the EU27, 1980-2023.

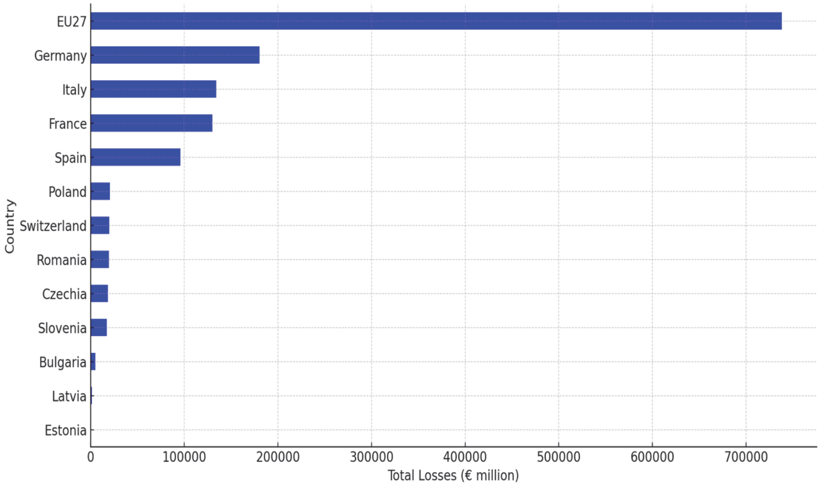


Marked peaks indicate years with the highest reported losses, particularly 2021, which recorded more than €62.9 billion in damages.
Source: EEA.

At the national level, there is considerable disparity (Fig. 2). Countries such as Germany, Italy, France, and Spain consistently experience substantial economic losses. In contrast, others, including Bulgaria, Latvia, and Estonia, report little to no losses over extended periods. This disparity suggests both differences in exposure and the resilience of national infrastructure and response systems.

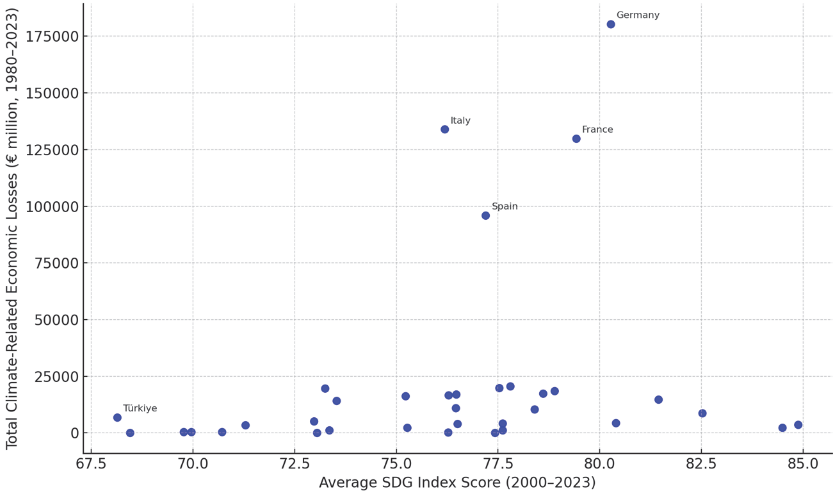
To explore the potential relationship between sustainable development progress and vulnerability to climate-related damages, we compare countries' average SDG Index scores with their cumulative economic losses. The following figure illustrates this relationship for European countries over the periods 1980-2023 (losses) and 2000-2023 (SDG performance).

Figure 2 - Cumulative climate-related economic losses by country in Europe, 1980-2023.



Source: EEA.

Figure 3 - Relationship between average SDG Index Score (2000-2023) and cumulative climate-related economic losses (1980-2023) in European countries.

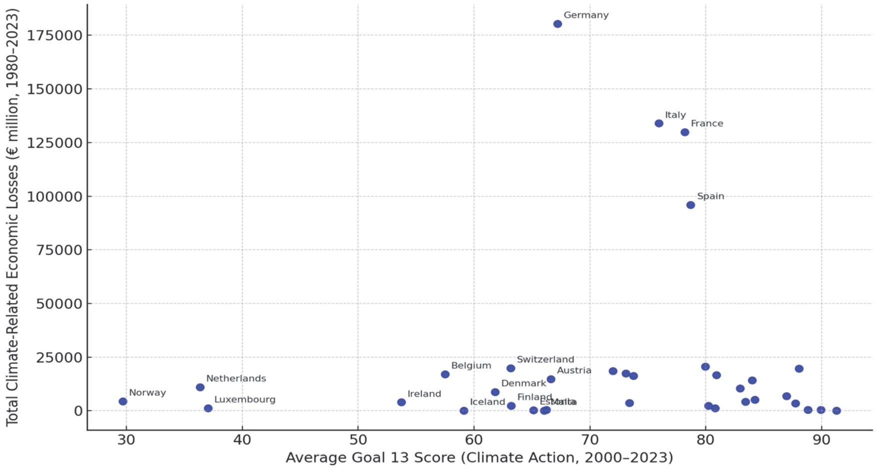


Source: authors' calculations on EEA, SDG UN data.

As shown in the figure above, countries with the highest losses, such as Germany, France, Italy, and Spain, tend to have relatively high SDG performance; however, no clear linear association is observed overall.

To better understand whether national progress on climate action is associated with resilience to economic damages, we compare countries' average scores for SDG Goal 13 (Climate Action) with their total reported losses. Goal 13 includes indicators on climate policies, disaster risk reduction, and adaptation planning, making it a relevant proxy for national climate preparedness. Figure 4 examines whether stronger national performance in climate action is correlated with reduced economic vulnerability.

Figure 4 - Relationship between average SDG Goal 13 score (2000-2023) and cumulative climate-related economic losses (1980–2023) in European countries



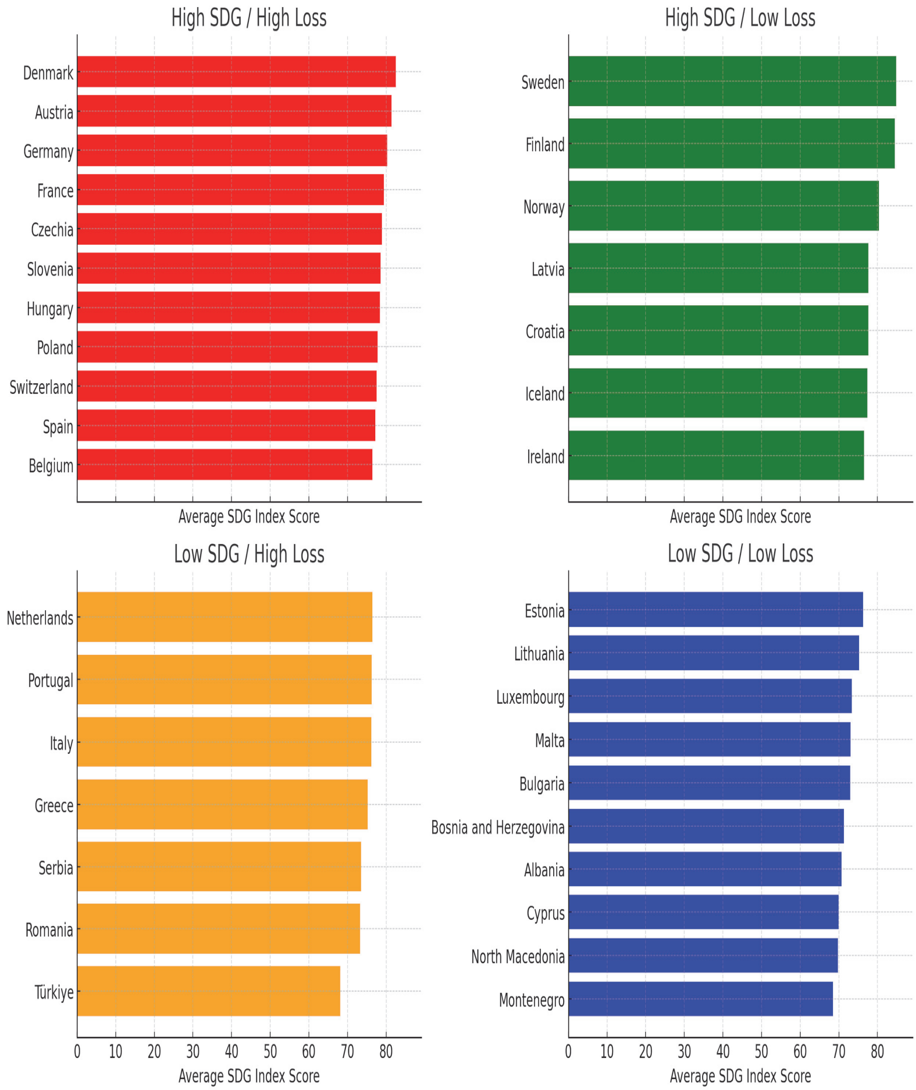
Source: authors' calculations on EEA, SDG UN data.

While some countries with higher Goal 13 scores experience lower losses, others, including Germany, France, and Italy, show both high preparedness and high levels of damage. This suggests that climate action progress alone may not be sufficient to offset structural exposure to extreme events, or that it reflects post-event policy improvement rather than pre-event prevention.

To further explore the typology of national resilience patterns, countries were categorised into four groups based on their average SDG Index Score (2000–2023) and total climate-related economic losses (1980–2023). This classification highlights the intersection of sustainable development performance and vulnerability to climate shocks.

Countries are divided into four groups: (1) High SDG / High Loss, (2) High SDG / Low Loss, (3) Low SDG / High Loss, and (4) Low SDG / Low Loss. Each panel displays the average SDG Index Score for each country within its respective typology.

Figure 5 - Typology of European countries based on SDG Index Score and climate-related economic losses



Source: authors' calculations on EEA, SDG UN data.

The visualisation shows that some countries, such as Slovenia and the Czech Republic, combine strong performance in sustainable development with relatively low exposure to climate-related damages. Others, including Germany, France, and Italy, appear in the High SDG/High Loss quadrant, indicating strong institutional development but continued structural vulnerability. This typology provides a foundation for identifying best practices and potential resilience gaps across Europe.

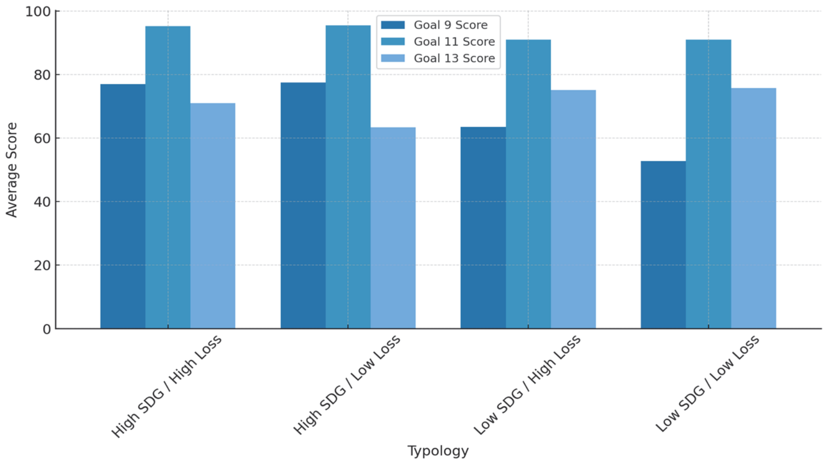
Building on the typological classification of European countries based on their sustainable development performance and exposure to climate-related economic losses, we proceed to a more focused exploration of national resilience profiles. The four identified groups – High SDG/High Loss, High SDG/Low Loss, Low SDG/High Loss, and Low SDG/Low Loss – serve as a conceptual lens for interpreting the interplay between development strategies and structural climate vulnerability.

To gain deeper insight into the characteristics that may contribute to these differences, we disaggregate SDG performance within each typology group. The analysis focuses on three goals that are particularly relevant to climate-related damages:

- Goal 9 (Industry, Innovation and Infrastructure), which reflects investment in resilient infrastructure and sustainable industrialisation;
- Goal 11 (Sustainable Cities and Communities), which captures urban resilience and risk-sensitive planning;
- Goal 13 (Climate Action) represents direct efforts to mitigate and adapt to climate change.

By comparing average scores across these goals within each group, we aim to identify patterns of strength or deficiency that may help explain variations in exposure and loss.

Figure 6 - Average SDG scores for Goals 9 (Infrastructure), 11 (Sustainable Cities), and 13 (Climate Action) across the four resilience typology groups



Source: Authors' calculations based on EEA and UN SDG data.

Figure 6 highlights meaningful contrasts between typology groups. Countries in the High SDG/Low Loss group demonstrate high average scores across all three goals – particularly for infrastructure and urban sustainability – suggesting that investments in resilient systems may play a role in reducing exposure to climate-related losses. However, their relatively lower scores for Goal 13 (Climate Action) suggest that low losses may reduce political urgency for implementing climate policy.

In contrast, the Low SDG/High Loss group exhibits weaker infrastructure and city-level preparedness, yet shows relatively high scores for Goal 13. This pattern may reflect reactive policy-making in response to repeated climate shocks, rather than pre-emptive resilience planning.

Interestingly, the Low SDG/Low Loss group exhibits the lowest capacity in infrastructure and urban resilience, but surprisingly high scores for climate action. This could indicate symbolic or aspirational commitments that are not yet backed by structural development. Meanwhile, the High SDG/High Loss group combines strong development with continued high exposure, likely due to geographic or economic factors beyond policy control.

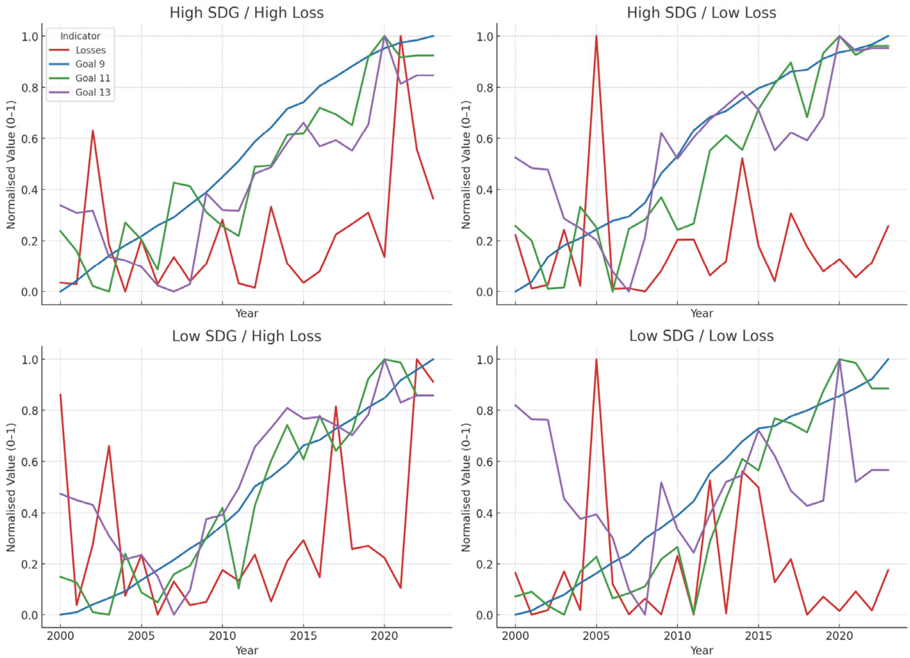
These patterns underscore the importance of targeted infrastructure and urban development, as well as context-specific climate strategies, in shaping the resilience outcomes of countries.

To better understand the temporal dynamics within each resilience typology, we examined the year-on-year evolution of climate-related economic losses. We selected SDG indicators (Goals 9, 11, and 13) for the period 2000-2023. Each indicator was normalised on a 0-1 scale to allow for comparison across metrics of different magnitudes. The resulting trends (Fig. 7) highlight the internal trajectories of resilience-building efforts, particularly in terms of the occurrence and intensity of economic losses.

Each panel on Fig. 7 shows standardised annual trends within one typology group, highlighting patterns of adaptation, infrastructure development, and loss exposure.

The visualisation reveals distinct group-specific patterns. In the High SDG/High Loss group, infrastructure and urban resilience have steadily improved; however, economic losses remain volatile, suggesting an exposure-driven vulnerability that persists despite development progress. The High SDG/Low Loss group shows stable or improving performance across all indicators with relatively low and stable loss levels, reflecting potentially effective long-term resilience strategies.

Figure 7 - Normalised trajectories (2000-2023) of climate-related losses and SDG Goals 9, 11, and 13 across the four typology groups



Source: Authors' calculations based on EEA and UN SDG data.

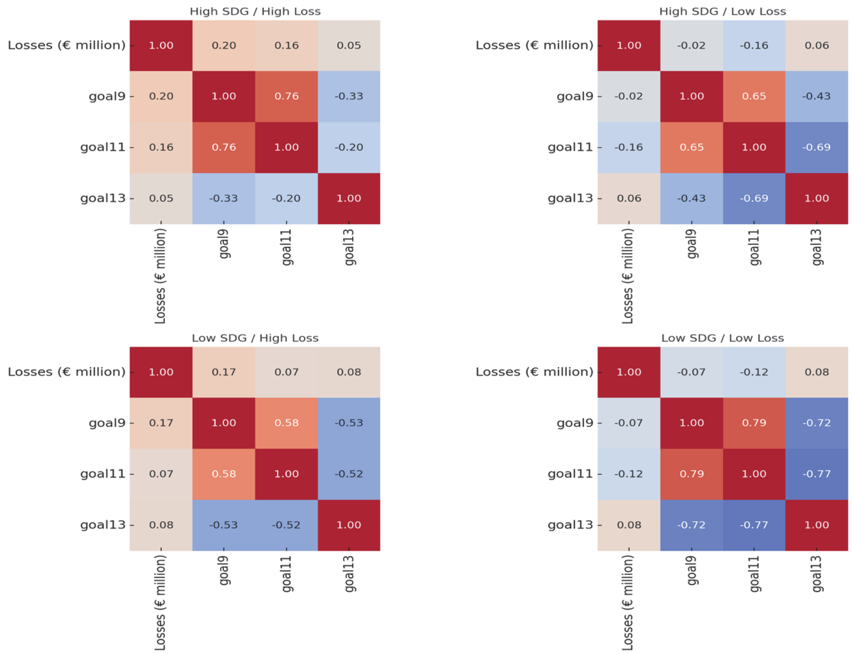
In contrast, the Low SDG/High Loss group exhibits fluctuations in both policy indicators and losses, with increases in Goal 13 performance often appearing reactive to prior loss spikes. The Low SDG/Low Loss group exhibits modest development trajectories with relatively low losses; however, the absence of upward SDG trends may indicate underinvestment or latent exposure risks.

These intra-group dynamics underscore the notion that climate resilience is a dynamic concept, shaped not only by structural development but also by the timing, frequency, and nature of climate impacts.

To assess whether patterns of sustainable development performance are statistically associated with climate-related economic losses, we computed Pearson correlation coefficients between annual loss values and selected SDG indicators (Goals 9, 11, and 13) within each typology group.

Fig. 8 presents the correlations for each group. Overall, the associations are weak to moderate, but specific patterns emerge. In the High SDG / High Loss group, we observe a slight positive correlation between losses and infrastructure development ($r = +0.20$), suggesting that improvements in Goal 9 may not be sufficient to mitigate loss exposure, possibly due to the high baseline value of existing infrastructure at risk. The relationship with Goal 11 (urban resilience) and Goal 13 (climate action) remains weak.

Figure 8 - Correlation matrices of climate-related economic losses and SDG Goals 9, 11, and 13, disaggregated by typology group



Source: Authors' calculations based on EEA and UN SDG data.

By contrast, the High SDG / Low Loss group shows a negative correlation between losses and Goal 11 (r = – 0.16), suggesting that investments in sustainable cities may be associated with reduced vulnerability. This group also exhibits a near-zero correlation with Goal 9, which may indicate a plateau in infrastructure expansion or a decoupling from exposure levels.

Interestingly, in the Low SDG / High Loss group, all correlations are slightly positive – especially with Goal 9 (r = + 0.17) – possibly reflecting a reactive development trajectory where infrastructure investment follows damages rather than precedes them.

The Low SDG/Low Loss group exhibits weak and mostly negative correlations, which may indicate either a low dynamic range in the data or latent risk factors not captured by the SDG indicators.

These patterns suggest that while higher SDG performance is not linearly associated with lower losses, targeted investments – especially those focused on Goal 11 – may play a modest role in reducing exposure. Further causal analysis would be required to confirm such relationships.

To assess whether long-term structural linkages exist between progress in sustainable development and climate-related economic losses, we conducted Engle-Granger cointegration tests for each typology group. These tests evaluate whether two non-stationary time series maintain a stable equilibrium relationship over time. Specifically, we tested for cointegration between annual losses and each of the three selected SDG indicators: Goal 9 (Infrastructure), Goal 11 (Sustainable Cities), and Goal 13 (Climate Action), using group-level averages from 2000 to 2023.

Across all four typology groups, the test statistics failed to reject the null hypothesis of no cointegration at standard significance levels ($p > 0.05$). Even in the High SDG / Low Loss group – which exhibited the closest fit – the lowest p-values hovered around 0.29 to 0.38, indicating no statistically significant long-term equilibrium relationships.

Table 1 - Engle–Granger Cointegration Test Results (2000-2023)

Group	*Losses ~ Goal9*	*Losses ~ Goal11*	*Losses ~ Goal 13*
High SDG/High Loss	0.93	0.95	0.45
Low SDG/High Loss	0.53	0.45	0.60
High SDG/Low Loss	0.38	0.29	0.31
Low SDG/Low Loss	0.90	0.90	0.90

These results suggest that, while SDG performance and climate-related losses may evolve simultaneously, they do not appear to be structurally or predictively linked over time. In practical terms, this means that development trajectories in areas like infrastructure and climate policy may not consistently translate into measurable reductions in losses, or vice versa. This lack of cointegration supports the idea that the interaction between development and resilience is dynamic, contingent, and shaped by both short-term shocks and long-term planning.

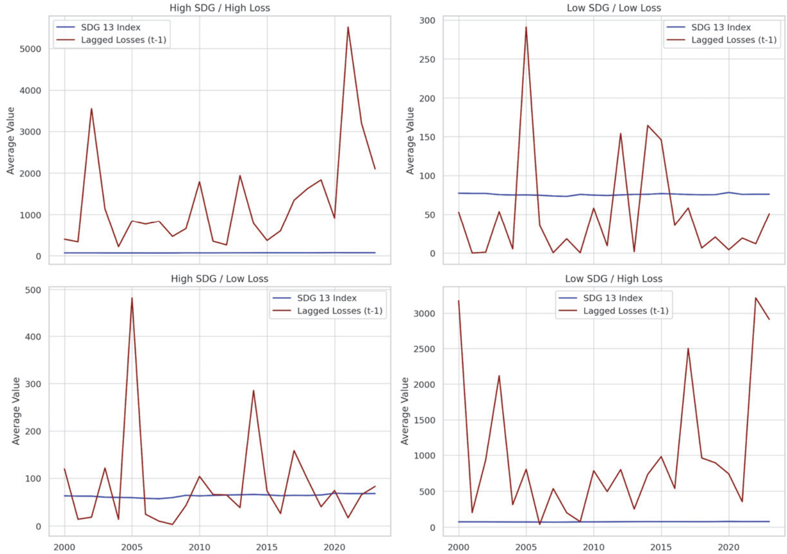
To investigate whether climate-related economic losses precede improvements in national climate action (as measured by SDG 13), we applied the Granger causality test to the average time series data for the *Low SDG / High Loss* group (comprising Bulgaria, Czechia, Greece, Croatia, Hungary, Poland, Portugal, Romania, Slovakia, and Slovenia). This group showed the most volatile loss patterns and dynamic trends in SDG 13 scores.

We constructed a panel of yearly averages (2000-2023) for two key indicators: Losses, which represent aggregated annual climate-related economic losses (€ million), and SDG 13, the climate action index (scale 0–

100). We then computed a 1-year lag of losses to test whether past damage levels Granger-cause improvements in climate policy.

To explore potential feedback dynamics between sustainable development and climate vulnerability, the figure below presents the average annual SDG 13 (Climate Action) scores alongside one-year lagged economic losses for each of the four typology groups. This comparison allows an initial visual assessment of whether policy improvements tend to follow (or precede) years of significant climate-related damages.

Figure 9 - Average SDG 13 Index Scores and One-Year Lagged Climate-Related Economic Losses by Typology Group (2000-2023)



Across the typologies, notable differences in temporal alignment can be observed. In the Low SDG/High Loss group, peaks in economic losses are frequently followed by subsequent increases in SDG 13, indicating reactive adaptation dynamics. Conversely, in the High SDG/ Low Loss group, both indicators remain relatively stable, suggesting more consistent policy trajectories. These patterns reinforce the findings from the Granger causality tests and imply the need for more anticipatory governance mechanisms in highly exposed states.

To further explore potential causal mechanisms between sustainable development trajectories and climate-related losses, we applied the Granger causality test (lags 1-3) and estimated Vector Autoregression (VAR) models for each typological group. These analyses aim to determine whether past climate losses predict subsequent changes in SDG 13 (Climate Action) scores and vice versa.

Granger Causality Test Results (see Table 2) reveal a statistically significant effect only in the Low SDG/High Loss group at lag 1 ($p = 0.098$), suggesting that previous-year losses Granger-cause increases in SDG 13 scores. This supports the hypothesis that these countries often pursue climate action reactively, rather than preventively, in response to disaster shocks. For other groups, p-values remain above conventional significance thresholds, indicating no consistent temporal causality.

Table 2 - Granger Causality Test Results (F-statistics and p-values)

Group	*Lag 1 F-stat*	*p-value*	*Lag 2 F-stat*	*p-value*	*Lag 3 F-stat*	*p-value*
High SDG / High Loss	2.415	0.154	1.212	0.381	0.874	0.501
High SDG / Low Loss	0.796	0.388	0.936	0.420	0.932	0.476
Low SDG / Low Loss	2.228	0.170	1.322	0.348	1.201	0.398
Low SDG / High Loss	3.235	0.098	1.602	0.274	1.498	0.302

To reinforce these findings, we also implemented VAR models (lag = 1) and extracted coefficient matrices (Table 3). The *Low SDG / High Loss* group again shows a small but directionally meaningful coefficient for Lagged Losses → SDG 13 (– 0.00026), consistent with the feedback logic. Across other groups, coefficients remain statistically and substantively weak, with minor or adverse effects and no clear patterns.

Table 3 - VAR Model Coefficients (Lag = 1)

Group	$SDG13_{(t-1)} \rightarrow SDG13_t$	$Losses_{(t-1)} \rightarrow SDG13_t$	$SDG13_{(t-1)} \rightarrow Losses_t$	$Losses_{(t-1)} \rightarrow Losses_t$
High SDG/High Loss	0.9434	– 0.000021	326.55	– 0.0343
High SDG/Low Loss	0.9040	– 0.00496	0.616	– 0.2055
Low SDG/Low Loss	0.4737	0.000234	– 3.85	– 0.1015
Low SDG/High Loss	0.972	– 0.00026	146.32	0.0164

These results provide quantitative support for the hypothesis that post-disaster increases in policy activity (SDG 13) occur primarily in structurally vulnerable contexts**.** While the effect sizes are modest due to data scale, their directionality and statistical support at short lags suggest the presence of a reactive adaptation pattern rather than proactive resilience planning.

Discussion

This study set out to investigate whether countries' performance on selected Sustainable Development Goals (SDGs) is meaningfully linked to their exposure to climate-related economic losses. By combining descriptive, typological, and time-series approaches, it advances the empirical understanding of how development trajectories interact with vulnerability to climate shocks across Europe.

To the first research question, the results reveal a weak or inconsistent correlation between overall SDG progress and climate-related losses. High-SDG countries such as Germany, France, and Italy continue to register some of the most significant economic damages. This suggests that structural exposure – such as urbanisation intensity, economic concentration, or geographic location – may outweigh development-based resilience in terms of actual damage levels. In other words, high SDG performance does not automatically translate into lower climate vulnerability.

Regarding the second question, our typological and temporal analysis indicates that countries with persistently high economic losses are not necessarily underperformers in terms of SDG implementation. However, these countries tend to exhibit a reactive pattern in their policy engagement. This is particularly evident in SDG 13 (Climate Action), where countries in the Low SDG / High Loss group show increased policy scores following, rather than preceding, significant climate-related damages.

This temporal insight is reinforced by the results of the Granger causality tests, which provide statistically significant evidence of short-term lag effects. Specifically, in the Low SDG / High Loss group, economic damages Granger-cause improvements in SDG 13 scores at a one-year lag ($p < 0.10$). This suggests the presence of reverse feedback mechanisms, whereby policy attention and institutional adaptation follow shocks rather than proactively prevent them. By contrast, no such feedback loops were found in the Low SDG/Low Loss group, where both exposure and response remain limited, possibly due to structural underinvestment or data limitations.

The third research question – whether targeted SDG progress reduces future losses – yields more nuanced insights. Countries in the High SDG / Low Loss group, such as the Netherlands, Austria, and the Nordic states, tend to achieve strong outcomes in SDG 9 (infrastructure) and SDG 11 (urban resilience) while maintaining stable or declining loss levels. While cointegration between SDG trends and losses was not detected in this group, correlation patterns suggest that integrated urban and infrastructure planning may offer a buffering effect against future damage.

Concerning the fourth research question, several countries emerge as exemplars of balanced development and risk management. The Czech Republic, Slovenia, and the Netherlands consistently display high performance in SDGs related to climate resilience, while also incurring comparatively low economic losses. These cases highlight the potential benefits of long-term, cross-sectoral strategies that integrate risk mitigation into development pathways.

More broadly, the typology developed in this study underscores the structural asymmetry in how EU countries experience and manage climate risk. The absence of long-term cointegration between SDG indicators and economic losses confirms that development and resilience often evolve on parallel tracks. This disconnect implies that without explicit institutional integration, policy ambition may not translate into reduced vulnerability.

Notably, the analysis of reverse causality offers both diagnostic and normative insights. In countries with high exposure and lagging development progress, reactive adaptation appears to be the dominant approach. This dynamic raises concerns about the sustainability of resilience-building efforts that are only mobilised post-disaster. To address this, EU-level governance and funding frameworks should move beyond reactive compensation models and support anticipatory adaptation, for example, by tying cohesion funding to ex-ante vulnerability assessments and SDG-aligned investments.

Policy implications arising from this study are threefold. First, resilience strategies should be explicitly linked to development planning, especially in high-risk countries. Second, monitoring systems should incorporate temporal indicators, not just aggregate scores, to detect whether resilience progress is driven by planning or by necessity. Third, funding mechanisms should incentivise integrated, long-term adaptation, rather than short-term crisis response.

Nevertheless, this study faces several limitations. The analysis relies on aggregate national-level data, which may mask subnational disparities and sectoral vulnerabilities. While SDG scores offer functional comparability, they are influenced by variations in reporting and the availability of indicators. Additionally, the time horizon, although spanning two decades, may still be insufficient to capture slow-moving institutional reforms or intergenerational development effects. The analysis also does not include qualitative policy content, governance capacity, or financing mechanisms, all of which likely influence both resilience outcomes and exposure dynamics.

Future research should address these limitations by incorporating subnational data, exploring nonlinear and multivariate models, and enriching quantitative findings with case-based policy analysis. Understanding not only why, but also how, certain countries achieve better alignment between development and risk remains a crucial area for interdisciplinary scholarship.

In conclusion, this study contributes new evidence to a growing body of research that highlights the fragile alignment between sustainability and resilience. While SDG progress is essential, it is not a substitute for integrated risk governance. Conversely, building resilience without addressing development gaps risks entrenching vulnerability in new forms. Bridging this divide requires not only better metrics but also political and institutional innovation.

Conclusions

This study examined the intricate relationship between climate-related economic losses and progress toward the Sustainable Development Goals (SDGs) across European countries. By combining descriptive analytics, typological clustering, and time-series comparisons, we identified notable disparities in how countries absorb, mitigate, and respond to the economic consequences of climate change.

The findings suggest that high SDG performance alone does not guarantee lower economic losses from climate extremes. Structural factors such as geographic exposure, infrastructure concentration, and the legacy of economic development patterns continue to shape national vulnerability. Nevertheless, certain SDG domains, particularly those related to infrastructure, innovation, and urban resilience, appear to contribute to more stable or moderate loss profiles over time.

The typology developed in this study provides a practical lens for understanding divergent national pathways. Countries with both high SDG progress and low economic losses, although few, demonstrate the potential value of integrating sustainability planning with proactive risk management. Conversely, states with high losses and low SDG performance underscore the urgency of closing institutional and investment gaps.

Overall, the study contributes to the growing field of integrated resilience assessment by linking two key policy frameworks: disaster loss tracking and sustainable development monitoring. It highlights the need for coordinated methodologies that assess not only whether countries are progressing on development goals, but also how resilient that progress is in the face of escalating climate risks.

Future research should build on these insights by incorporating more granular, subnational data, and by exploring dynamic interactions between institutions, investments, and exposure. This would support the design of more context-specific strategies that can reduce both risk and inequality in the transition to a climate-resilient Europe.

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Young consumers sustainable consumption behavior: A multi-country analysis between Germany and Colombia

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Abstract

This study aims to investigate the Sustainable Consumption Behaviors (SCB) of young consumers in two contrasting countries: Germany and Colombia. A quantitative research design was employed to gather data from 326 young undergraduate students. Using a self-report scale based on Quoquab et al. (2019) scale. The findings reveal that consumers in Colombia demonstrate a higher concern for quality of life, environmental well-being, and the well-being of future generations compared to their German counterparts. This research shows that emerging market companies should promote sustainable products to build on existing positive attitudes. In contrast, in developed countries, companies need to invest more in education and awareness efforts to emphasize the importance of sustainability.
Keywords: Sustainable Consumption Behavior, Young Consumers, Consumer Behavior, Cross-Cultural Analysis, Relative Deprivation Theory

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Introduction

The increasing focus on Sustainable Consumption Behavior (SCB) underscores the urgent need to address global environmental challenges intensified by overconsumption and unsustainable practices. Sustainable consumption is regarded as a critical catalyst for advancing sustainable development, as the unprecedented growth in consumption has led to the

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overuse and misuse of environmental resources, resulting in their rapid depletion (Alisat & Riemer, 2015; Bogueva et al., 2017; Quoquab et al., 2019). Current consumption patterns, as highlighted by the Global Footprint Network, (2024), require the resources of 1.75 Earths to sustain existing consumption levels, demonstrating that sustainability is indispensable for both the present and the future generations. To mitigate the resulting damage to global environmental systems, sustainable consumption practices prioritize the responsible use of resources that lie at the core of many environmental challenges (Warde, 2017).

Sustainability encompasses three interconnected dimensions: environmental, economic, and social sustainability (Kuhlman & Farrington, 2010). Environmentally, sustainable consumption promotes the conservation of natural resources, reduction of pollution, and minimization of waste (Kazmierczak-Piwko et al., 2022). Socially, it can enhance public health, improve quality of life, and ensure the well-being for current and future generations (Fesenfeld et al., 2021; Jiang & Pu, 2021). Economically, it drives innovation, creates new business opportunities, and fosters sustainable products and services (Osuji & Amajuoyi, 2019; Pérez-Franco et al., 2022). While these benefits are well-documented, most of the existing research has primarily focused on sustainability from macroeconomic perspectives, often overlooking the critical role of individual consumer behavior (Zhao & Schroeder, 2010). However, as Quoquab et al. (2019) argue, while government policies and social marketing campaigns can encourage sustainable consumption, individual consumers ultimately determine whether such practices are adopted in their daily lives. Interestingly, young consumers emerge as a crucial demographic whose consumption behaviors could significantly influence sustainable development efforts.

Research on young consumers' behavior highlights a notable contradiction, that is, while some studies suggest they display a low level of environmental concern and awareness (Witek & Kuźniar, 2021), other studies indicate that they are more environmentally conscious and mindful of the impact of their consumption choices (Sheoran & Kumar, 2022).

Furthermore, young consumers as a key target group for companies become crucial to understand the drivers, barriers, and cultural differences in their SCB (Joshi et al., 2019; Tran et al., 2022). Young consumers represent a growing market for green products and play an essential role in shaping environmentally conscious societies, making them a critical focus for marketers and policymakers (Tran et al., 2022). Despite their potential role as agents for change, research on young consumers' preferences is limited, particularly in emerging countries (Quoquab et al., 2019). Most existing research has predominantly focused on developed regions, such as Europe and North America, while emerging markets, like those in Latin America, have received comparatively less attention (Jiang & Pu, 2021). Given the socio-cultural and economic differences between these regions, further studies are needed to understand sustainable consumption behaviors in diverse settings.

By integrating insights from the Relative Deprivation Theory (RDT) with sustainable consumption, the study seeks to explore how perceptions of inequality and socio-economic contexts influence SCB across these different cultural and economic settings. RDT provides a framework for understanding how feelings of deprivation can drive consumer choices toward either unsustainable or sustainable practices, making it particularly relevant in contrasting contexts like Germany and Colombia (Bernstein & Crosby, 1980; Smith & Pettigrew, 2015)

The research questions guiding this study are: (1) To what extent do young consumers in Germany and Colombia engage in sustainable consumption behaviors, such as reducing waste, conserving resources, and avoiding overconsumption?, (2) What are the significant differences and similarities in sustainable consumption behaviors, including quality of life, care for environmental well-being, and consideration for future generations, among young consumers in Germany and Colombia?

The results of this study provide new insights into the sustainable consumption practices of young consumers, revealing significant differences between Germany and Colombia across three key variables: quality of life, care for environmental well-being, and consideration for future generations. Furthermore, these findings offer valuable contributions to academic literature and practical applications in marketing. First, they enrich the understanding of sustainable consumption from an individual consumer perspective, addressing a significant gap in current marketing research (Quoquab et al., 2019). Second, they highlight the behaviors and preferences of young consumers, a demographic that plays a crucial role in promoting sustainable consumption (Kazmierczak-Piwko et al., 2022). Third, by providing empirical evidence from two distinct countries, developed and emerging markets, the study enhances our understanding of how socio-cultural and institutional contexts shape sustainable consumption behaviors. Finally, the research validates and extends existing measurement tools by incorporating dimensions such as quality of life, environmental well-being, and consideration for future generations, providing a more comprehensive analysis of young consumers' sustainable consumption behaviors.

The remainder of this article is organized as follows: We first present the literature review, followed by the methodological section, which includes a discussion on the instrumentation and sampling techniques employed.

Subsequently, we present our study's findings and conclude with a discussion on the implications and limitations of our study alongside potential directions for future research.

Literature Review

Sustainable Consumption (SC) and Sustainable Consumption Behavior (SCB)

Sustainable Consumption (SC) is a multifaceted and integral concept aligned with global sustainable development goals, aimed at aligning consumption patterns with the planet's ability to provide resources for human needs in a manner that ensures safe and quality sustenance (Ermolaeva, 2019). SC goes beyond merely purchasing environmentally friendly products; it represents a comprehensive lifestyle change that involves reducing hyper-consumption, fostering a future orientation, and taking responsibility for the well-being of future generations (Dimitrova et al., 2022). Moreover, SC is not limited to individual actions but also includes broader considerations such as economic factors, behavioral, and policy considerations at both personal and national levels (Vergura et al., 2023).

Academic perspectives on SC vary. Importantly, SC is not merely an act of simplicity or anti-consumption; rather, it aims to minimize negative impacts on the environment, society, and the economy caused by irresponsible purchasing, use, and disposal of products and services (Joshi et al., 2019).

Although SC and SCB are closely related and often discussed together, they differ in scope and focus. SC is a broader framework encompassing cognitive, attitudinal, psychosocial factors, contextual factors, social norms, and perceived responsibility (Čapienė et al., 2021). In contrast, SCB specifically refers to the actions and behaviors of individuals that support these broader goals (Sargin & Dursun, 2023). SCB is a dynamic, multi-faceted concept defined as a three-stage process involving the acquisition, use, and disposal of goods and services (Piligrimiene et al., 2021), aligning with the lifecycle approach to consumption behavior, as proposed by Geiger et al., (2018)

Research on SCB has been extensively studied identifying various factors influencing individual behaviors including psychological, social, and economic determinants (Hosta & Zabkar, 2021; Kadic-Maglajlic et al., 2019; Liobikiene & Poškus, 2019; Piwowar-Sulej, 2020). SCB is characterized by three key dimensions: environmental, social, and economic. The environmental dimension focuses on the ecological implications of consumer choices emphasizing the need to reduce negative impacts on natural resources (Chang et al., 2020). The social dimension centers on the societal impacts of individual decisions including considerations of social equity and justice (Hosta & Zabkar, 2021). Finally, the economic dimension addresses the financial implications of individual consumption patterns highlighting the importance of balancing economic efficiency with responsible consumption (Hütter & Sweldens, 2018).

Determinants of SCB

SCB is shaped by various cultural and demographic factors. Cultural drivers, such as the perceived association between an eco-friendly lifestyle and an enhanced quality of life, long-term economic expectations, and a desire to decelerate modern life's pace, play a vital role in the adoption of new sustainable habits. These cultural drivers are particularly relevant in major consumer segments like food, household chemicals, beauty products, and clothing (Ermolaeva, 2019). Demographic factors, including age, gender, income, and rurality, are also key determinants of SCB (Gifford & Sussman, 2012). Age is a significant factor influencing environmental attitudes and behaviors, with studies suggesting that younger individuals may have different environmental perspectives compared to older groups (Collado Salas & Corraliza, 2016). Moreover, gender plays a significant role in shaping sustainable behaviors (El Ghoul et al., 2017). While Hunter et al. (2004) found that women were more likely to engage in pro-environmental behaviors, such as recycling. Other studies urge caution in generalizing gender differences in local environmental behaviors (Larson et al., 2010).

Furthermore, environmental concerns play a role in shaping SCB. According to Restall & Conrad (2015), consumers who feel a sense of association with nature protection believe in their exclusive contribution towards ecological security through the adoption of environmentally favorable practices. This intrinsic care for the planet's well-being motivates individuals to engage in genuine efforts to protect nature, embracing sustainable activities that support environmental conservation (Bauri & Kumar, 2018). Further studies suggest that individuals with a sensitive environmental attitude are more likely to engage in sustainable consumption practices, including the preference for green products (Jiang & Pu, 2021). Moreover, the acquisition of environmental knowledge in educational settings positively contributes to promoting sustainable consumption among students (Jiang & Pu, 2021), Likewise, empirical evidence supports the notion that environmentally conscious consumers exhibit distinct purchasing behavior. For instance, Kim & Choi (2005) reveal that consumers who prioritize environmental concerns are more inclined to choose green products over conventional alternatives. Importantly, this preference is not merely theoretical; environmentally conscious consumers are willing to allocate more financial resources to support sustainable choices, as demonstrated by the willingness to spend more money on green products compared to their less environmentally concerned counterparts (Wei et al., 2018).

SCB and Young Consumers

Young consumers, despite encountering certain legal and formal restrictions due to their age, play a pivotal role in the modern consumer market. Companies often target this demographic, manufacturing products specifically tailored to their preferences, (Kazmierczak-Piwko et al., 2022). Their role extends beyond mere consumption; young consumers are seen as vital agents in promoting sustainable development. This demographic is crucial for shaping future markets, making the study of their behavior essential to understanding how sustainable consumption patterns can be cultivated and sustained (Wyrwa et al., 2023).

The integration of sustainable consumption behaviors among young consumers relies heavily on educating this group about ecological and economic principles. The goal is to foster a generation of market-aware consumers capable of making sustainable decisions in the future (Kazmierczak-Piwko et al., 2022).

Studies reveal a divergence in environmental attitudes between younger and older consumers. While some findings suggest that young consumers exhibit lower environmental concern and knowledge compared to older counterparts (Dhir et al., 2021). Other findings contend that they are more environmentally concerned in considering the environmental impact of their consumption choices (Sheoran & Kumar, 2022).

The academic community increasingly recognizes the importance of studying young and educated consumers in sustainable consumption behavior. This demographic is considered crucial for bringing about preferred changes in consumption patterns, yet it has been understudied in the past (Kanchanapibul et al., 2014). Studying sustainable consumption behavior in young consumers is vital because it helps establish long-term habits that can shape future markets, societal norms, and environmental outcomes. As trendsetters and future decision-makers, young consumers have a significant influence on demand for sustainable products and ethical practices, making them a crucial market segment. Lastly, there is a recognized gap in understanding the slow adoption of sustainable consumption practices in emerging markets (Quoquab & Sukari, 2017).

SCB in Developed as well as Emerging Markets

Studies on SCB have emanated from developed countries, revealing an asymmetry in research focus and an inherent need for more inclusive global studies. Ukenna et al. (2019) stress the urgency for coordinated action from both rich and poor consumers and across developed as well as emerging markets. Addressing this asymmetry is essential for tackling the interconnected challenges posed by unsustainable consumption.

Emerging markets are increasingly acknowledging the significance of SCB. Efforts in emerging markets have typically concentrated on economic priorities, often overlooking sustainability concerns. This "grow first, clean up later" approach has been particularly notable in emerging markets (Wang et al., 2019). In contrast, developed economies, with mature production technologies, have prioritized altering over-consumption patterns (Wang et al., 2019). These efforts aim to reduce material and energy intensity by addressing both the supply and demand sides of consumption. Despite such initiatives, most developed countries continue to grapple with high ecological footprints, reflecting their heavy ecological debts (Ukenna et al., 2019).

Recent studies emphasize the growing importance of sustainable consumption in emerging markets. Consumers in these countries are becoming more aware of the ecological consequences of their consumption choices and are showing greater engagement with conscious behaviors (Arli et al., 2018). As awareness grows, so too does the adoption of sustainable consumption behaviors, despite institutional challenges and policy voids (Osuji & Amajuoyi, 2019).

A critical gap in the literature, however, is the lack of a holistic view of the role of consumer behavior in pursuing sustainability objectives (Quoquab et al., 2019). Despite the urgency of addressing sustainability challenges, few studies offer a comprehensive analysis of the factors and barriers influencing sustainable consumption (Quoquab et al., 2019). This gap highlights the need for more focused research into consumer attitudes, motivations, and behaviors related to environmental sustainability, particularly as consumers are central to driving sustainable practices.

While sustainability has become an important consideration, it has been less studied from a consumer's (Hwang & Kim, 2018). This calls for more targeted investigations into how consumers perceive and engage with sustainability considerations in their consumption decisions.

To better understand the underexplored area of consumer perspectives on sustainability, particularly among young consumers, it is essential to employ relevant theoretical frameworks that can illuminate the motivations and behaviors driving sustainable consumption. One such framework is Relative Deprivation Theory (RDT), which provides valuable insights into how perceived inequalities may influence consumer choices and behaviors toward sustainable consumption.

Theoretical background and hypothesis development

Relative Deprivation Theory (RDT)

Relative Deprivation Theory (RDT) is a concept rooted in social psychology that has received significant scholarly attention since its development in the 1950s. The theory explains how individuals or groups perceive themselves as disadvantaged compared to others, leading to feelings of anger, resentment, and dissatisfaction (Bernstein & Crosby, 1980). This perceived deprivation is not based on an absolute lack of resources or opportunities but on subjective assessments of inequality relative to others. Consequently, RDT has been used to understand a wide range of social, economic, and political phenomena, including social movements, collective actions, and individual behaviors (Smith et al., 2012)

RDT affirms that perceptions of inequality arise from comparisons individuals or groups make between their circumstances and those of others (Rios & Mackey, 2020). Gurr (1968) expanded on this by introducing the concepts of value expectations (the goods and life conditions individuals believe they should have) and value capabilities (what they can achieve). A significant gap between these expectations and capabilities results in feelings of relative deprivation.

This theory also explores different forms of deprivation, as discussed by Townsend (1987) and elaborated by Alcock (1997), which include lacking access to basic needs such as food and clothing or falling below a socially accepted standard of living. Townsend (1987) emphasizes that these deprivations impact people's standards of living, focusing on the services and resources deemed necessary to maintain an adequate quality of life. Relative deprivation can also manifest in efforts to establish new standards that may not align with current societal norms but are increasingly adopted, particularly in emerging markets.

In marketing, RDT helps to understand consumer behavior and develop strategies that promote sustainable consumption (Chipp et al., 2011). By examining how individuals assess their consumption relative to others, marketers can gain insights into the motivations behind purchasing decisions (Haider et al., 2022).

Moreover, studies conducted in different contexts have demonstrated that relative deprivation significantly impacts consumption patterns, underscoring the need to consider relative status across different cultural contexts when analyzing consumer behavior (Smith & Pettigrew, 2015). This cross-cultural approach highlights how relative consumption can vary depending on societal norms and values, suggesting that marketing strategies must be tailored to specific cultural environments to be effective.

Hypotheses Development

RDT provides a powerful framework for understanding how perceived disparities between one's current situation and that of others can drive behavioral and attitudinal responses, particularly in the context of sustainable consumption. RDT posits that individuals or groups perceive experience feelings of deprivation due to unfavorable comparisons with others or with their own expectations of what they believe they should have or achieve (Gurr, 1968). These feelings of deprivation can generate emotions such as frustration, resentment, and a desire for change, which can, in turn, influence consumer attitudes and behaviors (Bernstein & Crosby, 1980). In emerging markets, where rapid economic growth and societal changes are often accompanied by strong socio-economic inequalities, the psychological mechanisms of RDT are particularly relevant.

Individuals in these contexts may frequently compare their quality of life, environmental conditions, and prospects for the future with those in more developed nations. Specifically, individuals in emerging markets may perceive a greater gap between their current quality of life and the standards they aspire to those aspirations based on comparisons with developed countries. This perceived gap can heighten concerns about the quality of life, as individuals strive to achieve not just material comfort but also access to clean air, water, and healthier living environments, which are often seen as markers of a good life (Ermolaeva, 2019; Quoquab et al., 2019). This concern stems from the desire to reduce perceived deprivation by improving their living conditions and achieving a standard of life they consider equitable or desirable. Thus, we propose:

H1: Consumers from emerging markets have a higher concern for quality of life than their counterparts in developed markets.

In emerging markets, environmental deterioration is often more visible and directly impacts daily life, which can intensify feelings of relative deprivation (Bronfman et al., 2015). When individuals in these markets perceive that their environmental conditions are significantly worse than those in developed countries, they may experience a heightened sense of environmental concern as they seek to close the perceived gap (Gifford & Sussman, 2012). Additionally, as these consumers become more aware of global environmental challenges and the benefits of sustainable practices, their concern for the environment grows, driven by a desire to achieve parity with the environmental standards of more developed regions (Collado Salas & Corraliza, 2016). Driven by the psychological need to address perceived environmental inequalities and enhance their quality of life, we suggest:

H2: Consumers from emerging markets have a higher concern for the environment than their counterparts in developed markets.

RDT also helps explain why consumers in emerging markets may have heightened concern for future generations. In contexts where there is significant socio-economic uncertainty, consumers might feel a stronger sense of responsibility toward future generations, seeing sustainable practices as essential to ensuring long-term well-being and (Hwang & Kim, 2018). The perceived deprivation relative to developed countries – where prospects are often more secure – may prompt individuals in emerging markets to adopt a forward-looking perspective, seeking to secure a better future for themselves and their society (Quoquab et al., 2019). This reflects a psychological mechanism where concern for future generations serves to mitigate perceived current disadvantages and create a sense of hope and agency in shaping a more equitable future (Haider et al., 2022). Thus, we propose:

H3: Consumers from emerging markets have a higher concern for the care of the future than their counterparts in developed markets.

Overall, these hypotheses are grounded in the psychological mechanisms outlined by RDT, which suggest that perceptions of relative deprivation drive stronger concerns for quality of life, environmental conditions, and future generations among consumers in emerging markets. By addressing these concerns, individuals in these markets may aim to reduce perceived inequalities and improve their overall well-being, both now and in the future.

Materials and methods

Research Design and Data Collection

To better understand how sustainable consumption practices take place in different social, cultural, and institutional contexts, the study follows a quantitative research approach. Specifically, the study uses a self-report scale developed by Quoquab et al. (2019) to analyze the sustainable consumption behavior of young consumers from both a developed market and an emerging market. This scale assesses three factors – quality of life, environmental care, and resources for future generations – using a Likert scale ranging from 1 (totally disagree') to 5 (totally agree'). The measurement items are listed in Table 1.

Table 1 - Variables in the questionnaire

Variables	***Item***	***Measurement scale***	***Item description***
Quality of Life *(Quoquab et al., 2019)*	Item 1	Likert Scale Rating (1-5)	Indicate the level of agreement or disagreement: I don't like to waste food or beverages.
	Item 2	Likert Scale Rating (1-5)	Indicate the level of agreement or disagreement: I always try hard to reduce misuse of goods and services (e.g., I switch off lights and fans when not in use).
	Item 3	Likert Scale Rating (1-5)	Indicate the level of agreement or disagreement: I avoid overuse/consumption of goods and services (e.g., take print only when needed).
	Item 4	Likert Scale Rating (1-5)	Indicate the level of agreement or disagreement: I avoid being extravagant in my purchases.

Care for the Environmental Well-being *(Quoquab et al., 2019)*	Item 1	Likert Scale Rating (1-5)	Indicate the level of agreement or disagreement: I recycle daily newspaper (e.g., use as a pet's litter box, etc.).
	Item 2	Likert Scale Rating (1-5)	Indicate the level of agreement or disagreement: I purchase and use products that are environmentally friendly.
	Item 3	Likert Scale Rating (1-5)	Indicate the level of agreement or disagreement: I often pay extra to purchase environmentally friendly products (e.g., organic food).
	Item 4	Likert Scale Rating (1-5)	Indicate the level of agreement or disagreement: I use eco-friendly products and services.
Variables	**Item**	**Measurement scale**	**Item description**
Care for Future Generations (Quoquab et al., 2019)	Item 1	Likert Scale Rating (1-5)	Indicate the level of agreement or disagreement: I always remember that my excess consumption can create hindrance for future generations to meet their basic needs.
	Item 2	Likert Scale Rating (1-5)	Indicate the level of agreement or disagreement: I often think about future generations' quality of life.
	Item 3	Likert Scale Rating (1-5)	Indicate the level of agreement or disagreement: It is my responsibility to control my desire for excessive purchases for the sake of future generations.

	Item 4	Likert Scale Rating (1-5)	Indicate the level of agreement or disagreement: I am concerned about the future generation.
	Item 5	Likert Scale Rating (1-5)	Indicate the level of agreement or disagreement: I try to minimize excess consumption to preserve environmental resources for future generations.
Age			Write your age
Residence			Select your country of residence
Gender			Select your gender

The data was collected via a survey with fixed choice questions. As self-reported data may increase the risk of common method bias (CMB), which affects the validity and reliability of parameter estimates (Jarvis et al., 2003), the study followed an ex-ante approach to mitigate this issue. To reduce CMB, we implemented the following strategies. First, the questionnaire was translated from English into Spanish to ensure linguistic and cultural appropriateness for the survey conducted in Colombia. This translation was carefully proofread by two native Spanish speakers. Second, a pilot test was conducted with three academics and 25 students to assess the clarity and quality of the draft. Finally, participants were assured of anonymity and confidentiality to reduce social desirability bias (Jarvis et al., 2003).

The respondents selected for this study were young, educated undergraduate students of international business and management from Germany and Colombia. This specific group was chosen for several reasons: First, young consumers, particularly those in higher education, have been relatively underrepresented in research on sustainable consumption behavior (Kanchanapibul et al., 2014).

Examining this demographic is crucial, as they represent a generation that will increasingly influence consumption patterns and sustainability practices in the future (Pérez-Franco et al., 2022). Second, selecting young, educated students from both countries enhances the comparability of the sample, as these individuals share a similar level of education and exposure to global sustainability discourses. This comparability minimizes variations that could arise from differences in educational background, enabling a more accurate analysis of attitudes and behaviors toward sustainability (Abbas & Singh, 2012; Bauri & Kumar, 2018). Moreover, university students are considered vital for achieving long-term environmental sustainability, as they are more likely to be aware of environmental issues and engaged in sustainable practices (Gwekwerere, 2014; Pe'er et al., 2007). Their educational environment fosters critical thinking and awareness of global challenges, making them a key target for fostering sustainable consumption behaviors that can shape future market trends. By focusing on this group, the study aims to contribute to a better understanding of the behaviors of a demographic that will play a significant role in shaping future consumption patterns and sustainability efforts.

Surveys were distributed in classroom settings to ensure a controlled environment and to maximize the reliability of the responses. This in-person approach provided an opportunity for participants to seek clarification if needed, reducing potential misunderstandings and improving data quality. The decision to administer the survey in class also increased the response rate, minimizing nonresponse bias, which can occur when participants are required to complete surveys independently. As such, a total of 326 undergraduate participants, with 176 residing in Germany and 128 in Colombia were finally collected. The mean age of the participants was 22.08 years, with a standard deviation of 2.73 years. Females accounted for 60.9% of the respondents.

To investigate the differences between a developed and an emerging market regarding the variables of interest—specifically, quality of life, concern for environmental well-being, and care for future generations—we selected Germany as a representative of a developed country and Colombia as a representative of an emerging market (see International Monetary Fund 2024). These countries provide an ideal contrast due to their distinct economic, social, and environmental contexts. Germany, with its highly industrialized economy, strong environmental regulations, and high standard of living, offers valuable insights into attitudes and behaviors within a mature market. Conversely, Colombia, as an emerging market with unique developmental challenges allows for the examination of these variables within a different socioeconomic framework. This selection facilitates a comprehensive analysis of how these factors manifest across diverse economic environments.

To evaluate the reliability and validity of our measurements, we first conducted a confirmatory factor analysis using established procedures (Diamantopoulos & Winklhofer, 2001). The results showed that our scales met the recommended standards for composite reliability and average variance extracted (AVE; Bagozzi and Yi 1988; Fornell and Larcker 1981). Furthermore, the squared correlations between the latent constructs were found to be lower than the average variance extracted for each construct, providing evidence of discriminant validity (Fornell and Larcker 1981). We then assessed the internal consistency of our scales using Cronbach's alpha.

All scales exhibited Cronbach's alpha values above the recommended threshold of 0.70 (Nunnally 1978; see Table 2 for detailed values), indicating adequate reliability. Overall, these results suggest that our measurement scales possess both convergent and discriminant validity, along with satisfactory reliability. The mean values for variables quality of life, concern for environmental well-being, and care for future generations were derived from the average scores of their corresponding items.

Table 2 - Descriptive statistics and correlations

Variable	*V1*	*V2*	*V3*
V1: Care for the environmental well-being			
V2: Quality of life	.497*		
V3: Care for the future generations	.604*	.567*	
M	3.44	4.10	3.75
SD	.89	.67	.74
α	.811	.714	.836
AVE	.64	.55	.61
CR	.88	.83	.88

Note: M = mean; SD = standard deviation; α = Cronbach's alpha; AVE = average variance extracted; CR = composite reliability. *p < .001 (two-tailed).

Results

The data were analyzed using IBM SPSS Statistics, Version 29, an invaluable tool for professionals and researchers who require robust statistical analysis and data management capabilities. To examine the significance of mean differences, t-tests were conducted, utilizing SPSS's advanced statistical functions. A t-test is particularly effective in determining whether there are statistically significant differences between the means of two groups, providing a rigorous method to support or refute research hypotheses. The results of the study provide compelling evidence of significant differences in sustainable consumption concerns between young consumers in Germany and Colombia. Firstly, the data reveals a notable difference in the mean values concerning the quality of life between the two groups ($M_{Colombia/quality\ of\ life} = 4.29$; $M_{Germany/quality\ of\ life} = 3.96$; $t(302) = 4.24$; $p < 0.001$, two-tailed). See table 3. This finding supports Hypothesis H1, which proposed that consumers from emerging markets exhibit a higher concern for quality of life compared to those from developed countries.

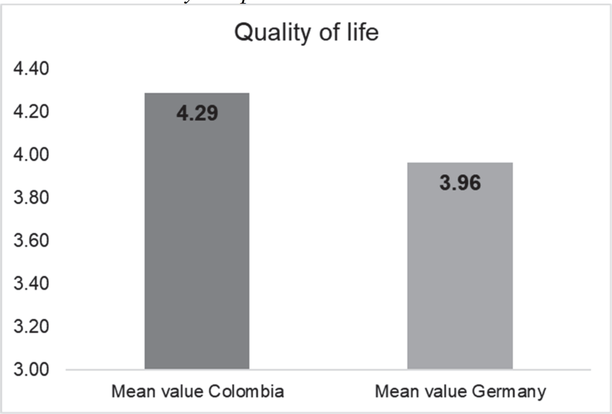
Additionally, the analysis shows a significant difference in the mean values for environmental well-being between the two groups ($M_{Colombia/care\ for\ the\ environmental\ well\text{-}being} = 3.97$; $M_{Germany/care\ for\ the\ environmental\ well\text{-}being} = 3.06$; $t(302) = 10.22$; $p < 0.001$, two-tailed). The higher mean value among Colombian respondents suggests a greater concern for environmental well-being, thus confirming Hypothesis H2, which posited that consumers from emerging markets have a stronger environmental concern than their counterparts in developed nations.

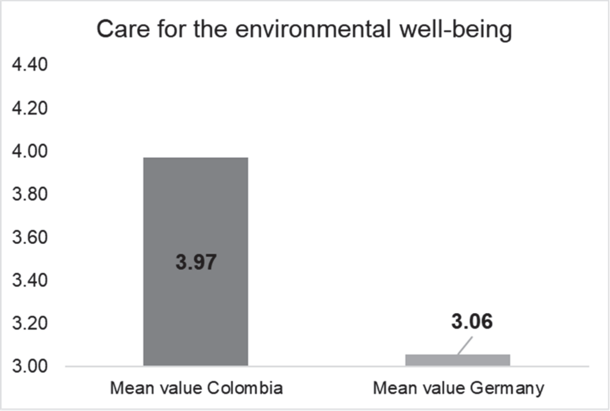
Similarly, the results demonstrate a significant difference in the mean values concerning the care for future generations ($M_{Colombia/care\ for\ the\ future\ generations} = 4.03$; $M_{Germany/care\ for\ the\ future\ generations} = 3.55$; $t(302) = 5,76$; $p < 0.001$, two-tailed). This supports Hypothesis H3, which proposed that consumers from emerging markets show a higher level of concern for future generations compared to those from developed countries.

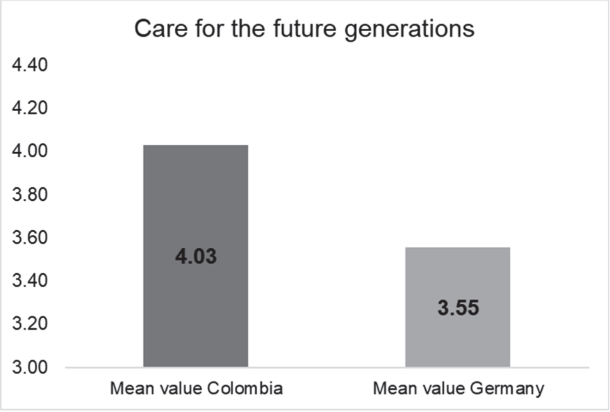
The findings suggest that young consumers in Colombia prioritize sustainable consumption practices that align with a higher quality of life, environmental stewardship, and intergenerational equity more than their German counterparts. These results align with the hypothesis derivations, which argue that consumers in emerging markets may have a heightened awareness and greater motivation to engage in sustainable consumption due to direct exposure to the adverse effects of environmental degradation, as well as cultural and socio-economic factors that shape their attitudes towards sustainability.

Overall, the results provide robust evidence supporting the hypotheses and highlight the significant role of socio-cultural context in shaping sustainable consumption behaviors among young consumers. The insights gained from this study contribute to a better understanding of how consumers from different economic settings prioritize sustainability and suggest that future research should continue to explore these dynamics in diverse cultural contexts.

Table 3 - Mean values in a country comparison







Discussion

Implications for research

First, our study enriches the current body of research by providing empirical evidence SCB across developed and emerging markets. This comparison deepens the understanding of how socio-economic contexts and cultural factors influence sustainable behaviors, a perspective often underexplored in existing literature (Fuchs & Lorek, 2005; Griskevicius et al., 2012). Further, our study expands the understanding of sustainable consumption by incorporating dimensions such as quality of life and intergenerational responsibility, moving beyond the traditional focus on environmental impact. This broader conceptualization adds depth to the literature and encourages future research to explore other factors influencing sustainable consumption behaviors (Quoquab et al., 2019). Second, by applying RDT to analyze sustainable consumption behaviors, our study supports the theoretical approach to understanding how perceptions of inequality and deprivation influence consumer choices in both developed and emerging markets (Chipp et al., 2011; Smith & Pettigrew, 2015). Third, the study emphasizes young consumers as a critical demographic for future sustainable consumption research, given that the younger generation will play a pivotal role in shaping the future of sustainability (Pérez-Franco et al., 2022). Our results provide valuable insights into their attitudes and behaviors toward sustainability, which is crucial for developing long-term strategies aimed at fostering sustainable habits and influencing future market trends.

This study provides critical insights into the field of sustainable consumption and consumer behavior, offering new dimensions to the current theoretical understanding of how young consumers engage with sustainability across different socio-economic contexts. First, the research expands the traditional view of sustainable consumption by demonstrating that consumer behavior is not merely influenced by product availability or environmental education but also by cultural and socio-economic factors that vary between developed and emerging markets. The finding that young consumers in emerging markets show a higher commitment to sustainable behaviors shifts the theoretical narrative, suggesting that direct exposure to environmental degradation and socio-economic inequalities might fuel stronger pro-environmental behaviors in emerging markets.

For the marketing discipline, this implies that cultural and contextual factors need to be incorporated into models of consumer behavior. Sustainable marketing strategies should not assume homogeneity across regions but instead recognize that young consumers in emerging economies may prioritize sustainability more due to the immediacy of environmental challenges. Future models must consider how regional differences in consumer psychology – particularly in how consumers perceive their role in addressing environmental issues – affect sustainable consumption patterns.

Furthermore, this study makes a significant contribution to RDT by applying it to the domain of sustainable consumption within a cross-cultural context. Traditionally, RDT has been used to explain social movements, political behavior, and collective action, often emphasizing how perceptions of inequality trigger dissatisfaction and drive action to improve one's status. By introducing RDT to the context of sustainability, this research reveals how feelings of deprivation in emerging markets can catalyze more responsible consumption behaviors aimed at closing perceived gaps in environmental quality and living standards between their region and more developed nations.

Our study suggests that relative deprivation extends beyond economics, encompassing environmental and social dimensions as well. In emerging markets, young consumers may perceive that their environmental conditions – pollution, resource scarcity, and long-term sustainability – are inferior compared to developed countries. This environmental deprivation appears to be a key motivator for adopting more sustainable behaviors, driven by the desire to achieve parity in terms of quality of life and ecological well-being. The integration of RDT in this context expands the theory's application field as it demonstrates that perceived environmental inequalities and concern for future generations can drive sustainable consumption as much as traditional economic or social deprivation.

The study also introduces the notion that intergenerational responsibility can be seen as an extension of RDT, where young consumers in emerging markets feel a sense of deprivation not only for themselves but for future generations. This extension of RDT highlights how psychological mechanisms of deprivation can influence sustainability behaviors across different cultural contexts. It also suggests that future applications of RDT in consumer behavior should include environmental and social dimensions of deprivation to more fully capture the range of factors influencing consumer decision-making in both emerging and developed markets.

Managerial implications

The study's findings have significant implications for marketing practitioners, companies, and consumers.

First, marketing professionals operating in emerging markets should capitalize on environmental awareness and concern for future generations among young consumers. Given their stronger inclination towards sustainability, marketing strategies in these regions should emphasize the alignment of products and services with sustainable values. Messaging that highlights eco-friendly attributes, ethical production processes, and long-term environmental benefits will likely resonate more with this demographic. Additionally, campaigns that foster a sense of intergenerational responsibility can further strengthen the emotional connection between consumers and sustainable brands.

Moreover, in developed markets, where young consumers exhibit comparatively lower levels of environmental concern, marketers should prioritize awareness-building initiatives. Investments in education campaigns and sustainability advocacy can help bridge the knowledge gap and foster a deeper understanding of the personal and societal benefits of sustainable consumption. By focusing on long-term health, economic, and environmental advantages, companies can help shift perceptions and attitudes, potentially stimulating demand for sustainable products.

Second, since young consumers in emerging markets are more likely to prioritize sustainability, businesses can focus on green innovation, eco-friendly product design, and transparent communication about their environmental efforts. By embedding sustainability into their core values, companies can tap into a growing market of conscientious consumers, strengthen brand loyalty, and position themselves as leaders in corporate responsibility.

Third, these results show policymakers in emerging markets that they should build on the existing sustainability awareness by implementing policies that further incentivize and support sustainable consumption. This could include offering subsidies for green products, tax breaks for companies producing eco-friendly goods, and regulations that promote sustainable business practices. Given that young consumers in these regions already prioritize sustainability, policies that reinforce and reward responsible consumption behaviors can accelerate the transition to more sustainable economies. In developed countries, where the study suggests lower levels of concern for sustainability among young consumers, policymakers should prioritize awareness-building initiatives. This could involve launching nationwide campaigns that emphasize the long-term benefits of sustainable consumption, both environmentally and economically. These campaigns should highlight the direct impact of individual actions on global environmental outcomes, stressing the urgency of adopting more responsible consumption patterns. Policymakers in developed markets should also explore regulatory mechanisms that encourage businesses to provide clearer and more transparent information about the environmental impact of their products. For instance, strengthening eco-labeling standards and ensuring they are prominently displayed could help consumers make more informed decisions. Additionally, incentives for sustainable practices, such as subsidies for eco-friendly products or penalties for wasteful consumption, could nudge consumers toward more responsible behaviors.

The authors report that there are no competing interests to declare

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Evaluation of companies' sustainability in crisis conditions

by *Iveta Pokromovica*[*]

Abstract

The study aims to identify the impact of global and national crises on the sustainability of companies in the example of manufacturing industries in Latvia and Ukraine. The study employed statistical analysis to identify the main trends and changes in global and national economic indicators that occurred due to the crisis. The regression analysis was used to establish a link between these indicators and the sustainability of manufacturing companies in the studied countries. The obtained results show that global and national indicators, changes which may indicate the presence of crisis phenomena, are related to the sustainability indicators of companies. However, this relationship is not the same for countries with different levels of economic openness and different degrees of economic integration into global markets. Thus, the sustainability indicators of Latvian companies are more closely correlated with the values of global and national gross domestic product, inflation, unemployment, production. In general, the resilience of Latvian companies is higher than that of Ukrainian companies. In both Latvia and Ukraine, companies' sustainability performance has been affected by the crisis, including the COVID-19 pandemic and the war in Ukraine. However, the war in Ukraine has had particularly severe consequences, including for the resilience of companies. Thus, the overall commercial profitability after tax, which was 10.11% in the country in 2021, fell to more than -3.24%. These results indicate the relevance of a study of the degree of influence of global and national trends in the process of assessing the sustainability of companies and may be useful for assessing the financial aspects of the sustainability of the manufacturing industry.

Keywords: global environment, local environment, macroeconomic indicators, financial indicators, war, pandemic.

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Introduction

In the modern world, companies operate under the constant influence of crises generated both at the micro level and in the global environment. Assessing the resilience of companies to the crisis in such conditions is a necessary activity, as it can identify weaknesses and hidden potential of the company to counteract or adapt to the crisis conditions. The sustainability of individual companies determines the overall sustainability of the business sector, which in turn affects the sustainable development of countries.

Sustainable development is defined as maintaining a balance between the economic, environmental, and social components of company development (Kubiczek and Tuszkiewicz, 2022; Hadasik et al., 2025). From a long-term perspective, one of the most important characteristics of a company's functioning is the stability of its financial position (Ismayilov et al., 2021; 2024). However, sustainability is not solely about financial stability; it also encompasses environmental stewardship and social responsibility. Environmental sustainability involves practices that reduce ecological footprints, such as minimizing waste, reducing carbon emissions, and utilizing renewable resources (Hussain et al., 2022; Remeshevska et al., 2021). Social sustainability focuses on fair labour practices, community engagement, and enhancing the well-being of employees and society at large. In today's environment, the financial stability of most companies is compromised due to the negative impact of internal and external environmental factors (Kredina et al., 2022). The impairment of financial sustainability, in turn, creates obstacles to the appropriate development of the environmental and social components. Without adequate financial support, it is impossible to guarantee, for example, the timely payment of salaries to staff, which violates the social aspects of sustainability (Kerimkulov et al., 2015; Khamzin et al., 2016). In addition, financial resources are needed to introduce more environmentally friendly technologies and implement other measures to preserve the environment.

Since the global financial crisis of 2008-2009, European countries, including Latvia, have been experiencing the most severe crises since then (Cheema et al., 2022; Vodovozov et al., 2021). These crises are caused, firstly, by the COVID-19 pandemic (2020) and secondly, by the war in Ukraine (2022) and subsequent problems with the supply of natural resources (Shahini et al., 2023). The consequences of these phenomena are catastrophic and global in scope (Boiko et al., 2025; Bisenovna et al., 2024; Tleubayev et al., 2024), affecting not only economic stability but also environmental and social structures.

Some papers highlight Latvia's particular achievements in dealing with the consequences of the crises. For instance, C. Challoumis (2021), studying the period after the global financial crisis (namely, 2012-2017), notes that the results of the assessment of the money cycle index for Latvia are higher than the global average value of this indicator. The researcher emphasises that a well-structured economy, as exemplified by Latvia, can withstand the economic crisis. However, the COVID-19 pandemic has exposed many problems in public administration in Latvia. Among the main problems are imperfect coordination between the economic sector and government agencies, lack of evaluation of the effectiveness of regulation, lack of learning from mistakes and inattention to identified shortcomings (Ketners et al., 2025). The pandemic created an impetus to address several shortcomings, contributing to the activation of the Latvian government. At the same time, the greatest positive effect of changes can be achieved if such changes are applied in long-term, refraining from a reaction to the crisis alone. It is important to increase the productivity of the Latvian economy; as low productivity is one of the most important factors determining the low gross domestic product (GDP) per capita in Latvia relative to other European Union (EU) countries. Increasing productivity depends primarily on the proper use of competitive advantages, including technological development, digitalisation and innovation. Crisis conditions can provide a significant impetus for more active use of these advantages (Krasnykov, 2023).

The speed of economic recovery from the crisis, including COVID-19, depends heavily on government support, its timeliness and scope. A good policy strategy can ensure a favourable environment for business development and encourage innovation. Innovations will ensure a business ecosystem that can adapt to shocks not only in the current crisis but also in the long term (Panchenko et al., 2022). These views are particularly relevant given that the pandemic crisis was immediately followed by a crisis due to the war in Ukraine. Latvia is actively supporting Ukraine in meeting the most urgent needs arising from the large-scale Russian invasion. In addition, as a state geographically close to Ukraine, Latvia recognises the potential danger that may arise in the future caused by the war. The Latvian National Defence Concept (2020) lists ensuring the sustainability of the national economy as one of the eight pillars. The document states that companies providing essential services and employing more than 250 people should ensure uninterrupted operations in times of crisis and war. The Concept also considers provisions on supply chain security, limiting economic and technological dependence on non-NATO and EU countries, creating backup systems (Bērziņš, 2023). Thus, ensuring the proper functioning of the economy in a crisis is one of the top priorities for the government and economic actors. Many researchers link corporate sustainability to sustainable development in general. For instance, C. Malesios et al. (2021) in their literature review found that most of the work in the relevant field of research examines the link between environmental and social practices and economic and environmental performance. A.A. Jan et al. (2023), F. Bartolacci et al. (2020), R. Khaled et al. (2021) investigate the role of corporate sustainability in sustainable development and the sustainable development of firms in general.

Several studies noted that ensuring sustainable economic development in Latvia in the context of the crisis is achieved through the active implementation of innovations and the development of the digital economy (Ketners et al., 2024). Several studies also focused on different approaches to assessing the resilience of Latvian companies to the crisis (Bistrova et al., 2020; Pokromovica et al., 2022; Subačienė et al., 2024).

While existing studies have provided valuable insights into the resilience and sustainability of companies, several research gaps remain that this study aims to address. There is a notable lack of detailed analysis on how global and local crisis trends specifically impact the sustainability of companies in Latvia and Ukraine. This study intends to fill this gap by conducting an in-depth analysis that encompasses the financial, environmental, and social dimensions of sustainability. Previous studies have often focused on isolated aspects of sustainability and resilience, but this study integrates resilience theory, systems thinking, and the triple bottom line framework to offer a more comprehensive understanding of corporate sustainability. Additionally, while financial indicators are crucial, there is a recognized need for a more balanced discussion that includes the environmental and social dimensions of sustainability. This study acknowledges this need and suggests future research directions to incorporate these dimensions more fully. By addressing these research gaps, this study aims to contribute significantly to the academic and practical understanding of corporate sustainability and resilience in the face of global and local crises.

Therefore, the research aims to determine the impact of global and local crisis trends on the sustainability of companies in Latvia and Ukraine. Tasks of the study: to analyse global and local crisis trends; to analyse the sustainability performance of companies in Latvia and Ukraine; to determine the relationship between global and local crisis trends and sustainability indicators of Latvian and Ukrainian companies. This study is grounded in several key theoretical frameworks that provide a comprehensive understanding of the concepts of sustainability and resilience.

Resilience theory, originating from ecological studies and later applied to social and economic systems, emphasizes the capacity of systems to absorb disturbances, reorganize, and continue functioning while retaining their essential structures and feedbacks. In the context of this study, resilience theory helps explain how companies in Latvia and Ukraine adapt to and recover from crises such as the COVID-19 pandemic and the war in Ukraine. By analyzing indicators such as financial stability, liquidity, and profitability, this study assesses the resilience of companies and their ability to withstand and adapt to external shocks.

Systems thinking provides a holistic approach to understanding complex systems by examining the interconnections and interdependencies among their components. This framework is particularly relevant for analyzing the macroeconomic indicators and their impact on company sustainability. By considering the global and national economic systems as interconnected entities, this study can identify how changes in one part of the system (e.g., global oil prices) affect other parts (e.g., company profitability). This study focuses on the financial aspect of sustainability but acknowledges the interconnectedness of social and environmental factors. The financial indicators used in this study, such as share of liabilities and commercial profitability, provide insights into the financial sustainability of companies, which is a prerequisite for achieving broader sustainability goals.

Materials and Methods

The sample for the study includes the manufacturing industries of Latvia and Ukraine, which can be used to demonstrate the differences in the sustainability of manufacturing companies and the factors that influence them. In addition, in the context of the research topic, it was necessary to study the unique experience of countries in crisis. For Latvia, this is due to the effects of the COVID-19 pandemic, as well as the territorial proximity to Ukraine, which is at war and experiencing the most severe crisis compared to many countries today. Latvia is also experiencing reverberations of the crisis and needs to take security measures, including to ensure the resilience of companies.

The sample of indicators for the study includes the following macroeconomic indicators (for the world, Latvia and Ukraine):

- GDP and GDP per capita are the most general indicators of economic development and sustainability of global and national economies;
- inflation – due to rising prices for products, raw materials, and resources, it directly affects the sustainability and financial position of companies;

- unemployment – often accompanies crises of various origins, reduces the purchasing power of citizens, which can also affect the sustainability and profitability of companies;
- raw material prices – fluctuations in raw material prices can affect the economic situation of companies, cause cost increases;
- production volume – reflects the demand for goods or services of companies.

The sample also includes indicators that indicate the resilience of companies to crisis conditions:

- share of liabilities in the balance sheet (at the end of the year, times) – shows how much of the assets are financed by borrowings;
- share of short-term liabilities in the balance sheet (at the end of the year, times) – shows what part of the assets is financed by short-term borrowings;
- total liquidity (at the end of the year, times) – characterises the ability to repay current liabilities with current assets;
- commercial profitability after taxes (%) – demonstrates the company's profitability after taxes.

The leading method for the study is the method of statistical analysis. This method was used to analyse the trends in the above indicators for 2013-2022 (currently, the necessary data from official sources are available only up to 2022). The method was used to identify how the values of the indicators changed in the years marked by certain crisis phenomena. In addition, the use of statistical analysis was used to identify general trends in the indicators and link them to economic dynamics in the countries. To elevate the methodological approach, this study integrates advanced econometric techniques such as regression analysis and structural equation modelling. These techniques provide a deeper understanding of the underlying mechanisms and causal relationships between variables. Qualitative insights from case studies and expert interviews are also incorporated to complement the quantitative analysis, offering a richer contextual understanding of the factors influencing sustainability and resilience.

The paper uses data that is publicly available on such resources as the World Bank (2024), Official Statistics Portal (2024), State Statistics Service of Ukraine (2024) and Forbes (Prasad, 2023). The following software was used in the analysis process: MS Excel and Statista.

Results

Global and local crisis trends

Over the past decade, the global economy has been subject to many shocks, but the crises associated with the COVID-19 pandemic in 2020 and the beginning of the full-scale invasion of Ukraine in 2022 have had the most extensive impact. These consequences are reflected both in the local economic development of Ukraine and its neighbouring countries (in particular, EU countries, including Latvia) and in global indicators. Table 1 shows some of the main macroeconomic indicators, the values of which, in the author's opinion, are closely related to global and national crisis trends. In other words, these are indicators whose growth or decline can determine the overall state of economic development, and which are closely correlated with global and local crises. The key macroeconomic indicators considered in this study include GDP (current USD), Inflation, consumer prices (annual %), Unemployment, total (% of the total labour force), Crude oil, average (USD/bbl), Manufacturing, value added (% of GDP) and GDP per capita (current USD).

Figures 1-6 illustrate the trends in the above indicators for the world. Sharp changes in indicators in a given period may indicate the global economy's response to the crisis.

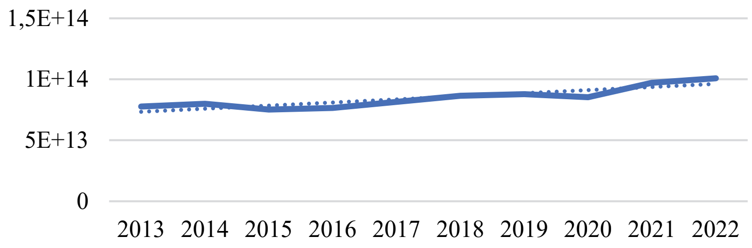

Figure 1 - Global GDP (current USD)
Source: compiled by the author based on the data from World Bank (2024).

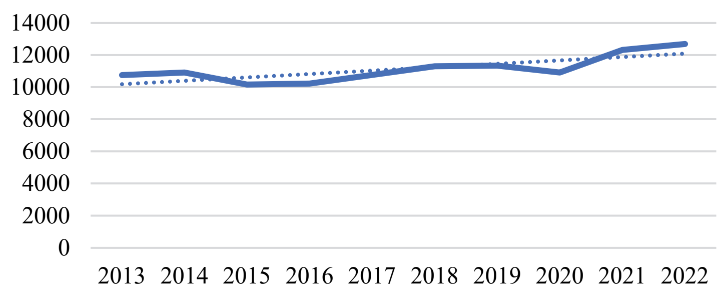

Figure 2 - GDP per capita (current USD)
Source: compiled by the author based on the data from World Bank (2024).

Table 1 - Importance of key macroeconomic indicators for the world, Latvia and Ukraine

Indicator	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*
World										
GDP (current USD)	7.77E+13	7.98E+13	7.53E+13	7.65E+13	8.15E+13	8.65E+13	8.78E+13	8.53E+13	9.72E+13	1.0088E+14
Inflation, consumer prices (annual %)	2.651673	2.354491	1.443857	1.605539	2.254277	2.450362	2.206073	1.936941	3.466926	7.967573616
Unemployment, total (% of total labour force)	6.163629	6.022234	6.055028	6.021302	5.92976	5.768692	5.591542	6.603279	6.064105	5.267477115
Crude oil, average (USD/bbl)	104.08	96.24	50.75	42.81	52.81	68.35	61.41	41.26	69.07	97.10
Manufacturing, value added (% of GDP)	15.8637	15.98736	16.44123	16.25112	16.31134	16.44001	16.03414	16.03266	16.5544	16.04771382
GDP per capita (current USD)	10749.96	10911.13	10168.12	10215.59	10754.93	11297.45	11338.15	10904.15	12316.1	12687.74189
Latvia										
GDP (current USD)	3.02E+10	3.14E+10	2.73E+10	2.81E+10	3.05E+10	3.44E+10	3.42E+10	3.44E+10	3.94E+10	40932030050
Inflation, consumer prices (annual %)	-0.02945	0.620491	0.174242	0.140633	2.930363	2.534454	2.811409	0.219065	3.275829	17.31028302

Unemployment, total (% of total labour force)	11.87	10.85	9.87	9.64	8.72	7.41	6.31	8.1	7.51	6.81
Manufacturing, value added (% of GDP)	11.09043	10.50167	10.46795	10.16648	10.47018	10.55715	10.64186	11.06913	12.38169	12.98333256
GDP per capita (current USD)	15007.49	15742.39	13786.46	14331.75	15695.12	17865.03	17883.35	18096.2	20930.4	21779.50426
Ukraine										
GDP (current USD)	1.9E+11	1.34E+11	9.1E+10	9.34E+10	1.12E+11	1.31E+11	1.54E+11	1.57E+11	2E+11	1.60503E+11
Inflation, consumer prices (annual %)	-0.23895	12.07186	48.69986	13.91271	14.43832	10.95186	7.886717	2.732492	9.363139	20.18363666
Unemployment, total (% of total labour force)	7.17	9.27	9.14	9.35	9.5	8.8	8.19	9.48	9.83	
Manufacturing, value added (% of GDP)	11.14059	12.22813	11.90278	12.21913	11.9803	11.53402	10.7886	10.10138	10.2833	7.576765142
GDP per capita (current USD)	4187.74	3104.654	2124.663	2187.728	2638.325	3096.563	3661.458	3751.737	4827.846	4533.975586

Source: compiled by the author based on World Bank (2024), Official Statistics Portal. (2024), State Statistics Service of Ukraine (2024).

As can be seen from Figures 1 and 2, global GDP, both in total and per capita terms, is on an upward trend, indicating a gradual growth of the global economy. In 2020, there was a slight decline, reflecting the overall economic downturn associated with the COVID-19 pandemic.

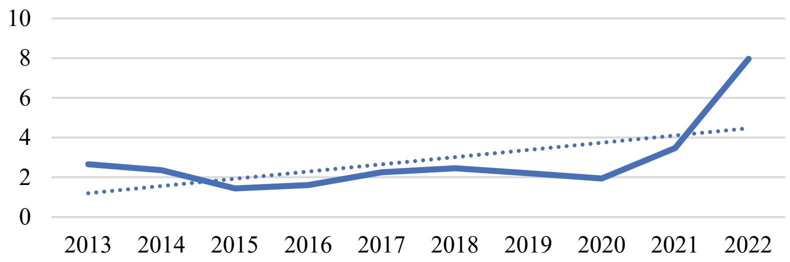

Figure 3 - Inflation, consumer prices (annual %)
Source: compiled by the author based on the data from World Bank (2024).

Figure 3 shows that after 2020, consumer prices began to rise rapidly. Inflation can be attributed to a pickup in consumption after the first year of quarantine restrictions. Another reason could be the rise in prices due to the limited supply under quarantine conditions.

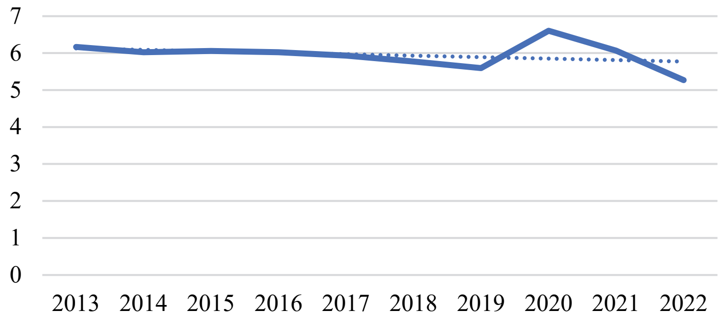

Figure 4 - Unemployment, total (% of total labour force)
Source: compiled by the author based on the data from World Bank (2024).

2020 was also a critical year in terms of rising unemployment, as the pandemic left many people unemployed, and many companies laid off workers (Figure 4). Instead, in 2020, there was an increase in Manufacturing, value added (% of GDP). Another factor could be the rise in resource and energy prices (Figure 5).

Growth peaked in 2021, and in 2022, it declined again to around 2020 levels. These trends may also reflect crisis phenomena, for example, it is possible to assume that the share of manufacturing in GDP increased after 2020 due to the decline in the share of the service sector associated with quarantine restrictions. When demand for services stabilised, the indicator also returned to its previous values. The macroeconomic indicators of Latvia and Ukraine are noteworthy (Figure 7). These countries, especially Ukraine, have been more affected by crisis trends related not only to the pandemic but also to the war in Ukraine.

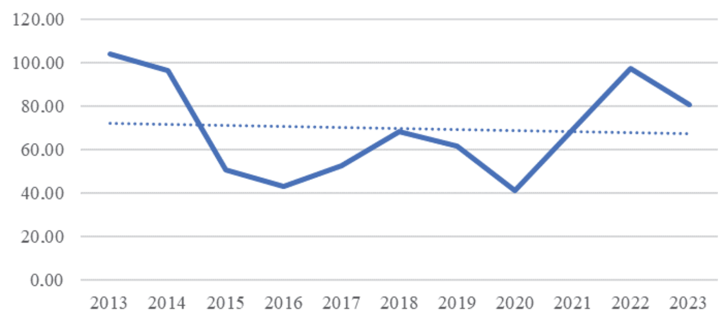

Figure 5 - Crude oil, average (USD/bbl)
Source: compiled by the author based on the data from World Bank (2024).

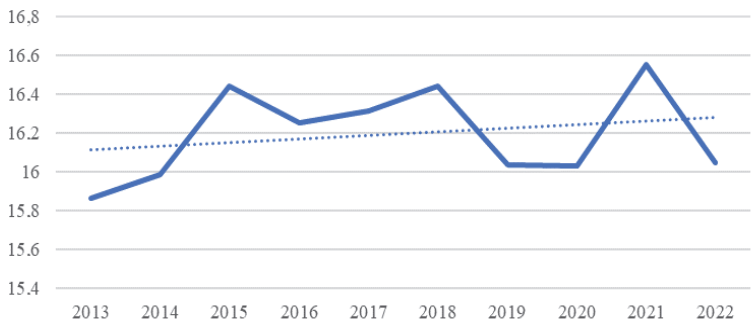

Figure 6 - Manufacturing, value added (% of GDP)
Source: compiled by the author based on the data from World Bank (2024).

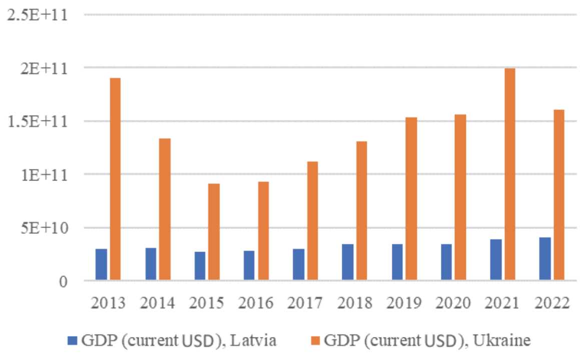

Figure 7 - GDP of Latvia and Ukraine (current USD)
Source: compiled by the author based on the data from Official Statistics Portal (2024), State Statistics Service of Ukraine (2024).

Figure 7 shows that Ukraine's GDP is significantly higher than Latvia's. However, the Latvian indicator is growing steadily, while Ukraine's GDP in 2022 experienced a significant decline. This decline coincides with the outbreak of the war in Ukraine, which has had a catastrophic impact on the country's economy (Figure 8).

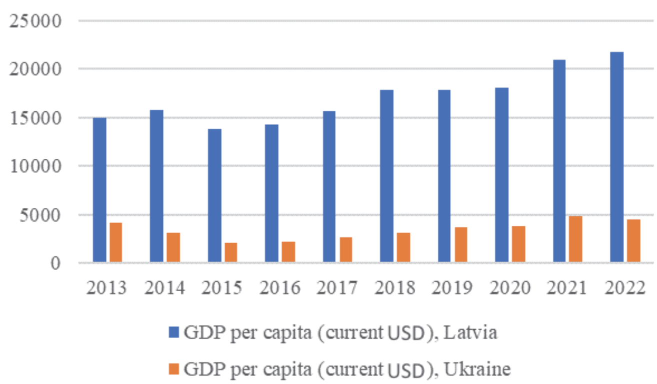

Figure 8 - GDP per capita of Latvia and Ukraine (current USD)
Source: compiled by the author based on the data from Official Statistics Portal (2024), State Statistics Service of Ukraine (2024).

GDP per capita is significantly higher in Latvia, although the total GDP in this country is lower than in Ukraine. This may indicate a higher standard of living in Latvia and a more even distribution of wealth due to social programmes and/or more efficient economic activity in general (Figure 9).

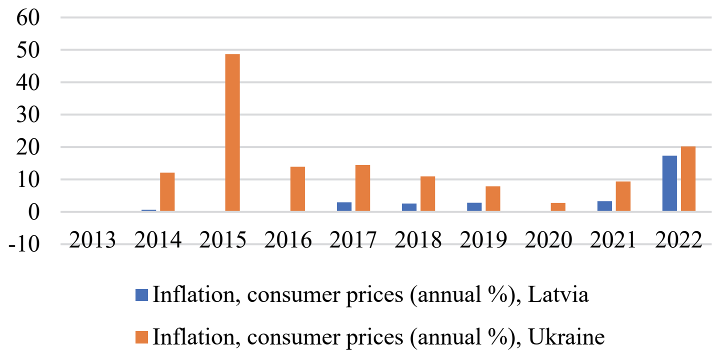

Figure 9 - Inflation of Latvia and Ukraine, consumer prices (annual %)
Source: compiled by the author based on the data from Official Statistics Portal (2024), State Statistics Service of Ukraine (2024).

Ukraine's inflation rate is significantly higher than Latvia's, but in 2022, both countries saw a significant increase in consumer prices. This may be a result of military operations and the associated rise in energy and resource prices (Figure 10).

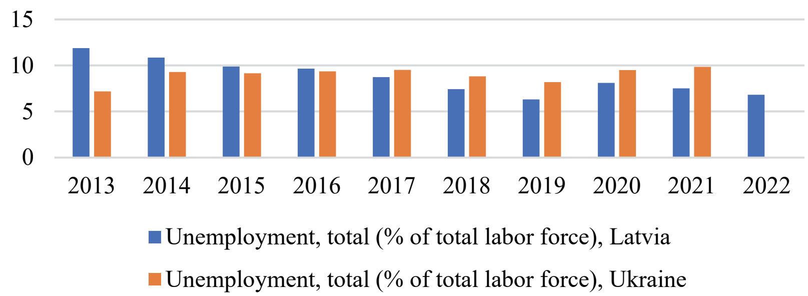

Figure 10 - Unemployment of Latvia and Ukraine, total (% of total labour force)
Source: compiled by the author based on the data from Official Statistics Portal (2024), State Statistics Service of Ukraine (2024).

The unemployment rate in Latvia is mostly on a downward trend, while in Ukraine it is unstable and growing in 2019-2021. The lack of data for Ukraine for 2022 makes it impossible to assess the impact of the war on unemployment in the country. At the same time, other sources indicate that the unemployment rate in Ukraine increased by 2.2% in 2022 compared to the previous period, although in 2023 it recovered to half of its pre-war level (Prasad, 2023).

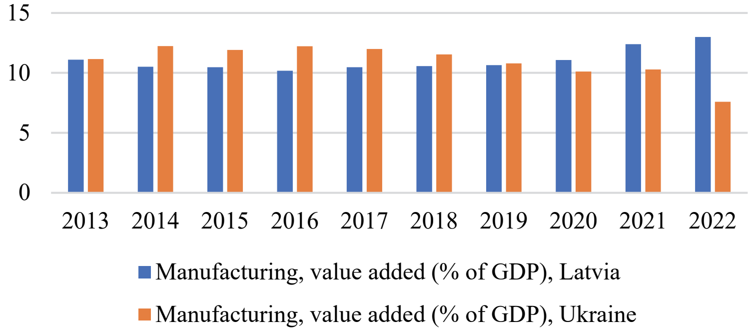

Figure 11 - Manufacturing of Latvia and Ukraine, value added (% of GDP)
Source: compiled by the author based on the data from Official Statistics Portal (2024), State Statistics Service of Ukraine (2024).

The share of manufacturing in Latvia's GDP is gradually increasing. In Ukraine, this indicator has the opposite trend, but it fell particularly sharply in 2022. This may be determined by a change in the structure of the participation of various sectors of the economy in GDP due to the war. Thus, the macroeconomic indicators of the world in general and Latvia and Ukraine in particular confirm the significant impact of the crisis on the global and national economies. Both the COVID-19 pandemic and the war in Ukraine have had a negative impact on the economy. Ukraine has been most affected by the war. Latvia, as a country geographically close to Ukraine, has also experienced some negative trends. At the same time, the impact of the war can also be traced at the global level, for example, through rising oil prices. The impact of the pandemic is visible at both the global and local levels.

Sustainability of companies in the example of Latvia and Ukraine

The analysis of the sustainability of companies in the example of Latvia and Ukraine includes indicators that characterise the financial stability, liquidity and profitability of companies. These indicators include share of liabilities in the balance sheet (at the end of the year, times), share of short-term liabilities in the balance sheet (at the end of the year, times), total liquidity (at the end of the year, times), commercial profitability after taxes (%). The values of these indicators for Latvia and Ukraine are presented in Table 2 and Table 3.

Table 2 - Values of company sustainability indicators for 2013-2022 for Latvia

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*
Share of liabilities in the balance sheet (at the end of the year, times)	0.656	0.645	0.635	0.626	0.614	0.596	0.590	0.559	0.515	0.512
Share of short-term liabilities in the balance sheet (at the end of the year, times)	0.320	0.303	0.298	0.294	0.295	0.296	0.284	0.259	0.256	0.272
Total liquidity (at the end of the year, times)	1.155	1.189	1.225	1.232	1.263	1.272	1.319	1.387	1.461	1.464
Commercial profitability after taxes (%)	2.365	2.744	3.066	3.747	4.980	6.303	6.242	4.488	7.546	6.827

Source: compiled by the author based on the data from Official Statistics Portal (2024).

Table 3 - Values of company sustainability indicators for 2013-2022 for Ukraine

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*
Share of liabilities in the balance sheet (at the end of the year, times)	0.658	0.753	0.716	0.755	0.753	0.751	0.731	0.736	0.707	0.728
Share of short-term liabilities in the balance sheet (at the end of the year, times)	0.471	0.526	0.51	0.585	0.579	0.589	0.588	0.585	0.576	0.595
Total liquidity (at the end of the year, times)	1.141	1.038	0.998	0.987	0.979	0.981	0.982	0.991	1.037	1.036
Commercial profitability after taxes (%)	-0.699	-14.163	-7.334	0.607	3.037	4.467	7.592	0.921	10.11	-3.243

Source: compiled by the author based on the data from State Statistics Service of Ukraine (2024).

The optimal value of the Share of liabilities in the balance sheet (at the end of the year, times) is usually considered to be less than 0.5, although the normative values vary depending on the approach to analysis, industry, region, and can reach 0.7-0.8. Latvia's score was declining over the study period and was approaching the optimal value. Ukraine's figure was higher, with particularly sharp increases in critical years for the country: after the start of Russian armed aggression in the east of the country in 2014 and after the start of a full-scale Russian invasion in 2022. The growth of this indicator may indicate an increase in the financial dependence of companies and a breach of financial security in general. The share of short-term liabilities in the balance sheet (at the end of the year, times) also gradually decreased for Latvian companies and increased for Ukrainian ones. This may indicate liquidity problems, increased dependence on short-term borrowed funds, and lead to greater financial risks and reduced sustainability.

The optimal value of total liquidity (at the end of the year, times) should be in the range of 1-2. As Table 2 shows, the values of this indicator for Latvian companies were within the normal range. Table 3 shows that for Ukraine, the indicator was slightly below the norm during the period from 2015 to 2020 but reached the normative values by the end of the period. In general, this indicator describes the ability of companies to meet their current obligations. Thus, the growth of the previous indicator of the share of short-term liabilities in the balance sheet is ensured by the corresponding volume of current assets. Commercial profitability after taxes (%) grew steadily for Latvian companies until 2020 when there was a noticeable decline. However, in 2021, the indicator reached its highest level in the study period, and in 2022 it declined slightly again. Ukraine's score was negative from 2013 to 2015, which was due to the outbreak of armed Russian aggression in eastern Ukraine, but then gradually increased until 2020. In 2020, Ukraine's indicator, like Latvia's, experienced a significant decline, and in 2021 it reached its highest level in the study period. However, after the full-scale invasion, the indicator took on negative values, indicating the severe consequences of the war for the profitability of enterprises.

The relation between resilience and crises

In the previous section, the sustainability indicators of Latvian and Ukrainian companies were analysed, and thus providing assumptions regarding the relationship between changes in the indicators and the most significant crisis events of the period under study. It is also necessary to identify whether there is a link between the sustainability indicators of companies and the global indicators identified in the paper as those most closely related to global crisis trends. This will help determine how companies are responding to the crisis in general, and which global trends are having the most significant impact on their operations. The results of the analysis should serve as a basis for developing anti-crisis and/or adaptation strategies in response to the factors that will be most significant for the companies' operations. The results of the regression analysis between the sustainability indicators of Latvian and Ukrainian enterprises and global indicators are presented in Table 4.

Table 4 - Results of regression analysis between sustainability indicators of Latvian and Ukrainian enterprises and global indicators

	Ukraine				*Latvia*			
	Share of liabilities in the balance sheet (at the end of the year, times)	*Share of short-term liabilities in the balance sheet (at the end of the year, times)*	*Total liquidity (at the end of the year, times)*	*Commercial profitability after taxes (%)*	*Share of liabilities in the balance sheet (at the end of the year, times)*	*Share of short-term liabilities in the balance sheet (at the end of the year, times)*	*Total liquidity (at the end of the year, times)*	*Commercial profitability after taxes (%)*
GDP (current USD)	-0.009	0.578	-0.019	0.423	-0.937	-0.727	0.908	0.88
Inflation, consumer prices (annual %)	-0.117	0.271	0.257	-0.024	-0.665	-0.337	0.624	0.511
Unemployment, total (% of total labour force)	-0.159	-0.337	0.105	-0.067	0.294	-0.038	-0.258	-0.51
Crude oil, average (USD/bbl)	-0.47	-0.456	0.783	-0.347	0.032	0.346	-0.101	-0.081
Manufacturing, value added (% of GDP)	0.253	0.302	-0.482	0.373	-0.244	-0.282	0.237	0.425
GDP per capita (current USD)	-0.105	0.438	0.142	0.339	-0.857	-0.6	0.815	0.809

Source: compiled by the author based on the data from World Bank (2024), Official Statistics Portal. (2024), State Statistics Service of Ukraine (2024).

Firstly, it is worth noting that Latvia's indicators are generally more correlated with global indicators than Ukraine's. One of the reasons for this may be the greater openness of the Latvian market, which may indicate both greater economic efficiency and greater dependence on global economic processes. In general, GDP and GDP per capita correlate most strongly with the sustainability indicators of Latvian enterprises. Accordingly, GDP and GDP per capita are inversely related to indicators of enterprise sustainability that are disincentives (share of liabilities in the balance sheet and share of short-term liabilities in the balance sheet), while GDP and GDP per capita are directly related to stimulants (total liquidity and commercial profitability after taxes). In other words, the overall improvement in prosperity, as measured by global GDP, may affect the resilience of companies by reducing the share of borrowed funds in general and the share of short-term borrowed funds in particular. However, there is no such correlation for Ukraine, which may indicate a lower integration of the Ukrainian economy into global markets or internal features (Stychynska et al., 2024). In particular, the war in Ukraine and economic instability may affect the linkage of internal sustainability indicators of enterprises with global indicators. The only significant correlation between the global macroeconomic indicator and the internal sustainability indicator of companies in Ukraine is between the crude oil price and total liquidity. One likely reason is that rising oil prices may contribute to the sustainability and profitability of energy sector companies, which is closely linked to the increased liquidity of these companies.

Tables 5 and 6 present the results of a regression analysis between the internal sustainability indicators of Latvian and Ukrainian enterprises and national macroeconomic indicators. Such an analysis will deepen the understanding of which domestic macroeconomic trends affect the resilience of enterprises.

As shown in Table 5, the trends in the sustainability indicators of Latvian companies are closely linked to the trends in national macroeconomic indicators. This may indicate the relative stability of the companies' operations, as well as support for the companies due to economic growth in the country.

Table 6 shows that in Ukraine, companies' operations are less dependent on trends in national macroeconomic indicators than in Latvia. The analysis suggests that the more open the economy, the higher the interdependence of economic indicators in general and company sustainability indicators in particular on global trends. Economies that are less integrated into global markets are heavily influenced by domestic factors, especially local crises (Ketners and Petersone, 2021). At the same time, events such as the war in Ukraine have an impact on neighbouring countries, and in some respects on global indicators. Thus, the sustainability of Latvian companies is correlated with both global and national macroeconomic indicators. The resilience of Ukrainian companies is dependent on internal factors, in particular, it is significantly affected by the economic instability in the country caused by military aggression and subsequent war. At the same time, the resilience of companies in both Latvia and Ukraine is affected by global crises such as the COVID-19 pandemic.

Table 5 - Results of regression analysis between sustainability indicators of Latvian enterprises and national macroeconomic indicators

	Share of liabilities in the balance sheet (at the end of the year, times)	*Share of short-term liabilities in the balance sheet (at the end of the year, times)*	*Total liquidity (at the end of the year, times)*	*Commercial profitability after taxes (%)*
GDP (current USD)	-0.914081	-0.715764	0.879405	0.830288
Inflation, consumer prices (annual %)	-0.671449	-0.359745	0.642228	0.578919
Unemployment, total (% of total labour force)	0.788303	0.719458	-0.79587	-0.914777
Manufacturing, value added (% of GDP)	-0.826256	-0.590203	0.79543	0.596556
GDP per capita (current USD)	-0.940817	-0.758249	0.911337	0.857118

Source: compiled by the author.

Comparing the examples of the two countries under study suggests that improving the sustainability of companies in Latvia and Ukraine should be based on the implementation of different strategies. The definition of specific goals and objectives of such strategies should address national peculiarities and the current situation in the country and the world. In addition, strategies may vary from industry to industry and from company to company. Various offensive anti-crisis strategies may be effective for Latvian companies, which involve strengthening their competitive advantages in the long term, for example, by attracting investment and actively implementing innovations. Ukrainian companies should consider defensive anti-crisis strategies aimed at using their existing potential to maintain their competitive position. In addition, such strategies should address the adaptation component, because, in the context of war and uncertainty about its duration and consequences, it is important to find a way to adapt to difficult conditions. This may involve relocating companies, moving certain activities online, providing additional security measures.

Table 6 - Results of the regression analysis between sustainability indicators of Ukrainian enterprises and national macroeconomic indicators

	Share of liabilities in the balance sheet (at the end of the year, times)	*Share of short-term liabilities in the balance sheet (at the end of the year, times)*	*Total liquidity (at the end of the year, times)*	*Commercial profitability after taxes (%)*
GDP (current USD)	-0.645383	-0.146566	0.61753	0.426602
Inflation, consumer prices (annual %)	0.131398	-0.213383	-0.328615	-0.39199
Unemployment, total (% of total labour force)	0.649728	0.563322	-0.616922	0.001741
Manufacturing, value added (% of GDP)	0.403758	-0.229746	-0.125658	-0.603547
GDP per capita (current USD)	-0.570613	-0.042207	0.521604	0.478279

Source: compiled by the author.

Discussion

The paper proposes an approach to assessing the sustainability of companies, which provides for the assessment of sustainability by four main indicators that characterise the financial stability, liquidity and profitability of companies. At the same time, the proposed approach included determining the relationship between the sustainability indicators of companies, on the one hand, and global indicators and national macroeconomic indicators, on the other. Assessing this relationship can help determine the dependence of companies' sustainability on global and local economic trends. The works of other authors present their approaches to assessing the sustainability of companies, which should be considered in more detail.

M. Kudej et al. (2021) assessed the potential and resilience of Czech companies to the crisis. The researchers used traditional ratios such as operating efficiency margin, total efficiency margin, total debt ratio, operating return on assets, and return on equity. The sample for the research included more than 25 thousand companies of different sizes, but all of them were characterised by high financial stability. To analyse the performance of these companies, the paper applies the Kruskal-Wallis test. As a result of the analysis, the researchers found that the impact of the crisis on Czech companies was not as long and severe as it was assumed before the study began. Companies were characterised by high resilience in the fight against the crisis, which is true both for the global financial crisis of 2008 and the crisis associated with the spread of the COVID-19 virus. Government measures to resolve the crisis played a particularly important role in supporting companies and the country's economy. In addition, the study assessed the post-crisis development, which revealed positive trends in the companies' condition and suggested that they will successfully overcome the crisis. The author's research also included an analysis covering a large sample of companies, as it included all companies in the manufacturing sectors of Latvia and Ukraine. However, unlike the study, which, judging by the analysed indicators, was aimed at assessing business activity, financial stability and profitability, the author's work also contained an analysis of liquidity. Liquidity analysis is an important area of analysis, as it allows us to assess whether companies can meet their short-term obligations promptly and in full, whether they are sufficiently flexible and whether they manage their working capital efficiently.

C. Acciarini et al. (2021) studied the resilience of Italian companies to the COVID-19 crisis. The main method used in the study was a case study, which examined the response of large companies to the risks of the pandemic and how they managed to ensure business continuity. Based on the results of the analysis, the authors have developed a policy framework that should improve the resilience of companies in times of crisis. The advantage of this approach is the use of the successful experience of companies that have managed to survive the crisis and recover from it. However, the study did not analyse the negative experience of companies, which is also important for policy-making. T. Neise et al. (2021) investigated aspects of the resilience of German institutions to the crisis. The study uses an approach based on the method of interviewing experts. The researchers surveyed experts on the anticipated problems in business and the aspects that ensure greater resilience in a crisis. This study has led to an important conclusion about the importance of preconditions and their impact on business resilience to the current crisis. This approach differs from the author's approach, as it does not involve the calculation of financial indicators. This may lead to some subjectivity of the results, but it is valuable in terms of addressing the practical experience of professionals who have faced the need to overcome the crisis.

I. Danilevičienėč and N. Lace (2021) assessed the growth of sustainable competitiveness in various industrial sectors. The researchers have built their approach to evaluation by combining theoretical provisions with practical aspects and statistical data analysis. This has revealed that companies should prioritise such areas as the introduction of technology, innovation, and capital accumulation. The study used such indicators as total factor productivity (TFP) and return on equity (ROE). These indicators provided valuable information about the company's performance, but they did not consider all the aspects that should be covered when assessing the resilience of companies to the crisis. The research of scientists focuses more on the sustainability of companies in the context of sustainable development, so the choice of indicators differs significantly from the one proposed in the author's article. At the same time, this work is worth noting because it adds another dimension to the sustainability of companies. In this context, further research could be focused on assessing the impact of sustainable development on companies' resilience to the crisis.

The study by I. Upite et al. (2022) reveals another approach to assessing the resilience of companies to the crisis. This approach used an in-depth analysis of the risks faced by companies in the crisis. As in the author's study, scholars have investigated the main trends caused by the crisis and their impact on certain aspects of companies' activities. However, this study focuses on risk assessment, which is an extremely important area in a crisis and is an undoubted advantage of the work. A comprehensive study of organisational resilience is presented in S.S. Rai et al. (2021). Scientists have identified three aspects of sustainability: expectations of the crisis, organisational strength and recovery capabilities. In addition, sustainability was discussed in terms of two aspects – social sustainability and economic sustainability. The study used a structural equation modelling approach, which revealed that crisis forecasting had a positive impact on the economic and social aspects of sustainability. While the inclusion of a social component is an advantage of this study, the use of a survey for evaluation raises the possibility of some subjectivity in the results. The author's research, in turn, is based on actual numerical data, which is an advantage in terms of objectivity. However, this approach does not allow for a more comprehensive analysis of sustainability, as in the researchers' work.

In conclusion, it is worth mentioning another approach to assessing sustainability, which is fundamentally different from the previous ones. M. Kūle (2022) noted that EU countries need to address warfare issues, which is important for further prevention and response to any security crisis. The researcher noted that strategic management in European countries should not be based on GDP growth alone. Improving crisis prevention and enhancing the EU's resilience should not only involve the application of a technocratic approach and aspects of economic development but also the organisation of a synthetic perception of truths about human nature, responsibility and freedom (de-Almeida-e-Pais et al., 2023). While this approach has revealed the problem of sustainability in times of crisis from a philosophical point of view, it is worth mentioning in this context to demonstrate that the sustainability of companies in today's environment is indeed not limited to the financial dimension. The author's research focuses on the financial aspects that are important for ensuring the social and environmental dimensions of sustainability. However, in the context of sustainable development and the reassessment of the values of the modern world, this should be only one stage of sustainability assessment (Spankulova et al., 2024).

This review has revealed the existence of numerous approaches to assessing sustainability, which have their advantages and disadvantages compared to the author's approach. At the same time, the author's approach is valuable in terms of identifying the relationship between the sustainability indicators of companies and global and national economic trends. In addition, an important observation was that this relationship varies across economies with different degrees of openness.

Conclusions

The analysis of global economic indicators was used to identify the main trends and changes that occurred in these indicators in the context of the global crisis. This suggests that global crises such as the COVID-19 pandemic and the war in Ukraine have had a significant impact on the global economy. The same can be stated regarding trends and changes in local macroeconomic indicators in Latvia and Ukraine. The war in Ukraine has had a particularly strong impact on Ukraine's macroeconomic indicators, but it has also had an impact on the Latvian and global economies in some respects. This impact can be traced to changes in oil prices and inflation.

A comparison of the macroeconomic indicators of Latvia and Ukraine can be used to draw the following conclusions. The volume of GDP is much higher in Ukraine, but Latvia's GDP per capita is several times higher than Ukraine's. This indicates a more equitable distribution of wealth and an efficient economy in the country. Inflation is likely to rise in both countries in 2022, which may be because of the war in Ukraine and rising resource and energy prices. Production in Latvia is gradually growing, while in Ukraine it is declining, and the war is making the situation worse. The sustainability indicators of Latvian and Ukrainian companies indicate that Latvian companies are significantly more resilient, given their greater financial independence (in terms of the share of liabilities in the balance sheet currency), overall liquidity and profitability. In addition, the war has had a significant impact on Ukrainian companies' sustainability performance. For example, the profitability of Ukrainian companies in 2021 was 10.11%, and after the start of the invasion, it dropped to -3.24%. At the same time, the financial stability indicators declined only slightly, and the total liquidity ratio remained almost unchanged, which may indicate resilience to the crisis in some respects.

The regression analysis between global indicators and national macroeconomic indicators, on the one hand, and the sustainability indicators of the companies in the countries studied, on the other hand, revealed that the correlations are significantly higher for Latvian indicators. In other words, the Latvian economy is more dependent on global trends, but at the same time more integrated into global markets. Given the findings, Latvian companies can be advised to implement various offensive anti-crisis strategies aimed at strengthening their competitiveness in the long term, in particular by attracting investment and stimulating innovation. Ukrainian companies should adopt defensive anti-crisis strategies designed to realise the existing potential to maintain their competitive advantage. Such strategies should include an adaptation component, which, in times of war and uncertainty, will be used to find a way to adapt to the current environment. Some of the measures include relocating companies to safer regions, moving certain activities online, providing employees and fixed assets with additional security measures.

The study's limitations include the lack of statistical information on certain indicators and the limited sample of companies. Thus, it is important to assess the crisis resilience of companies operating in the service sector in further research. In addition, the paper has only covered the financial aspects of sustainability, so further work by the authors may focus more closely on environmental, social and other aspects.

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Technical Efficiency of Agriculture in the EU and Ukraine: A Stochastic Frontier Analysis Based on Factor Income

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Abstract

This paper evaluates the technical efficiency of agricultural sectors in EU and Ukraine using the Stochastic Frontier Analysis methodology. The analysis is based on factor income as the dependent variable and includes labor input, fixed capital consumption, utilized agricultural area, and intermediate consumption as key inputs. The findings reveal that EU countries on average operate under conditions of nearly constant returns to scale, while Ukraine exhibits increasing returns to scale but low efficiency due to underinvestment. The technical efficiency scores highlight significant disparities, with Western European countries outperforming Eastern counterparts. The results offer important policy implications for enhancing agricultural productivity and guiding investment strategies.
Keywords: stochastic frontier analysis, technical efficiency, agricultural sector, factor income, European Union, Ukraine.

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Introduction

The countries of the European Union exhibit considerable heterogeneity in the efficiency of agricultural production, which is influenced not only by natural and climatic conditions but also by the intensity of resource

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utilization, the level of technological advancement, and the scale of government support. For Ukraine – one of the largest agricultural producers in Europe – enhancing production efficiency is of particular relevance, especially in the context of integration into the common European market, constrained financial resources, and the urgent need for structural modernization of the agricultural sector. Conventional productivity assessment methods often fail to adequately disentangle inefficiency from random shocks, potentially leading to biased estimations and suboptimal policy decisions. In contrast, the stochastic frontier analysis (SFA) framework provides a more robust analytical tool by enabling the estimation of technical efficiency while simultaneously accounting for statistical noise and exogenous random effects beyond the control of producers. This methodological advantage facilitates more accurate cross-country comparisons of agricultural performance and allows for the identification of key determinants underlying efficiency gaps or advantages across national agri-food systems.

In the context of intensified global competition, rising quality standards, and the increasing necessity for the sustainable use of natural resources, it becomes critically important to assess how efficiently countries utilize their available production inputs. A comparative analysis of agricultural efficiency using the Stochastic Frontier Analysis (SFA) methodology can serve as a valuable foundation for the development of evidence-based agricultural support policies – both within the European Union and in Ukraine. This approach enables the identification of structural weaknesses in Ukraine's agricultural sector and reveals latent potential for improving its international competitiveness.

Recent trends underscore the growing relevance of efficient use of land, labor, capital, and energy resources as a central pillar of sustainable agricultural development strategies. The absence of rigorous efficiency assessments based on advanced quantitative techniques increases the risk of misallocating public subsidies and investment flows. The application of SFA enables precise estimation of deviations from the production frontier and quantifies the degree of technical inefficiency – thereby providing critical insights for enhancing productivity and profitability in the agri-food sector.

Literature review

Many modern scientific publications are devoted to the problem of assessing the efficiency of the agricultural sector of EU countries. They provide a multi-dimensional understanding of efficiency in agriculture, ranging from technical assessments to subsidy effects and ecological sustainability. There is strong consensus that efficiency improvements are vital for competitiveness and sustainability. However, the path to improvement is influenced by policy design, regional conditions, and technological adaptation. The combination of SFA and DEA remains dominant in empirical studies. Staniszewski & Matuszczak (2023) reviewed 200 studies on environmentally adjusted agricultural efficiency from the Scopus database, focusing on those using DEA or SFA methods, following the PRISMA approach. It identifies key trends, such as a focus on European agriculture and growing interest in Asia, and highlights research gaps, including limited studies from Africa and North America, underexplored horticultural and non-dairy livestock production, and insufficient consideration of behavioral factors, biodiversity, soil quality, and agricultural externalities.

A separate set of studies assesses agriculture's interaction with environmental sustainability. Focusing on 26 EU member states in 2019, Domagała (2021) conducts a comprehensive analysis of economic, energy, and environmental efficiency using an input-oriented DEA model. The study establishes benchmarks, categorizes countries into four eco-efficiency groups, and emphasizes the strategic importance of reducing input usage and emissions for sustainable agricultural advancement. Zhen et al. (2022) examine the relationship between renewable energy consumption, financial development, and technical efficiency on the ecological footprint in 27 EU countries over the period 1980-2018 using CS-ARDL and Westerlund cointegration methods. The findings suggest that while financial development increases ecological pressure, both renewable energy and technical efficiency contribute positively to environmental sustainability, with their interaction further mitigating ecological degradation. Using a DEA framework, Coluccia et al. (2020) assess the eco-efficiency of the Italian agricultural sector by examining the balance between productivity and environmental sustainability across regional divisions. The analysis highlights clear regional contrasts – Southern Italy excels in resource conservation, while Northern Italy leads in productivity – underscoring the necessity for CAP policies that incentivize environmentally responsible practices. Rokicki et al. (2021) focus on the evolution of agricultural energy use patterns across EU countries between 2005 and 2018, examining the diversification of energy sources and their relationship with economic development. Results confirm a steady shift toward renewable energy and reveal strong correlations between energy consumption structures and macroeconomic indicators, especially in leading agricultural economies like France and Poland.

Another cluster of literature focuses on how various subsidy mechanisms influence efficiency. Using stochastic metafrontier analysis, Martinez et al. (2021) explore the effects of different types and levels of agricultural subsidies on the technical efficiency of beef farms in Ireland, France, Great Britain, and Germany. The results demonstrate that fully decoupled subsidies contribute to improved farm efficiency, while partially decoupled payments may obstruct technological progress and slow innovation uptake. Quiroga et al. (2017) explore how four types of CAP (Common Agricultural Policy) subsidy programs influence farm efficiency and environmental sustainability across 98 EU regions, employing the Stochastic Frontier Analysis methodology. While the results confirm that CAP contributes to greater convergence in technical efficiency across Europe, they also reveal that both first-pillar crop subsidies and environmental schemes may unintentionally discourage productivity improvements. Galluzzo (2020) examines the Romanian agricultural sector, evaluating how CAP subsidies influenced technical efficiency between 2007 and 2017. The analysis indicates that targeted support for disadvantaged rural areas yields notable efficiency gains, whereas the impact of decoupled first-pillar payments appears to be relatively limited. Poczta et al. (2020) assess the economic conditions of dairy farms across the EU by classifying them into five categories based on production potential using hierarchical clustering. The research finds that although larger, specialized farms dominate milk production and labor productivity, those with limited structural capacity often struggle to convert financial performance into sustainable income and investment.

A group of articles examines the structural features and comparative performance of agricultural systems. By applying Ward's agglomerative clustering method, Pawlak et al. (2021) compare the agricultural competitiveness of EU countries with that of the United States, using indicators related to production structure and input efficiency. It concludes that only a handful of EU nations – such as Germany, France, and the Netherlands – can effectively compete with the U.S., while many others face structural barriers that limit their agricultural potential. Coca et al. (2023) shift the focus toward the broader performance of EU agriculture under conditions of rising energy and input costs. Instead of traditional output-based evaluations, the study uses correlation analysis among key determinants and uncovers atypical performance trends across member states, arguing that derived indicators can enhance the precision of efficiency assessments at both the national and EU-wide levels. Đokić et al. (2022) evaluate agricultural technical efficiency in EU and Western Balkan countries through the application of stochastic frontier analysis. The study reveals substantial efficiency disparities and stresses the necessity of enhancing internal development factors and farmer education in the Western Balkans to support long-term economic and environmental goals.

A large group of articles is devoted to the analysis of methods and models used in assessing the efficiency of the agricultural sector. Strange et al. (2021) address the topic of benchmarking in forestry by synthesizing findings from 56 studies and highlighting the dominance of DEA and SFA methodologies in assessing efficiency at various scales. Special attention is given to the emerging role of automated data transmission, which opens new opportunities for real-time performance tracking, while also acknowledging the methodological constraints and practical challenges of applying benchmarking in forest management. Zhen et al. (2022) focus on evaluating the technical efficiency of dairy farms across EU member states using FADN data from 2004 to 2019, applying the Stochastic Frontier Analysis methodology. The results demonstrate notable disparities across countries and farm sizes, emphasizing the influence of subsidies, structural factors, and diversification on efficiency levels. Carrer et al. (2022) investigate the determinants and efficiency outcomes of adopting Precision Agriculture Technologies (PATs) on sugarcane farms in São Paulo, Brazil, using a selectivity-corrected stochastic metafrontier model. To assess agricultural efficiency in 27 European countries from 2005 to 2012, Moutinho et al. (2018) employ an integrated methodology combining DEA, SFA, and generalized cross-entropy. Despite methodological differences, both models reliably identify the most and least efficient performers and underscore the role of resource productivity and subsidies in enhancing efficiency.

Aims and objectives

The primary aim of this study is to assess the technical efficiency of agricultural sectors in European Union countries and Ukraine using the Stochastic Frontier Analysis (SFA) methodology, with a particular focus on identifying disparities in efficiency levels and the determinants influencing them.

Objectives of the article are the following:

- to evaluate the technical efficiency of the agricultural sectors in European Union countries and Ukraine using the Stochastic Frontier Analysis (SFA) based on factor income as the dependent variable;
- to test for the presence of technical inefficiency and determine the appropriate functional form of the production frontier using statistical hypothesis testing, including the likelihood ratio test;

- to conduct a comparative analysis across EU countries and Ukraine in terms of efficiency levels, returns to scale and input productivity.

Methods

In the subsequent analysis we employ the Stochastic Frontier Analysis (SFA) to evaluate the technical efficiency of the agricultural sectors in the EU countries and Ukraine. This methodological approach accounts for both systematic determinants and random shocks affecting production performance. The general form of the stochastic production function is specified as follows:

$$LnY_i = f(X_i;\beta) + v_i - u_i, \tag{1}$$

where Y_i - dependent variable (Factor Income);

X_i - a set of independent variables (inputs that affect profitability);

β - model parameters that need to be estimated;

$v_i \approx N(0,\sigma_v^2)$ - random component that takes into account statistical noise;

$u_i \approx |N(0,\sigma_u^2)|$ - the inefficiency component, which is always non-negative, since it models the deviation from the maximum possible profit. The main assumptions of this approach are as follows:

- v_i represents a symmetric random error term, assumed to be normally distributed, capturing statistical noise and measurement errors
- u_i denotes a one-sided non-negative inefficiency term, typically assumed to follow an exponential or half-normal distribution.

The level of technical efficiency TE_i is calculated using the following formula:

$$TE_i = e^{-u_i}, \tag{2}$$

where TE_i is technical efficiency ($0 < TE_i \leq 1$). If $TE_i \approx 1$, then the country's agricultural sector operates as efficiently as possible.

Stochastic Frontier Analysis (SFA) employs the Maximum Likelihood Estimation (MLE) method, which enables the simultaneous estimation of the production function parameters and the inefficiency components. The Maximum Likelihood Estimation method is based on estimating the parameters β , σ_v^2 and σ_u^2 in such a way as to maximize the likelihood of the observed data.

The log-likelihood function is specified as follows:

$$L(\beta,\sigma_u,\sigma_v)=\sum_{i=1}^{N}\ln\left[\frac{1}{\sigma}\phi\left(\frac{Y_i-X_i\beta}{\sigma}\right)\Phi\left(\lambda\frac{Y_i-X_i\beta}{\sigma}\right)\right], \quad (3)$$

where ϕ(·) – the probability density function (PDF) of the standard normal distribution, Φ(·) – the cumulative distribution function (CDF) of the standard normal distribution.

The estimate of u_i can be obtained using its conditional expectation:

$$E[u_i|\varepsilon_i]=\sigma_u^2\left[\frac{\phi(\varepsilon_i\lambda/\sigma)}{\Phi(\varepsilon_i\lambda/\sigma)}-\frac{\varepsilon_i\lambda}{\sigma}\right], \quad (4)$$

where $\varepsilon_i = Y_i - X_i\beta$ denotes the residuals of the model.

Before estimating the model, it is necessary to choose between different specifications of the production function. Therefore, the first null hypothesis is formulated to determine the appropriate functional form of the profit frontier:

- Null hypothesis (H_0): The production function is linear (Cobb-Douglas).
- Alternative hypothesis (H_1): The production function is nonlinear (Translog).

This hypothesis is tested using the Likelihood Ratio (LR) test, based on the comparison of the log-likelihood values of the restricted and unrestricted models.

$$LR = -2\left(L_{restricted} - L_{unrestricted}\right) \quad (5)$$

where $L_{restricted}$ is the log-likelihood of the Cobb-Douglas model, and $L_{unrestricted}$ is the log-likelihood of the Translog model. If $LR > \chi^2_{critical}$ (the critical value of the chi-squared distribution for the chosen significance level and degrees of freedom), then the null hypothesis H0H_0H0 is rejected, indicating that the Cobb-Douglas model is insufficient and the Translog specification should be used. Conversely, if $LR \le \chi^2_{critical}$, the null hypothesis is not rejected, suggesting that the Cobb-Douglas model is adequate for representing the production frontier.

The second null hypothesis is used to confirm or reject the presence of technical inefficiency in the proposed model:

− Null hypothesis (H_0): The inefficiency component is not present in the model $\gamma = 0$.
− Alternative hypothesis (H_1): $\gamma > 0$, indicating that technical inefficiency is significant.

If the null hypothesis is not rejected, it implies a lack of evidence for technical inefficiency, suggesting that the use of the SFA model is not justified and that a conventional OLS model would be sufficient.

Since γ cannot take negative values, the standard chi-squared distribution is not appropriate; instead, a one-sided test based on a mixed chi-squared distribution is applied. The decision rule is as follows:

- If $LR > \chi^2_{critical}$, the null hypothesis is rejected, indicating that the OLS model is inadequate and the SFA model should be used.
- If $LR \leq \chi^2_{critical}$, there is no statistical evidence of significant inefficiency, and the conventional OLS regression may be considered appropriate.

To assess the efficiency of the agricultural sector in EU countries, four independent variables were employed (see Table 1), namely: total agricultural labour input **(**Labour**)**, consumption of fixed capital (Fixed), utilised agricultural area **(**Area), agricultural output **(**Output**)**, and intermediate consumption in agriculture **(**Inter).

Table 1 - Variables used in the SFA model

Variable	Explanation
Factor	Factor income (Agriculture) [12],[23] Million euro
Labour	Total labour force input (Agriculture) [10],[23] (1 000 annual work units)
Fixed	Fixed capital consumption (Agriculture) [12],[23] Million euro
Area	Utilized agricultural area (tag00025) [11],[24] Main area (1000 ha)
Inter	Intermediate consumption (Agriculture) [12],[23] Million euro

The estimation of the stochastic frontier parameters was conducted using the Maximum Likelihood Estimation (MLE) method, implemented through the FRONTIER 4.1 software package. The statistical basis of the study comprises data on the functioning of the agricultural sector in EU countries for the years 2021, 2022, and 2023 (European Commission, 2024a; 2024b; 2024c), as well as data from the State Statistics Service of Ukraine for the year 2021 (State Statistics Service of Ukraine, 2025a; 2025b).

Experiment and results

The results of hypothesis testing within the framework of the SFA model are presented in Table 2.

Table 2 - Results of hypothesis testing within the SFA model

	Hypotheses tested	LR Statistic	Lrestricted	Lunrestricted	Critic. value
2023	H_0: γ = 0 (No technical inefficiency)	157.61	-231.27	-152.46	1.92
	H_0: Cobb–Douglas functional form	149.80	-198.11	-123.21	12.59
2022	H_0: γ = 0 (No technical inefficiency)	216,18	-342,52	-234,43	1.92
	H_0: Cobb–Douglas functional form	125,98	-241,21	-178,22	12.59
2021	H_0: γ = 0 (No technical inefficiency)	174,92	-243,78	-156,32	1.92
	H_0: Cobb–Douglas functional form	65,82	-178,13	-145,22	12.59

Since the LR statistics exceed the respective critical values for both hypotheses, the null hypotheses are rejected. This provides statistical evidence of inefficiency and supports the use of the translog specification over the Cobb–Douglas functional form:

$$\begin{aligned}\ln(Factor) &= \beta_0 + \beta_1 \ln(Labour) + \beta_2 \ln(Fixed) + \beta_3 \ln(Area) + \beta_4 \ln(Inter) + \\ &+ \frac{1}{2}\beta_{11}(\ln(Labour))^2 + \frac{1}{2}\beta_{22}(\ln(Fixed))^2 + \frac{1}{2}\beta_{33}(\ln(Area))^2 \frac{1}{2}\beta_{44}(\ln(Intre))^2 + \\ &+ \beta_{12}\ln(Labour)\cdot\ln(Fixed) + \beta_{13}\ln(Labour)\cdot\ln(Area) + \beta_{14}\ln(Labour)\cdot\ln(Inter) + \\ &+ \beta_{23}\ln(Area)\cdot\ln(Fixed) + \beta_{24}\ln(Inter)\cdot\ln(Fixed) + \beta_{34}\ln(Area)\cdot\ln(Inter)\end{aligned} \quad (6)$$

The estimation of the stochastic frontier parameters (Table 3) was conducted using the maximum likelihood method with the FRONTIER 4.1 software package.

The estimated value of γ = 0.81 indicates that a substantial proportion of deviations from optimal productivity are attributable to technical inefficiency rather than to random factors such as weather conditions or market fluctuations. This suggests that there exists considerable potential for improving efficiency by addressing the sources of technical inefficiency.

Table 3. Maximum likelihood estimates of regression parameters

	2021			2022			2023		
	Coef.	Standard error	t-statistic	Coef.	Standard error	t-statistic	Coef.	Standard error	t-statistic
β_0	1,429	1,005	1,422	1,986	1,043	1,904	3,479	0,843	4,127
β_1	0,212	0,084	2,524	0,314	0,114	2,754	0,251	0,094	2,670
β_2	0,091	0,026	3,500	0,088	0,026	3,385	0,133	0,065	2,046
β_3	0,413	0,198	2,086	0,546	0,099	5,515	0,411	0,099	4,152
β_4	0,142	0,053	2,679	0,112	0,052	2,154	0,213	0,022	9,682

β_{11}	0,049	0,011	4,455	0,84	0,111	7,568	4,937	2,011	2,455
β_{22}	2,105	0,404	5,210	1,124	0,404	2,782	3,278	0,404	8,114
β_{33}	1,388	0,366	3,792	0,734	0,366	1,913	0,764	0,366	2,087
β_{44}	0,61	0,296	2,061	4,031	1,296	3,110	1,602	0,786	2,038
β_{12}	2,399	0,611	3,926	3,638	0,611	5,954	2,333	0,611	3,818
β_{13}	2,317	1,862	1,244	1,331	0,362	3,677	3,537	1,862	1,900
β_{14}	0,423	0,135	3,133	0,131	0,035	3,743	0,843	0,235	3,587
β_{23}	0,249	0,084	2,964	4,533	0,624	7,264	1,482	0,624	2,375
β_{24}	1,828	0,548	3,336	0,361	0,048	7,521	0,808	0,248	3,258
β_{34}	0,977	0,114	8,570	4,545	0,844	5,385	1,868	0,844	2,213
sigma-squared	0,793	0,369	2,149	0,731	0,364	2,008	0,780	0,239	3,264
gamma	0,812	0,298	2,725	0,765	0,238	3,214	0,820	0,342	2,397

Unlike the Cobb-Douglas specification, the calculation of returns to scale (RTS) in the translog model is more complex and cannot be derived from a simple summation of the β coefficients. In our case, RTS depends not only on the linear coefficients but also on the interaction and squared terms. Consequently, returns to scale are not constant but vary depending on the values of the input variables. For each of the 28 countries analyzed, efficiency can be calculated using the following formula:

$$RTS_i = \sum_{k=1}^{4}\left(\beta_k + \sum_{m=1}^{4}\beta_{km}\cdot\ln\left(x_{mi}\right)\right), \qquad i = 1 \ldots 28 \tag{7}$$

The results of the returns to scale (RTS) assessment for EU countries and Ukraine are presented in Table 4. Ukraine in 2021 and Romania in 2023 recorded the highest values of this index, indicating the presence of potential for increasing returns to scale. This can be attributed to the still unrealized efficiency reserves in the utilization of production resources, opportunities for technological modernization, and the enhancement of managerial practices in the agricultural sector.

On average, EU countries exhibit nearly constant returns to scale (RTS_{av} = 0.99), indicating that the agricultural sector operates in a balanced manner. A 1% increase in the use of key production inputs (land, labor, capital, and intermediate consumption) results in a proportional 1% increase in factor income. In other words, such an agricultural sector has reached a mature stage of development, where resources are utilized efficiently, without surplus or deficit. This situation is also typical for stable and advanced agricultural sectors in EU countries with well-established agricultural policies and a high level of government regulation.

Table 4 - Returns to scale (RTS) in the agricultural sectors of EU member states and Ukraine

	2021	2022	2023
Luxembourg	0,9	0,91	0,9
Malta	0,9	0,89	0,88
Cyprus	0,92	0,94	0,92
Belgium	0,95	0,95	0,96
Netherlands	0,95	0,97	0,96
France	0,96	0,97	0,96
Denmark	0,97	0,97	0,98
Germany	0,97	0,98	1
Italy	0,97	0,97	1
Sweden	0,97	0,98	0,95
Austria	0,98	0,98	0,98
Finland	0,98	0,98	0,97
Spain	0,98	0,98	0,97
Ireland	0,99	0,99	1
Greece	1	0,99	1
Portugal	1	1	0,99
Slovenia	1	0,99	0,98
Estonia	1,01	1	1,01
Croatia	1,02	1	1,02
Lithuania	1,02	1,02	1,03
Bulgaria	1,03	1,02	1,05
Latvia	1,03	1,02	1,03
Slovakia	1,03	1,02	1,04
Czech Republic	1,04	1,04	1,04
Poland	1,04	1,05	1,05
Hungary	1,05	1,05	1,04
Romania	1,05	1,06	1,07
Ukraine	1,07		
Geometric Mean	0,99	0,99	0,99

An RTS value greater than 1 in EU countries indicates the existence of potential for scale expansion with increasing returns. This pattern is typically observed in countries experiencing dynamic growth in the agricultural sector, modernization of production, or the active implementation of innovations. According to the obtained results, this situation is characteristic of Central and Eastern European countries, where the agricultural sector is still undergoing an active development phase.

Conversely, an RTS value below 1 signals oversaturation of the agricultural sector or the presence of structural and technological constraints. Additional expansion of production resources does not lead to a proportional increase in factor income. The decreasing returns to scale observed – based on the estimated SFA model – in most Western European countries highlight the need to shift the focus from increasing input volumes to enhancing productivity through innovation, precision farming, digitalization, and intensive technologies.

Since the estimation was based on a translogarithmic functional form, the returns to scale are not constant and depend on the combination of input factors specific to each country. The calculated individual RTS values for EU member states revealed the presence of countries with constant returns to scale as well as cases of decreasing returns, which may indicate resource oversaturation and declining efficiency in certain agricultural systems. This underscores the need for a more individualized approach to agricultural development policy, taking into account the structure of resource endowments and existing technological constraints.

Table 5 presents the results of profit efficiency estimates for the agricultural sectors of EU countries and Ukraine for the year 2021. Due to the unavailability of statistical data for most agricultural performance indicators in Ukraine for 2022 and 2023, efficiency for these years was calculated only for the 27 EU countries.

The undisputed leaders in this ranking are the Netherlands, Belgium, and Denmark. In the pre-war period, Ukraine's agricultural sector demonstrated a technical efficiency level of approximately 0.5, which allowed it to outperform several Eastern European countries, although it remained in the lower tier of the overall ranking. Interestingly, the average efficiency of the agricultural sectors across EU countries has shown a steady increase of approximately 1% per year over the analyzed period.

Table 5 - Agricultural sector efficiency of EU countries based on the SFA model

Integr. rating	Country	2021	2022	2023
1	Netherlands	0,96	0,97	0,97
2	Belgium	0,97	0,96	0,95
3	Denmark	0,92	0,93	0,94
4	Spain	0,91	0,91	0,93
5	Italy	0,88	0,87	0,9
6	France	0,86	0,85	0,9
7	Germany	0,82	0,81	0,82
8	Malta	0,81	0,83	0,81
9	Greece	0,79	0,76	0,78
10	Ireland	0,78	0,78	0,76
11	Bulgaria	0,74	0,7	0,73
12	Cyprus	0,72	0,74	0,72
13	Slovenia	0,7	0,67	0,72
14	Slovakia	0,67	0,72	0,71
15	Lithuania	0,63	0,65	0,67
16	Luxembourg	0,63	0,62	0,67
17	Austria	0,63	0,6	0,62
18	Portugal	0,55	0,58	0,53

19	Sweden	0,53	0,56	0,52
20	Poland	0,51	0,53	0,52
21	Finland	0,5	0,49	0,5
22	Croatia	0,44	0,52	0,49
23	Estonia	0,45	0,48	0,49
24	Czechia	0,47	0,46	0,47
25	Romania	0,42	0,42	0,42
26	Latvia	0,4	0,39	0,41
27	Hungary	0,41	0,4	0,4
28	Ukraine	0,5	-	-
Geom. mean		0,66	0,67	0,68

Unfortunately, Ukraine's position in the agricultural efficiency ranking among EU countries can be assessed only based on the statistical data available for 2021, as official data for the period of ongoing military aggression have not yet been published. Therefore, efficiency was estimated using the proposed SFA model for the year 2021 (for both EU countries and Ukraine) and for 2022–2023 (for EU countries only).

Overall, territories in Ukraine affected by occupation, military operations, and landmines account for approximately 31.74% of the country's total area. Agricultural land comprises about 70% of Ukraine's territory, with a total area of approximately 41.3 million hectares (State Statistics Service of Ukraine, 2023). As a result of Russian aggression and temporary occupation, around 25–30% of agricultural land (over 12 million hectares) is currently located in zones of active hostilities, occupation, or contamination by landmines. These factors have led to a substantial decline in the production potential of the agricultural sector, weakened Ukraine's export capacity on the global market, and created serious threats to food security not only at the national level but also globally. In addition to economic losses, the situation poses long-term challenges for the restoration of soils and agricultural infrastructure.

When comparing the efficiency of the agricultural sector across regions, Western European countries emerged as the leaders, with an average efficiency score of 0.82 in 2023 (see Figure 1). The lowest efficiency was observed in Eastern European countries, with an average of 0.55. The efficiency of agriculture in Southern EU countries was significantly higher than in the Northern ones – 0.78 and 0.61, respectively. This can be attributed to the favorable climate in Southern Europe, characterized by a long growing season that allows for multiple harvests per year and the cultivation of high-margin crops such as grapes, olives, citrus fruits, and vegetables. In contrast, Northern countries face a shorter agricultural season, greater weather-related risks, and a more limited range of crops.

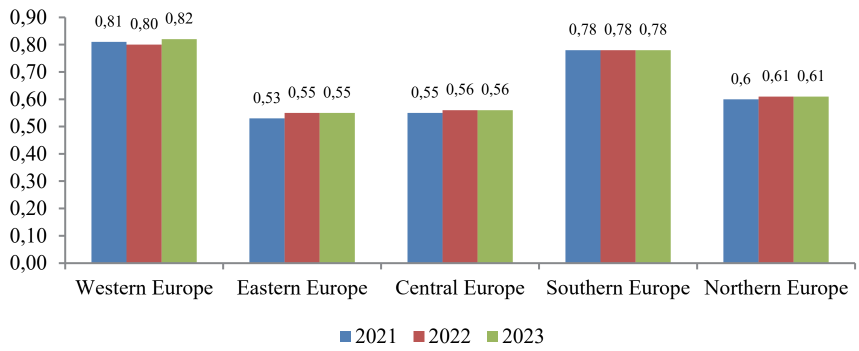

Figure 1 - Average agricultural sector efficiency across EU regions

The availability of vast agricultural land presents significant opportunities while simultaneously posing challenges related to the rational use of these resources. Large land areas require substantial investments in machinery, infrastructure, irrigation systems, and modern agricultural technologies. Insufficient renewal of fixed capital or excessive reliance on extensive farming methods reduces overall efficiency. Ukraine's vast agricultural land represents a strategic advantage in the global agricultural market—provided it is used efficiently. With appropriate agricultural policies and targeted investments, this resource can significantly enhance the country's export potential.

Even without accounting for the temporarily occupied territories, Ukraine currently possesses the largest area of agricultural land in Europe (see Figure 2). However, this considerable predominance in land area partly explains the relatively low efficiency of Ukraine's agricultural sector compared to average EU levels. As shown in Figure 3, the indicator of gross fixed capital consumption (depreciation) in Ukraine is significantly lower compared to countries with smaller or comparable agricultural land areas, such as France and Spain. This reflects insufficient renewal of fixed assets and a low level of capital intensity in agricultural production. While Ukraine's agricultural sector benefits from vast land resources, it fails to provide an adequate level of investment in fixed capital, which may constrain productivity and overall production efficiency. In terms of factor income in the agricultural sector in 2021, Ukraine ranked sixth among the countries analyzed (see Figure 4). However, due to the significantly larger agricultural land area compared to most other countries, Ukraine exhibited a relatively low level of efficiency in its agricultural sector.

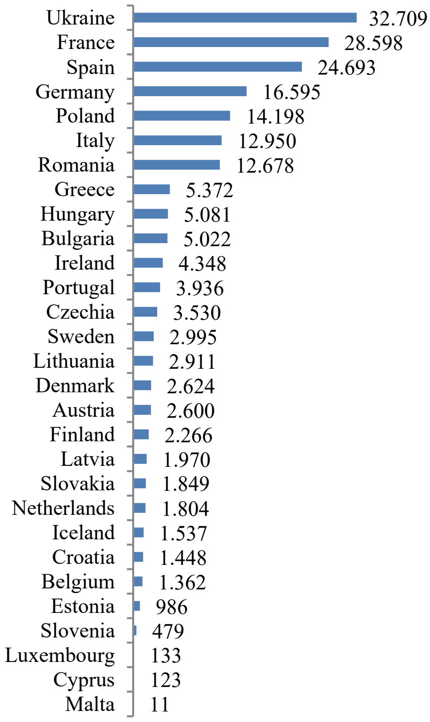

Figure 2 - Agricultural land areas in EU and Ukraine in 2023, thousand hectares

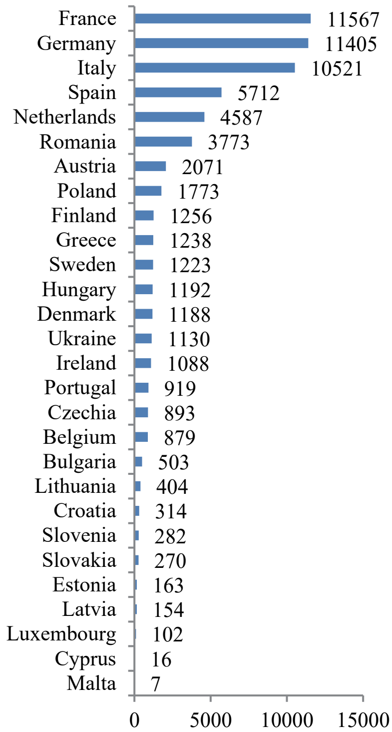

Figure 3 - Gross fixed capital consumption in agriculture in 2021, million euros

Intermediate consumption is an important indicator of resource expenditure and reflects the costs of materials, energy, services, seeds, and feed – resources that directly influence the volume of output or profit. In agriculture, intermediate consumption refers to the value of all goods and services used in the production process for generating agricultural output during the reporting period, which were entirely consumed in that process (i.e., not retained as assets or inventory). In the production function, intermediate consumption serves as a key short-term input factor alongside labor, land, and capital. In essence, intermediate consumption represents material resources that are directly transformed into output – either in the form of produced goods or factor income. In Ukraine, the level of intermediate consumption is relatively high (see Figure 5).

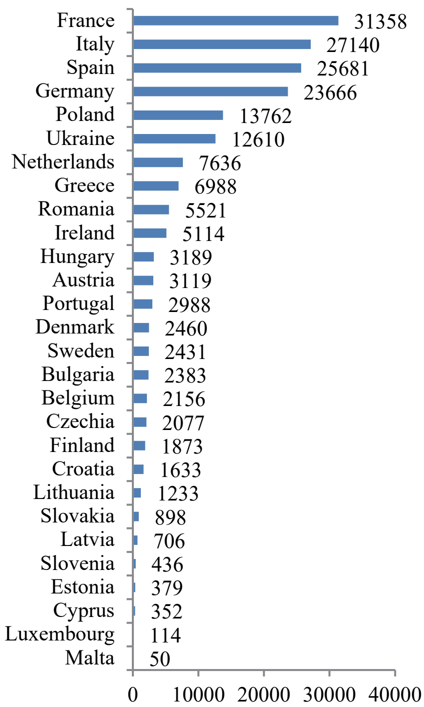

Figure 4 - Factor income in agriculture in 2021, million euros

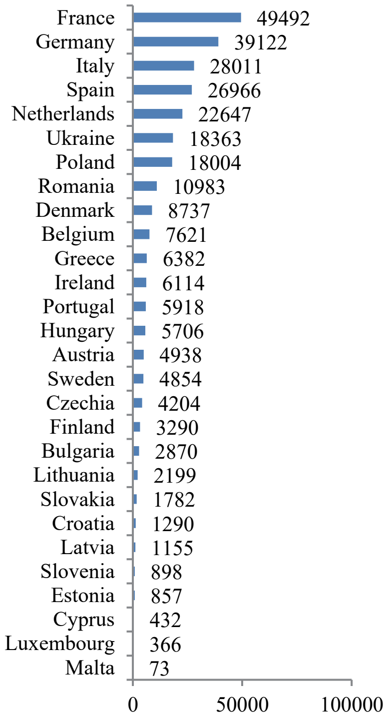

Figure 5 - Intermediate consumption in the agricultural sector in 2021, million euros

Discussion

The findings of this study offer valuable insights into the technical efficiency and scale dynamics of agricultural production across EU member states and Ukraine. The use of a translog stochastic frontier model allowed for a nuanced interpretation of how multiple input factors – land, labor, fixed capital, and intermediate consumption – contribute to factor income in the agricultural sector. One of the key contributions of this analysis lies in the observation that, on average, EU countries operate under nearly constant returns to scale (RTS ≈ 0.99), implying an efficient balance between input use and output generation. This outcome is consistent with earlier research by Kocisova and Sedliaciková (2022), who emphasized the stabilizing role of institutional and technological maturity in the EU's western agricultural systems. Similarly, Đokić et al. (2022) found that countries such as the Netherlands, France, and Germany consistently exhibit high efficiency levels, largely due to long-term investments in modernization and sustained agricultural policy support. Conversely, the increasing returns to scale (RTS > 1) observed in Central and Eastern European countries, as well as in Ukraine (RTS = 1.07), align with findings from Galluzzo (2020), which analyzed Romania's agricultural sector. These results suggest underutilized potential that could be unlocked through structural reforms, enhanced access to capital, and adoption of precision agriculture technologies. In this context, the findings reinforce arguments presented by Zhen et al. (2022), who highlighted those improvements in technical efficiency – particularly when combined with renewable energy integration – can yield environmental and economic co-benefits.

However, the efficiency score for Ukraine (TE ≈ 0.50) remains below the geometric mean of the EU sample (TE ≈ 0.66-0.68). While Ukraine ranks sixth in factor income in absolute terms, its relative efficiency is diluted by the sheer scale of agricultural land. This indicates a low level of capital intensity and limited renewal of fixed assets, reinforcing the conclusions of Martinez et al. (2021) and Quiroga et al. (2017) regarding the critical role of subsidy mechanisms and investment incentives in influencing farm-level performance. As these studies suggest, mere availability of land or labor is insufficient, efficient transformation of inputs into outputs hinges on modernization and institutional support.

The present study also affirms the importance of intermediate consumption as a short-term determinant of technical efficiency. This result supports prior studies (e.g., Moutinho et al., 2018; Coluccia et al., 2020) showing a strong association between intermediate input use and both profitability and productivity in agri-food systems, particularly in the Mediterranean and Southern regions of the EU. The observed regional disparities – namely, higher efficiency in Southern Europe compared to Northern and Eastern counterparts – reflect ecological and climatic conditions highlighted by Domagała (2021), who emphasized the significant impact of climate suitability and crop specialization on output efficiency. Additionally, our results emphasize the significance of tailoring agricultural policies to regional contexts. Variations in efficiency across EU countries mirror the typologies outlined by Poczta et al. (2020) and Pawlak et al. (2021), emphasizing the combined influence of structural features, policy measures, and environmental limitations on national-level results. Countries with decreasing RTS should prioritize innovation, digitalization, and sustainability, while those with increasing RTS, require targeted support to realize scale economies and modernization gains.

Overall, the outcomes of this research confirm the robustness of the SFA framework in disentangling inefficiency from random shocks, and they underscore the necessity for differentiated and evidence-based agricultural strategies. The implications are particularly relevant for Ukraine's post-war recovery planning. Investments in capital stock, institutional reform, and access to innovation will be essential in transforming its extensive land base into a source of sustainable productivity and global competitiveness.

Conclusions

This study provides a detailed assessment of the technical efficiency of the agricultural sectors in the European Union and Ukraine using stochastic frontier analysis (SFA) based on the translog production function. Ukraine possesses one of the largest areas of agricultural land among European countries, which creates substantial production potential. However, gross fixed capital consumption (depreciation and technical renewal) per hectare is below the EU average. This indicates the need for increased investment in the modernization of machinery, equipment, irrigation systems, and other fixed assets to enhance the efficiency of land use.

According to the estimated SFA model, the agricultural sector in EU countries exhibits, on average, nearly constant returns to scale (RTS ≈ 0.99), indicating balanced and efficient use of production resources without overexploitation or shortage. This pattern is particularly characteristic of economically developed Western European countries with strong governmental support and substantial investment in modernization. In contrast, Central and Eastern European countries show increasing returns to scale (RTS > 1), suggesting significant potential for growth in efficiency through resource consolidation, modernization, and the implementation of innovations.

Technical efficiency in the EU agricultural sector demonstrates a consistent upward trend, growing by approximately 1% annually. The highest efficiency levels were observed in the Netherlands, Belgium, and Denmark, while Eastern European countries continue to lag behind, with efficiency levels around 0.55–0.60. Ukraine's agricultural sector recorded a technical efficiency score of 0.5 in 2021, which allowed it to outperform some Eastern European countries, although it remained in the lower range of the overall ranking. At the same time, Ukraine's high RTS value (1.07) indicates strong potential for efficiency improvements through modernization and institutional reforms. Regional differences in agricultural sector efficiency across the EU underscore the need for individualized agricultural policies. Countries experiencing resource saturation and low RTS should focus on innovation, digitalization, and intensive technologies, while those with high RTS should prioritize support for scaling up and modernization.

Thus, the results of this study may serve as a basis for defining strategic directions for the development of Ukraine's agricultural sector in the context of European integration, shaping state support mechanisms, and designing policies aimed at stimulating investment in the recovery and modernization of agricultural production.

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utilization, the level of technological advancement, and the scale of government support. For Ukraine – one of the largest agricultural producers in Europe – enhancing production efficiency is of particular relevance, especially in the context of integration into the common European market, constrained financial resources, and the urgent need for structural modernization of the agricultural sector. Conventional productivity assessment methods often fail to adequately disentangle inefficiency from random shocks, potentially leading to biased estimations and suboptimal policy decisions. In contrast, the stochastic frontier analysis (SFA) framework provides a more robust analytical tool by enabling the estimation of technical efficiency while simultaneously accounting for statistical noise and exogenous random effects beyond the control of producers. This methodological advantage facilitates more accurate cross-country comparisons of agricultural performance and allows for the identification of key determinants underlying efficiency gaps or advantages across national agri-food systems.

In the context of intensified global competition, rising quality standards, and the increasing necessity for the sustainable use of natural resources, it becomes critically important to assess how efficiently countries utilize their available production inputs. A comparative analysis of agricultural efficiency using the Stochastic Frontier Analysis (SFA) methodology can serve as a valuable foundation for the development of evidence-based agricultural support policies – both within the European Union and in Ukraine. This approach enables the identification of structural weaknesses in Ukraine's agricultural sector and reveals latent potential for improving its international competitiveness.

Recent trends underscore the growing relevance of efficient use of land, labor, capital, and energy resources as a central pillar of sustainable agricultural development strategies. The absence of rigorous efficiency assessments based on advanced quantitative techniques increases the risk of misallocating public subsidies and investment flows. The application of SFA enables precise estimation of deviations from the production frontier and quantifies the degree of technical inefficiency – thereby providing critical insights for enhancing productivity and profitability in the agri-food sector.

Literature review

Many modern scientific publications are devoted to the problem of assessing the efficiency of the agricultural sector of EU countries. They provide a multi-dimensional understanding of efficiency in agriculture, ranging from technical assessments to subsidy effects and ecological sustainability. There is strong consensus that efficiency improvements are vital for competitiveness and sustainability. However, the path to improvement is influenced by policy design, regional conditions, and technological adaptation. The combination of SFA and DEA remains dominant in empirical studies. Staniszewski & Matuszczak (2023) reviewed 200 studies on environmentally adjusted agricultural efficiency from the Scopus database, focusing on those using DEA or SFA methods, following the PRISMA approach. It identifies key trends, such as a focus on European agriculture and growing interest in Asia, and highlights research gaps, including limited studies from Africa and North America, underexplored horticultural and non-dairy livestock production, and insufficient consideration of behavioral factors, biodiversity, soil quality, and agricultural externalities.

A separate set of studies assesses agriculture's interaction with environmental sustainability. Focusing on 26 EU member states in 2019, Domagała (2021) conducts a comprehensive analysis of economic, energy, and environmental efficiency using an input-oriented DEA model. The study establishes benchmarks, categorizes countries into four eco-efficiency groups, and emphasizes the strategic importance of reducing input usage and emissions for sustainable agricultural advancement. Zhen et al. (2022) examine the relationship between renewable energy consumption, financial development, and technical efficiency on the ecological footprint in 27 EU countries over the period 1980-2018 using CS-ARDL and Westerlund cointegration methods. The findings suggest that while financial development increases ecological pressure, both renewable energy and technical efficiency contribute positively to environmental sustainability, with their interaction further mitigating ecological degradation. Using a DEA framework, Coluccia et al. (2020) assess the eco-efficiency of the Italian agricultural sector by examining the balance between productivity and environmental sustainability across regional divisions. The analysis highlights clear regional contrasts – Southern Italy excels in resource conservation, while Northern Italy leads in productivity – underscoring the necessity for CAP policies that incentivize environmentally responsible practices. Rokicki et al. (2021) focus on the evolution of agricultural energy use patterns across EU countries between 2005 and 2018, examining the diversification of energy sources and their relationship with economic development. Results confirm a steady shift toward renewable energy and reveal strong correlations between energy consumption structures and macroeconomic indicators, especially in leading agricultural economies like France and Poland.

Another cluster of literature focuses on how various subsidy mechanisms influence efficiency. Using stochastic metafrontier analysis, Martinez et al. (2021) explore the effects of different types and levels of agricultural subsidies on the technical efficiency of beef farms in Ireland, France, Great Britain, and Germany. The results demonstrate that fully decoupled subsidies contribute to improved farm efficiency, while partially decoupled payments may obstruct technological progress and slow innovation uptake. Quiroga et al. (2017) explore how four types of CAP (Common Agricultural Policy) subsidy programs influence farm efficiency and environmental sustainability across 98 EU regions, employing the Stochastic Frontier Analysis methodology. While the results confirm that CAP contributes to greater convergence in technical efficiency across Europe, they also reveal that both first-pillar crop subsidies and environmental schemes may unintentionally discourage productivity improvements. Galluzzo (2020) examines the Romanian agricultural sector, evaluating how CAP subsidies influenced technical efficiency between 2007 and 2017. The analysis indicates that targeted support for disadvantaged rural areas yields notable efficiency gains, whereas the impact of decoupled first-pillar payments appears to be relatively limited. Poczta et al. (2020) assess the economic conditions of dairy farms across the EU by classifying them into five categories based on production potential using hierarchical clustering. The research finds that although larger, specialized farms dominate milk production and labor productivity, those with limited structural capacity often struggle to convert financial performance into sustainable income and investment.

A group of articles examines the structural features and comparative performance of agricultural systems. By applying Ward's agglomerative clustering method, Pawlak et al. (2021) compare the agricultural competitiveness of EU countries with that of the United States, using indicators related to production structure and input efficiency. It concludes that only a handful of EU nations – such as Germany, France, and the Netherlands – can effectively compete with the U.S., while many others face structural barriers that limit their agricultural potential. Coca et al. (2023) shift the focus toward the broader performance of EU agriculture under conditions of rising energy and input costs. Instead of traditional output-based evaluations, the study uses correlation analysis among key determinants and uncovers atypical performance trends across member states, arguing that derived indicators can enhance the precision of efficiency assessments at both the national and EU-wide levels. Đokić et al. (2022) evaluate agricultural technical efficiency in EU and Western Balkan countries through the application of stochastic frontier analysis. The study reveals substantial efficiency disparities and stresses the necessity of enhancing internal development factors and farmer education in the Western Balkans to support long-term economic and environmental goals.

A large group of articles is devoted to the analysis of methods and models used in assessing the efficiency of the agricultural sector. Strange et al. (2021) address the topic of benchmarking in forestry by synthesizing findings from 56 studies and highlighting the dominance of DEA and SFA methodologies in assessing efficiency at various scales. Special attention is given to the emerging role of automated data transmission, which opens new opportunities for real-time performance tracking, while also acknowledging the methodological constraints and practical challenges of applying benchmarking in forest management. Zhen et al. (2022) focus on evaluating the technical efficiency of dairy farms across EU member states using FADN data from 2004 to 2019, applying the Stochastic Frontier Analysis methodology. The results demonstrate notable disparities across countries and farm sizes, emphasizing the influence of subsidies, structural factors, and diversification on efficiency levels. Carrer et al. (2022) investigate the determinants and efficiency outcomes of adopting Precision Agriculture Technologies (PATs) on sugarcane farms in São Paulo, Brazil, using a selectivity-corrected stochastic metafrontier model. To assess agricultural efficiency in 27 European countries from 2005 to 2012, Moutinho et al. (2018) employ an integrated methodology combining DEA, SFA, and generalized cross-entropy. Despite methodological differences, both models reliably identify the most and least efficient performers and underscore the role of resource productivity and subsidies in enhancing efficiency.

Aims and objectives

The primary aim of this study is to assess the technical efficiency of agricultural sectors in European Union countries and Ukraine using the Stochastic Frontier Analysis (SFA) methodology, with a particular focus on identifying disparities in efficiency levels and the determinants influencing them.

Objectives of the article are the following:

- to evaluate the technical efficiency of the agricultural sectors in European Union countries and Ukraine using the Stochastic Frontier Analysis (SFA) based on factor income as the dependent variable;
- to test for the presence of technical inefficiency and determine the appropriate functional form of the production frontier using statistical hypothesis testing, including the likelihood ratio test;

− to conduct a comparative analysis across EU countries and Ukraine in terms of efficiency levels, returns to scale and input productivity.

Methods

In the subsequent analysis we employ the Stochastic Frontier Analysis (SFA) to evaluate the technical efficiency of the agricultural sectors in the EU countries and Ukraine. This methodological approach accounts for both systematic determinants and random shocks affecting production performance. The general form of the stochastic production function is specified as follows:

$$LnY_i = f(X_i; \beta) + v_i - u_i, \qquad (1)$$

where Y_i - dependent variable (Factor Income);

X_i - a set of independent variables (inputs that affect profitability);

β - model parameters that need to be estimated;

$v_i \approx N(0, \sigma_v^2)$ - random component that takes into account statistical noise;

$u_i \approx |N(0, \sigma_u^2)|$ - the inefficiency component, which is always non-negative, since it models the deviation from the maximum possible profit**.** The main assumptions of this approach are as follows:

- v_i represents a symmetric random error term, assumed to be normally distributed, capturing statistical noise and measurement errors
- u_i denotes a one-sided non-negative inefficiency term, typically assumed to follow an exponential or half-normal distribution.

The level of technical efficiency TE_i is calculated using the following formula:

$$TE_i = e^{-u_i}, \qquad (2)$$

where TE_i is technical efficiency ($0 < TE_i \leq 1$). If $TE_i \approx 1$, then the country's agricultural sector operates as efficiently as possible.

Stochastic Frontier Analysis (SFA) employs the Maximum Likelihood Estimation (MLE) method, which enables the simultaneous estimation of the production function parameters and the inefficiency components. The Maximum Likelihood Estimation method is based on estimating the parameters β , σ_v^2 and σ_u^2 in such a way as to maximize the likelihood of the observed data.

The log-likelihood function is specified as follows:

$$L(\beta, \sigma_u, \sigma_v) = \sum_{i=1}^{N} \ln\left[\frac{1}{\sigma}\phi\left(\frac{Y_i - X_i\beta}{\sigma}\right)\Phi\left(\lambda\frac{Y_i - X_i\beta}{\sigma}\right)\right], \qquad (3)$$

where ϕ(·) – the probability density function (PDF) of the standard normal distribution, Φ(·) – the cumulative distribution function (CDF) of the standard normal distribution.

The estimate of u_i can be obtained using its conditional expectation:

$$E[u_i|\varepsilon_i] = \sigma_u^2\left[\frac{\phi(\varepsilon_i\lambda/\sigma)}{\Phi(\varepsilon_i\lambda/\sigma)} - \frac{\varepsilon_i\lambda}{\sigma}\right], \qquad (4)$$

where $\varepsilon_i = Y_i - X_i\beta$ denotes the residuals of the model.

Before estimating the model, it is necessary to choose between different specifications of the production function. Therefore, the first null hypothesis is formulated to determine the appropriate functional form of the profit frontier:

- Null hypothesis (H_0): The production function is linear (Cobb-Douglas).
- Alternative hypothesis (H_1): The production function is nonlinear (Translog).

This hypothesis is tested using the Likelihood Ratio (LR) test, based on the comparison of the log-likelihood values of the restricted and unrestricted models.

$$LR = -2\left(L_{restricted} - L_{unrestricted}\right) \qquad (5)$$

where $L_{restricted}$ is the log-likelihood of the Cobb-Douglas model, and $L_{unrestricted}$ is the log-likelihood of the Translog model. If $LR > \chi^2_{critical}$ (the critical value of the chi-squared distribution for the chosen significance level and degrees of freedom), then the null hypothesis H0H_0H0 is rejected, indicating that the Cobb-Douglas model is insufficient and the Translog specification should be used. Conversely, if $LR \leq \chi^2_{critical}$, the null hypothesis is not rejected, suggesting that the Cobb-Douglas model is adequate for representing the production frontier.

The second null hypothesis is used to confirm or reject the presence of technical inefficiency in the proposed model:

− Null hypothesis (H_0): The inefficiency component is not present in the model $\gamma = 0$.
− Alternative hypothesis (H_1): $\gamma > 0$, indicating that technical inefficiency is significant.

If the null hypothesis is not rejected, it implies a lack of evidence for technical inefficiency, suggesting that the use of the SFA model is not justified and that a conventional OLS model would be sufficient.

Since γ cannot take negative values, the standard chi-squared distribution is not appropriate; instead, a one-sided test based on a mixed chi-squared distribution is applied. The decision rule is as follows:

- If $LR > \chi^2_{critical}$, the null hypothesis is rejected, indicating that the OLS model is inadequate and the SFA model should be used.
- If $LR \leq \chi^2_{critical}$, there is no statistical evidence of significant inefficiency, and the conventional OLS regression may be considered appropriate.

To assess the efficiency of the agricultural sector in EU countries, four independent variables were employed (see Table 1), namely: total agricultural labour input (Labour), consumption of fixed capital (Fixed), utilised agricultural area (Area), agricultural output (Output), and intermediate consumption in agriculture (Inter).

Table 1 - Variables used in the SFA model

Variable	Explanation
Factor	Factor income (Agriculture) [12],[23] Million euro
Labour	Total labour force input (Agriculture) [10],[23] (1 000 annual work units)
Fixed	Fixed capital consumption (Agriculture) [12],[23] Million euro
Area	Utilized agricultural area (tag00025) [11],[24] Main area (1000 ha)
Inter	Intermediate consumption (Agriculture) [12],[23] Million euro

The estimation of the stochastic frontier parameters was conducted using the Maximum Likelihood Estimation (MLE) method, implemented through the FRONTIER 4.1 software package. The statistical basis of the study comprises data on the functioning of the agricultural sector in EU countries for the years 2021, 2022, and 2023 (European Commission, 2024a; 2024b; 2024c), as well as data from the State Statistics Service of Ukraine for the year 2021 (State Statistics Service of Ukraine, 2025a; 2025b).

Experiment and results

The results of hypothesis testing within the framework of the SFA model are presented in Table 2.

Table 2 - Results of hypothesis testing within the SFA model

	Hypotheses tested	LR Statistic	L restricted	L unrestricted	Critic. value
2023	H_0: γ = 0 (No technical inefficiency)	157.61	-231.27	-152.46	1.92
	H_0: Cobb–Douglas functional form	149.80	-198.11	-123.21	12.59
2022	H_0: γ = 0 (No technical inefficiency)	216,18	-342,52	-234,43	1.92
	H_0: Cobb–Douglas functional form	125,98	-241,21	-178,22	12.59
2021	H_0: γ = 0 (No technical inefficiency)	174,92	-243,78	-156,32	1.92
	H_0: Cobb–Douglas functional form	65,82	-178,13	-145,22	12.59

Since the LR statistics exceed the respective critical values for both hypotheses, the null hypotheses are rejected. This provides statistical evidence of inefficiency and supports the use of the translog specification over the Cobb–Douglas functional form:

$$\ln(Factor) = \beta_0 + \beta_1 \ln(Labour) + \beta_2 \ln(Fixed) + \beta_3 \ln(Area) + \beta_4 \ln(Inter) +$$
$$+\frac{1}{2}\beta_{11}(\ln(Labour))^2 + \frac{1}{2}\beta_{22}(\ln(Fixed))^2 + \frac{1}{2}\beta_{33}(\ln(Area))^2 \frac{1}{2}\beta_{44}(\ln(Intre))^2 +$$
$$+\beta_{12}\ln(Labour)\cdot\ln(Fixed) + \beta_{13}\ln(Labour)\cdot\ln(Area) + \beta_{14}\ln(Labour)\cdot\ln(Inter) +$$
$$+\beta_{23}\ln(Area)\cdot\ln(Fixed) + \beta_{24}\ln(Inter)\cdot\ln(Fixed) + \beta_{34}\ln(Area)\cdot\ln(Inter) \quad (6)$$

The estimation of the stochastic frontier parameters (Table 3) was conducted using the maximum likelihood method with the FRONTIER 4.1 software package.

The estimated value of γ = 0.81 indicates that a substantial proportion of deviations from optimal productivity are attributable to technical inefficiency rather than to random factors such as weather conditions or market fluctuations. This suggests that there exists considerable potential for improving efficiency by addressing the sources of technical inefficiency.

Table 3. Maximum likelihood estimates of regression parameters

	2021			2022			2023		
	Coef.	Standard error	t-statistic	Coef.	Standard error	t-statistic	Coef.	Standard error	t-statistic
β_0	1,429	1,005	1,422	1,986	1,043	1,904	3,479	0,843	4,127
β_1	0,212	0,084	2,524	0,314	0,114	2,754	0,251	0,094	2,670
β_2	0,091	0,026	3,500	0,088	0,026	3,385	0,133	0,065	2,046
β_3	0,413	0,198	2,086	0,546	0,099	5,515	0,411	0,099	4,152
β_4	0,142	0,053	2,679	0,112	0,052	2,154	0,213	0,022	9,682

β_{11}	0,049	0,011	4,455	0,84	0,111	7,568	4,937	2,011	2,455
β_{22}	2,105	0,404	5,210	1,124	0,404	2,782	3,278	0,404	8,114
β_{33}	1,388	0,366	3,792	0,734	0,366	1,913	0,764	0,366	2,087
β_{44}	0,61	0,296	2,061	4,031	1,296	3,110	1,602	0,786	2,038
β_{12}	2,399	0,611	3,926	3,638	0,611	5,954	2,333	0,611	3,818
β_{13}	2,317	1,862	1,244	1,331	0,362	3,677	3,537	1,862	1,900
β_{14}	0,423	0,135	3,133	0,131	0,035	3,743	0,843	0,235	3,587
β_{23}	0,249	0,084	2,964	4,533	0,624	7,264	1,482	0,624	2,375
β_{24}	1,828	0,548	3,336	0,361	0,048	7,521	0,808	0,248	3,258
β_{34}	0,977	0,114	8,570	4,545	0,844	5,385	1,868	0,844	2,213
sigma-squared	0,793	0,369	2,149	0,731	0,364	2,008	0,780	0,239	3,264
gamma	0,812	0,298	2,725	0,765	0,238	3,214	0,820	0,342	2,397

Unlike the Cobb-Douglas specification, the calculation of returns to scale (RTS) in the translog model is more complex and cannot be derived from a simple summation of the β coefficients. In our case, RTS depends not only on the linear coefficients but also on the interaction and squared terms. Consequently, returns to scale are not constant but vary depending on the values of the input variables. For each of the 28 countries analyzed, efficiency can be calculated using the following formula:

$$RTS_i = \sum_{k=1}^{4} \left(\beta_k + \sum_{m=1}^{4} \beta_{km} \cdot \ln\left(x_{mi}\right) \right), \quad i = 1 \ldots 28 \tag{7}$$

The results of the returns to scale (RTS) assessment for EU countries and Ukraine are presented in Table 4. Ukraine in 2021 and Romania in 2023 recorded the highest values of this index, indicating the presence of potential for increasing returns to scale. This can be attributed to the still unrealized efficiency reserves in the utilization of production resources, opportunities for technological modernization, and the enhancement of managerial practices in the agricultural sector.

On average, EU countries exhibit nearly constant returns to scale ($RTS_{av} = 0.99$), indicating that the agricultural sector operates in a balanced manner. A 1% increase in the use of key production inputs (land, labor, capital, and intermediate consumption) results in a proportional 1% increase in factor income. In other words, such an agricultural sector has reached a mature stage of development, where resources are utilized efficiently, without surplus or deficit. This situation is also typical for stable and advanced agricultural sectors in EU countries with well-established agricultural policies and a high level of government regulation.

Table 4 - Returns to scale (RTS) in the agricultural sectors of EU member states and Ukraine

	2021	2022	2023
Luxembourg	0,9	0,91	0,9
Malta	0,9	0,89	0,88
Cyprus	0,92	0,94	0,92
Belgium	0,95	0,95	0,96
Netherlands	0,95	0,97	0,96
France	0,96	0,97	0,96
Denmark	0,97	0,97	0,98
Germany	0,97	0,98	1
Italy	0,97	0,97	1
Sweden	0,97	0,98	0,95
Austria	0,98	0,98	0,98
Finland	0,98	0,98	0,97
Spain	0,98	0,98	0,97
Ireland	0,99	0,99	1
Greece	1	0,99	1
Portugal	1	1	0,99
Slovenia	1	0,99	0,98
Estonia	1,01	1	1,01
Croatia	1,02	1	1,02
Lithuania	1,02	1,02	1,03
Bulgaria	1,03	1,02	1,05
Latvia	1,03	1,02	1,03
Slovakia	1,03	1,02	1,04
Czech Republic	1,04	1,04	1,04
Poland	1,04	1,05	1,05
Hungary	1,05	1,05	1,04
Romania	1,05	1,06	1,07
Ukraine	1,07		
Geometric Mean	0,99	0,99	0,99

An RTS value greater than 1 in EU countries indicates the existence of potential for scale expansion with increasing returns. This pattern is typically observed in countries experiencing dynamic growth in the agricultural sector, modernization of production, or the active implementation of innovations. According to the obtained results, this situation is characteristic of Central and Eastern European countries, where the agricultural sector is still undergoing an active development phase.

Conversely, an RTS value below 1 signals oversaturation of the agricultural sector or the presence of structural and technological constraints. Additional expansion of production resources does not lead to a proportional increase in factor income. The decreasing returns to scale observed – based on the estimated SFA model – in most Western European countries highlight the need to shift the focus from increasing input volumes to enhancing productivity through innovation, precision farming, digitalization, and intensive technologies.

Since the estimation was based on a translogarithmic functional form, the returns to scale are not constant and depend on the combination of input factors specific to each country. The calculated individual RTS values for EU member states revealed the presence of countries with constant returns to scale as well as cases of decreasing returns, which may indicate resource oversaturation and declining efficiency in certain agricultural systems. This underscores the need for a more individualized approach to agricultural development policy, taking into account the structure of resource endowments and existing technological constraints.

Table 5 presents the results of profit efficiency estimates for the agricultural sectors of EU countries and Ukraine for the year 2021. Due to the unavailability of statistical data for most agricultural performance indicators in Ukraine for 2022 and 2023, efficiency for these years was calculated only for the 27 EU countries.

The undisputed leaders in this ranking are the Netherlands, Belgium, and Denmark. In the pre-war period, Ukraine's agricultural sector demonstrated a technical efficiency level of approximately 0.5, which allowed it to outperform several Eastern European countries, although it remained in the lower tier of the overall ranking. Interestingly, the average efficiency of the agricultural sectors across EU countries has shown a steady increase of approximately 1% per year over the analyzed period.

Table 5 - Agricultural sector efficiency of EU countries based on the SFA model

Integr. rating	Country	2021	2022	2023
1	Netherlands	0,96	0,97	0,97
2	Belgium	0,97	0,96	0,95
3	Denmark	0,92	0,93	0,94
4	Spain	0,91	0,91	0,93
5	Italy	0,88	0,87	0,9
6	France	0,86	0,85	0,9
7	Germany	0,82	0,81	0,82
8	Malta	0,81	0,83	0,81
9	Greece	0,79	0,76	0,78
10	Ireland	0,78	0,78	0,76
11	Bulgaria	0,74	0,7	0,73
12	Cyprus	0,72	0,74	0,72
13	Slovenia	0,7	0,67	0,72
14	Slovakia	0,67	0,72	0,71
15	Lithuania	0,63	0,65	0,67
16	Luxembourg	0,63	0,62	0,67
17	Austria	0,63	0,6	0,62
18	Portugal	0,55	0,58	0,53

19	Sweden	0,53	0,56	0,52
20	Poland	0,51	0,53	0,52
21	Finland	0,5	0,49	0,5
22	Croatia	0,44	0,52	0,49
23	Estonia	0,45	0,48	0,49
24	Czechia	0,47	0,46	0,47
25	Romania	0,42	0,42	0,42
26	Latvia	0,4	0,39	0,41
27	Hungary	0,41	0,4	0,4
28	Ukraine	0,5	-	-
Geom. mean		0,66	0,67	0,68

Unfortunately, Ukraine's position in the agricultural efficiency ranking among EU countries can be assessed only based on the statistical data available for 2021, as official data for the period of ongoing military aggression have not yet been published. Therefore, efficiency was estimated using the proposed SFA model for the year 2021 (for both EU countries and Ukraine) and for 2022–2023 (for EU countries only).

Overall, territories in Ukraine affected by occupation, military operations, and landmines account for approximately 31.74% of the country's total area. Agricultural land comprises about 70% of Ukraine's territory, with a total area of approximately 41.3 million hectares (State Statistics Service of Ukraine, 2023). As a result of Russian aggression and temporary occupation, around 25–30% of agricultural land (over 12 million hectares) is currently located in zones of active hostilities, occupation, or contamination by landmines. These factors have led to a substantial decline in the production potential of the agricultural sector, weakened Ukraine's export capacity on the global market, and created serious threats to food security not only at the national level but also globally. In addition to economic losses, the situation poses long-term challenges for the restoration of soils and agricultural infrastructure.

When comparing the efficiency of the agricultural sector across regions, Western European countries emerged as the leaders, with an average efficiency score of 0.82 in 2023 (see Figure 1). The lowest efficiency was observed in Eastern European countries, with an average of 0.55. The efficiency of agriculture in Southern EU countries was significantly higher than in the Northern ones – 0.78 and 0.61, respectively. This can be attributed to the favorable climate in Southern Europe, characterized by a long growing season that allows for multiple harvests per year and the cultivation of high-margin crops such as grapes, olives, citrus fruits, and vegetables. In contrast, Northern countries face a shorter agricultural season, greater weather-related risks, and a more limited range of crops.

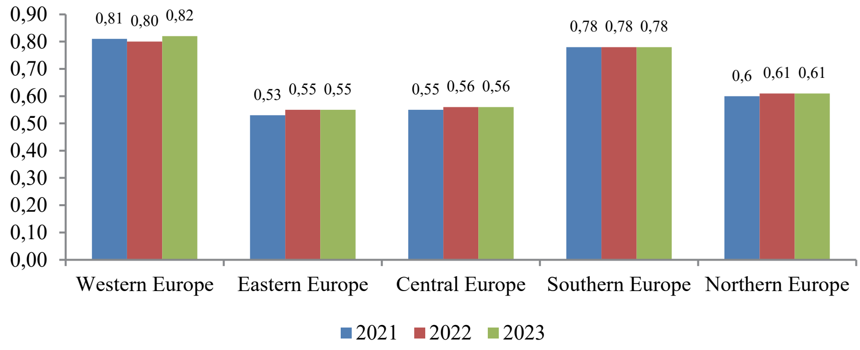
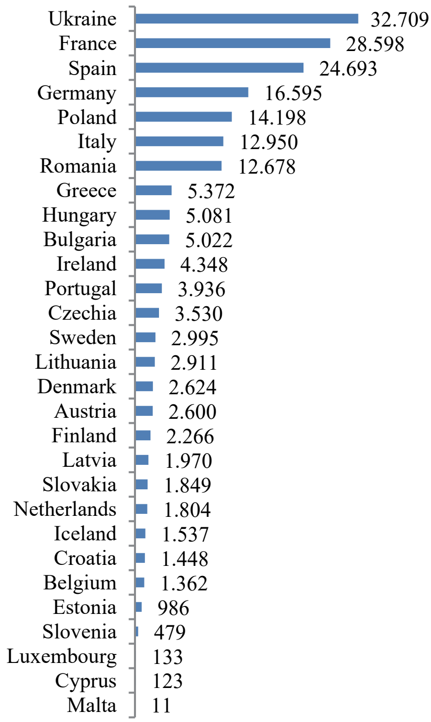


Figure 1 - Average agricultural sector efficiency across EU regions

The availability of vast agricultural land presents significant opportunities while simultaneously posing challenges related to the rational use of these resources. Large land areas require substantial investments in machinery, infrastructure, irrigation systems, and modern agricultural technologies. Insufficient renewal of fixed capital or excessive reliance on extensive farming methods reduces overall efficiency. Ukraine's vast agricultural land represents a strategic advantage in the global agricultural market—provided it is used efficiently. With appropriate agricultural policies and targeted investments, this resource can significantly enhance the country's export potential.

Even without accounting for the temporarily occupied territories, Ukraine currently possesses the largest area of agricultural land in Europe (see Figure 2). However, this considerable predominance in land area partly explains the relatively low efficiency of Ukraine's agricultural sector compared to average EU levels. As shown in Figure 3, the indicator of gross fixed capital consumption (depreciation) in Ukraine is significantly lower compared to countries with smaller or comparable agricultural land areas, such as France and Spain. This reflects insufficient renewal of fixed assets and a low level of capital intensity in agricultural production. While Ukraine's agricultural sector benefits from vast land resources, it fails to provide an adequate level of investment in fixed capital, which may constrain productivity and overall production efficiency. In terms of factor income in the agricultural sector in 2021, Ukraine ranked sixth among the countries analyzed (see Figure 4). However, due to the significantly larger agricultural land area compared to most other countries, Ukraine exhibited a relatively low level of efficiency in its agricultural sector.



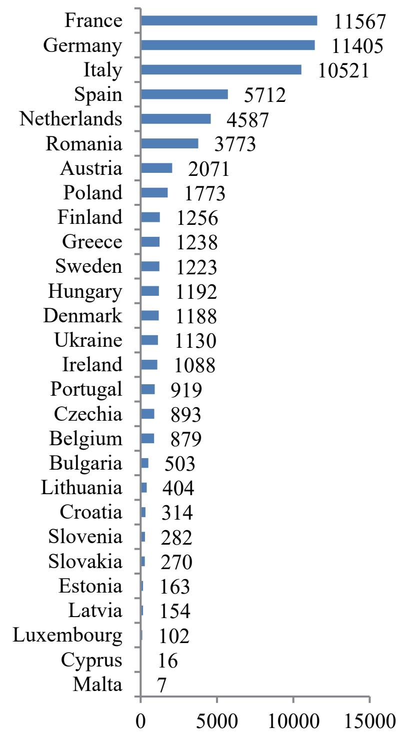


Figure 2 - Agricultural land areas in EU and Ukraine in 2023, thousand hectares

Figure 3 - Gross fixed capital consumption in agriculture in 2021, million euros

Intermediate consumption is an important indicator of resource expenditure and reflects the costs of materials, energy, services, seeds, and feed – resources that directly influence the volume of output or profit. In agriculture, intermediate consumption refers to the value of all goods and services used in the production process for generating agricultural output during the reporting period, which were entirely consumed in that process (i.e., not retained as assets or inventory). In the production function, intermediate consumption serves as a key short-term input factor alongside labor, land, and capital. In essence, intermediate consumption represents material resources that are directly transformed into output – either in the form of produced goods or factor income. In Ukraine, the level of intermediate consumption is relatively high (see Figure 5).

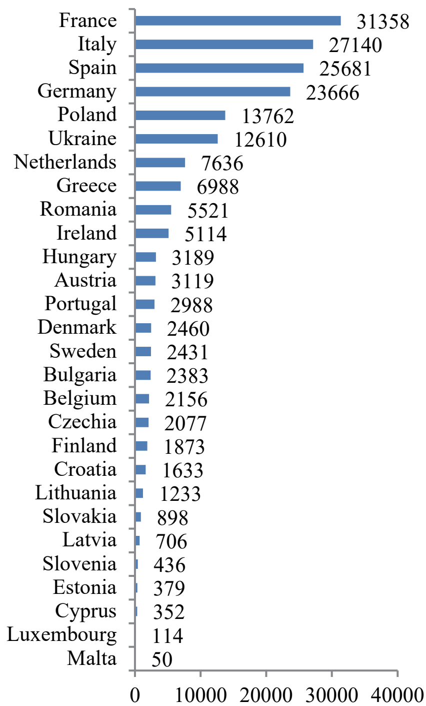


Figure 4 - Factor income in agriculture in 2021, million euros

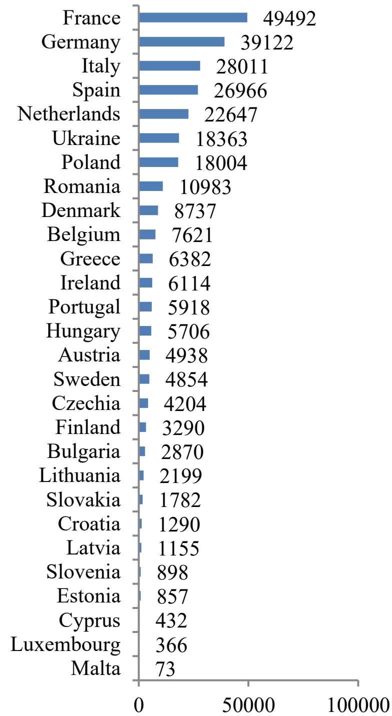


Figure 5 - Intermediate consumption in the agricultural sector in 2021, million euros

Discussion

The findings of this study offer valuable insights into the technical efficiency and scale dynamics of agricultural production across EU member states and Ukraine. The use of a translog stochastic frontier model allowed for a nuanced interpretation of how multiple input factors – land, labor, fixed capital, and intermediate consumption – contribute to factor income in the agricultural sector. One of the key contributions of this analysis lies in the observation that, on average, EU countries operate under nearly constant returns to scale (RTS ≈ 0.99), implying an efficient balance between input use and output generation. This outcome is consistent with earlier research by Kocisova and Sedliaciková (2022), who emphasized the stabilizing role of institutional and technological maturity in the EU's western agricultural systems. Similarly, Đokić et al. (2022) found that countries such as the Netherlands, France, and Germany consistently exhibit high efficiency levels, largely due to long-term investments in modernization and sustained agricultural policy support. Conversely, the increasing returns to scale (RTS > 1) observed in Central and Eastern European countries, as well as in Ukraine (RTS = 1.07), align with findings from Galluzzo (2020), which analyzed Romania's agricultural sector. These results suggest underutilized potential that could be unlocked through structural reforms, enhanced access to capital, and adoption of precision agriculture technologies. In this context, the findings reinforce arguments presented by Zhen et al. (2022), who highlighted those improvements in technical efficiency – particularly when combined with renewable energy integration – can yield environmental and economic co-benefits.

However, the efficiency score for Ukraine (TE ≈ 0.50) remains below the geometric mean of the EU sample (TE ≈ 0.66-0.68). While Ukraine ranks sixth in factor income in absolute terms, its relative efficiency is diluted by the sheer scale of agricultural land. This indicates a low level of capital intensity and limited renewal of fixed assets, reinforcing the conclusions of Martinez et al. (2021) and Quiroga et al. (2017) regarding the critical role of subsidy mechanisms and investment incentives in influencing farm-level performance. As these studies suggest, mere availability of land or labor is insufficient, efficient transformation of inputs into outputs hinges on modernization and institutional support.

The present study also affirms the importance of intermediate consumption as a short-term determinant of technical efficiency. This result supports prior studies (e.g., Moutinho et al., 2018; Coluccia et al., 2020) showing a strong association between intermediate input use and both profitability and productivity in agri-food systems, particularly in the Mediterranean and Southern regions of the EU. The observed regional disparities – namely, higher efficiency in Southern Europe compared to Northern and Eastern counterparts – reflect ecological and climatic conditions highlighted by Domagała (2021), who emphasized the significant impact of climate suitability and crop specialization on output efficiency. Additionally, our results emphasize the significance of tailoring agricultural policies to regional contexts. Variations in efficiency across EU countries mirror the typologies outlined by Poczta et al. (2020) and Pawlak et al. (2021), emphasizing the combined influence of structural features, policy measures, and environmental limitations on national-level results. Countries with decreasing RTS should prioritize innovation, digitalization, and sustainability, while those with increasing RTS, require targeted support to realize scale economies and modernization gains.

Overall, the outcomes of this research confirm the robustness of the SFA framework in disentangling inefficiency from random shocks, and they underscore the necessity for differentiated and evidence-based agricultural strategies. The implications are particularly relevant for Ukraine's post-war recovery planning. Investments in capital stock, institutional reform, and access to innovation will be essential in transforming its extensive land base into a source of sustainable productivity and global competitiveness.

Conclusions

This study provides a detailed assessment of the technical efficiency of the agricultural sectors in the European Union and Ukraine using stochastic frontier analysis (SFA) based on the translog production function. Ukraine possesses one of the largest areas of agricultural land among European countries, which creates substantial production potential. However, gross fixed capital consumption (depreciation and technical renewal) per hectare is below the EU average. This indicates the need for increased investment in the modernization of machinery, equipment, irrigation systems, and other fixed assets to enhance the efficiency of land use.

According to the estimated SFA model, the agricultural sector in EU countries exhibits, on average, nearly constant returns to scale (RTS ≈ 0.99), indicating balanced and efficient use of production resources without overexploitation or shortage. This pattern is particularly characteristic of economically developed Western European countries with strong governmental support and substantial investment in modernization. In contrast, Central and Eastern European countries show increasing returns to scale (RTS > 1), suggesting significant potential for growth in efficiency through resource consolidation, modernization, and the implementation of innovations.

Technical efficiency in the EU agricultural sector demonstrates a consistent upward trend, growing by approximately 1% annually. The highest efficiency levels were observed in the Netherlands, Belgium, and Denmark, while Eastern European countries continue to lag behind, with efficiency levels around 0.55–0.60. Ukraine's agricultural sector recorded a technical efficiency score of 0.5 in 2021, which allowed it to outperform some Eastern European countries, although it remained in the lower range of the overall ranking. At the same time, Ukraine's high RTS value (1.07) indicates strong potential for efficiency improvements through modernization and institutional reforms. Regional differences in agricultural sector efficiency across the EU underscore the need for individualized agricultural policies. Countries experiencing resource saturation and low RTS should focus on innovation, digitalization, and intensive technologies, while those with high RTS should prioritize support for scaling up and modernization.

Thus, the results of this study may serve as a basis for defining strategic directions for the development of Ukraine's agricultural sector in the context of European integration, shaping state support mechanisms, and designing policies aimed at stimulating investment in the recovery and modernization of agricultural production.

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Issues and challenges of regulation of relations on the Internet to guarantee adherence to human rights

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Abstract

This article addresses the critical issue of human rights protection in digital environment, with the legal frameworks governing digital rights as a core concept. The main research questions examine key threats to human rights online and effectiveness of existing international and national mechanisms for safeguarding these rights. The study employs a comparative analysis of legal systems and their modifications responding to the impact of evolving digital technologies and markets in the EU and the U.S. The study also addresses how Internet access has impacted user rights during the Russian-Ukrainian war. Using formal-legal and systemic methods, the research assesses the effectiveness of these regulatory approaches. The results reveal significant differences in protection of digital rights across the EU, the U.S., and Ukraine, highlighting gaps in enforcement and practical application. The findings contribute to the ongoing discourse on the need for stronger global collaboration in digital rights regulation and propose recommendations for

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enhancing legal protections in the digital sphere, particularly in Ukraine's context. This research advances the understanding of how international legal standards can be integrated into national legislation, offering new perspectives for policymakers and legal scholars.
Keywords: Internet, human rights and freedoms, information rights, digital freedom, international law.

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Introduction

In the modern digital age, human rights issues have acquired new meanings since governments are required to develop legislative mechanisms to protect and maintain fundamental rights in the digital space. In this regard, legal support should empower both businesses and individuals, ensure and guarantee rights and freedoms enshrined in the European Convention on Human Rights, which are implemented in the digital sphere (Aristova et al., 2021). Human rights are fundamental to democratic societies and reflect the principal values and principles that ensure freedom, security, and dignity of every person (Holovko et al., 2021). In the EU countries, the U.S., and Ukraine, human rights are given great importance; they are documented in detail in national and international documents. The EU and the U.S. are among the most significant regions in terms of digital technology development, policy adoption, and global influence. Regulations often set trends affecting other jurisdictions worldwide. Hence, the analysis of the EU and U.S. legislation on Internet provides insight into global standards and practices in the field of digital rights. In the EU, they are enshrined in the Charter of Fundamental Rights of the European Union and the European Convention on Human Rights, in the U.S. digital rights are defined in the Constitution and the Bill of Rights, while in Ukraine, they are provided for in the Constitution and laws governing the rights and freedoms of citizens. These documents enshrine the values that form the foundation for the rule of law, including equality, freedom, privacy, non-discrimination, human dignity, inclusiveness, and democracy. These values include freedom of expression, the right to privacy, protection from discrimination, and the right to redress in cases of rights violations.

Basic rights such as privacy, freedom of expression, and personal sovereignty are greatly affected by the rise of digital technology. The impact of digitalization is observed in all spheres of life, which brings both opportunities and threats to the realization and protection of these rights. The state and private companies, possessing large amounts of personal data, are able to violate the privacy of citizens and have the ability to control digital platforms, which jeopardizes freedom of speech. During warfare, when the online space becomes a field for information wars and a tool for mobilizing the population, these risks become even more acute. In other words, the Internet has become a means of manipulating public opinion and a platform for violating people's rights to privacy and freedom of expression, in particular through the use of technology for surveillance and control.

In the context of digital transformation, the question arises whether digitalization creates new rights for users? This right can be interpreted as the right to privacy and autonomy in the digital environment. This is especially acute in the face of the constant growth of digitalization and the introduction of new technologies that provide access to vast amounts of information and create new challenges for personal privacy. In traditional legal framework, the right to privacy provided for the protection of privacy and information from interference by the state or third parties. However, in the context of digitalization, this right takes new forms. For example, the right to freedom from intrusive advertising, the right to protection from cyberbullying, and the right to be forgotten require that a person can control what data about him/her is available on the Internet. In such a way, a person can defend his/her personal integrity in the digital space. These issues prompt discussions about the need for new legal mechanisms that can adequately protect the rights of users on the Internet.

Therefore, the aim of the article is to establish the main problems and challenges in regulations of relations on the Internet, related to the observance of human rights, and analyze the approaches of different countries to address these issues on the example of the EU, the U.S, and Ukraine. Accordingly, the hypothesis that the effectiveness of legal protection of human rights in the digital environment depends on the integration of international standards, national regulatory mechanisms, and clear state enforcement. Therefore, the novelty of the article consists in filling the gaps in the study of practical aspects of law enforcement and the integration of international norms into national legislation. This research also suggests new approaches to the analysis of digital rights protection not only by legislative acts, but also through mechanisms of international cooperation and legal standards harmonization in the global digital space.

In order to achieve the aim of the research, a number of research methods is applied. Thus, the analysis of the regulatory framework is carried out, including the study of international acts such as the Universal Declaration of Human Rights, the International Covenant on Civil and Political Rights, the EU General Data Protection Regulation (hereinafter – GDPR), and the U.S. California Consumer Privacy Act (2018) (hereinafter – CCPA). This analysis helps understand the basic principles of legal protection in the digital sphere. This stage facilitates assessing differences in approaches to the digital rights regulation, using legal frameworks such as GDPR and CCPA as key examples. In particular, the principles on the protection of privacy, freedom of speech, and cybersecurity are investigated. Moreover, the mechanisms of control and practices of Internet companies in EU, the U.S, and Ukraine are compared.

Furthermore, the content analysis is used to analyze case law on digital rights violations, in particular in cases of blocking content or illegal data collection. In addition, the academic literature is analyzed to identify key challenges and approaches that affect human rights on the Internet. The quantitative and qualitative analysis of statistical data on citizens' complaints about violations of rights on the Internet in Ukraine, the EU and the U.S. is also carried out. This statistical analysis helps assess the effectiveness of existing legal mechanisms of protection. Moreover, the method of comparative legal analysis allows the researchers to identify gaps in regulations and determine directions for improving the digital rights regulation. In this regard, the results of the implementation of different legal norms and their impact on freedom of speech and privacy in different countries are compared.

The system method is used to determine the relationships between different legal institutions and mechanisms that protect human rights in the digital space. This approach made it possible to consider regulation as an integral system functioning in the interaction of international and national law. This multidimensional approach ensures research reproducibility and facilitates the evaluation of the reliability and validity of results.

Discussions on the protection of human rights in the digital environment: Literature review

The problem of human rights on the Internet has always been relevant in modern Ukrainian legal doctrine. Currently, the basic doctrinal provisions on human rights in the digital space have not been significantly changed. It should be noted that all theoretical developments regarding human rights on the Internet are mainly based on the proclamation of guaranteeing any human rights in the digital space as a modern way of their implementation (Holovko et al., 2021). In this regard, each right or freedom on the Internet is investigated as a specific opportunity.

When studying the guarantees of human rights in the digital environment, considerable attention is paid to the analysis of the main approaches to their regulation in various jurisdictions. A review of academic sources shows that most authors focus on privacy and data protection issues, as well as the need to strengthen regulatory mechanisms to prevent rights violations online (Sarakutsa & Piliuk, 2021).

According to Bocharova (2021), the information society is developing in a new paradigm, where information and knowledge become the main products of human activity. Moreover, technologies perform not only a technical function, but also serve as a social tool for realizing human potential. However, the widespread use of technology can adversely affect fundamental human rights, especially in the face of insufficient privacy protections and a lack of clear regulations of digital platforms. The Internet can also have a detrimental effect on democracy and human rights through the use of algorithmic filters that provide users with information that matches their beliefs. As Rosmetaeva (2020) claims, this can strengthen prejudice and cause radicalization of views, which in turn affects the tolerance level in society.

Furthermore, Mironyuk (2021) focuses on the need to create state mechanisms for the implementation of human rights on the Internet and increase the legal awareness of citizens regarding their rights and obligations in the digital space. Although most studies emphasize existing legislative initiatives, issues related to practical enforcement and the interaction between international and national norms remain understudied.

The comparison of different approaches to human rights protection on the Internet on the example of the GDPR (European Parliament and Council of the European Union, 2016) in the European Union and the CCPA (2018) in the United States highlights the differences in the protection of users' rights in these regions. However, they do not focus on the digital environment impact on human rights in crisis situations. The EU is known for its proactive and comprehensive approach to the digital environment regulation through the GDPR, which focuses on privacy and user consent. In turn, the U.S. has a more fragmented regulatory landscape that often favors innovation and economic growth over strict privacy protections. This distinction facilitates a rich comparative analysis of how different philosophical frameworks can shape digital rights and freedoms. While the EU regulations may provide stronger privacy protections, the U.S. system may facilitate faster technological innovation. Understanding these complementary perspectives can inform policy makers and stakeholders about potential lessons and best practices.

At the same time, both the EU and the U.S. face similar challenges arising from rapid technological progress such as cybersecurity issues, disinformation, and the ethical aspects of AI. The literature review shows that human rights on the Internet are under threat due to a number of factors such as privacy violations, restrictions on freedom of speech, and the influence of algorithms on the formation of public opinion. Modern literature offers different approaches to solving these problems although the development of universal standards and mechanisms is necessary to ensure the protection of human rights on the Internet, regardless of the jurisdiction and specifics of a particular country. In addition, there is a lack of comprehensive analysis of how countries with different cultural and legal traditions can integrate international standards of digital rights into their legal systems.

Statistics on citizens' complaints about violations of human rights in the digital space

The realities of the modern stage of development of civilization and society give rise to new forms of activity and relations between people who naturally use all the privileges of information and technological development of society. The information society today is seen as a new historical phase of civilization, in which the main products of human activity are information and knowledge, and technology is becoming important not only technical means but also social tools for realizing human potential. The information model of building the future society has become a new paradigm of social development as opposed to the past mechanistic paradigm (Bocharova, 2021).

This model of building a social order allows people to fully unleash the full potential of technology, such as the Internet, which creates new responsibilities both in the societies of individual states and in the world as a whole. Using technology can be as much a problem-solver as a problem-creator. Such tools have the potential to advance justice and equality, bolster the foundations of democratic governance, and guarantee transparency, accountability, and engagement between the public authorities, individuals, and groups. It is evident that one of the most significant developments of the information era is the Internet. Its unprecedented proliferation and influence warrant particular attention and recognition (Razmietaieva, 2020). This, in turn, raises a range of various challenges related to the regulation of human rights issues that need to be put on the agenda in all civilized countries seeking to ensure respect for human rights, at all levels, including both international and national.

Today, according to Worldometers (2024), 7.8 billion people live on our planet. According to the UN, 4.2 of them use the Internet. At the beginning of 2020, the number of new Internet users increased by 298 million compared to January 2019, i.e. by 7%. However, the coronavirus epidemic, which began in early 2020, changed the life of the planet, demonstrating the extreme importance of the Internet for modern man. This is evidenced by recently published UN statistics: in a pandemic, Internet traffic has tripled. These changes have affected the world, and at the same time the so-called digital divide has become even more apparent. After all, 3.6 billion people worldwide lack access to the Internet (Novytskyi, 2016).

The statistics indicate numerous complaints of citizens regarding violations of rights in the digital sphere. For example, during the COVID-19 pandemic and the war in Ukraine, the number of cases where online platforms are used to spread misinformation or promote hatred has increased, making it difficult to monitor and respond to such violations. According to the data, the rights of Internet users, who are victims of violations, are poorly protected in Ukraine. This fact emphasizes the need to improve the legal framework and introduce effective mechanisms for restoring violated rights.

In the 21st century, the issue of human rights protection in the Internet is very important because the development of technology, the achievement of scientific and technological progress require legal regulation. Cyber security provides protection of resources, information, data at the stage of their exchange and storage. After all, not everyone understands their rights and responsibilities in the space of the latest technologies (Myroniuk & Halak, 2021).

Modern people, even if they have information about their rights and responsibilities, do not often understand how to protect or restore violated rights, and the issue of these rights in the context of the Internet further deepens the misunderstanding and inability of people to protect and restore their rights. It is a question of creation of the state mechanisms of realization of these rights, and their normative fixing. In the digital sphere, human rights and freedoms are violated in various ways. On the one hand, governments can commit the most egregious violations such as mass surveillance, censorship of the Internet content, arrests of journalists and activists for their online activities. For example, in countries with authoritarian regimes (Belarus or China), governments control access to information and block social networks to suppress opposition. On the other hand, individuals can also violate the rights of others in the digital environment by cyberbullying, disclosing personal information without consent (the so-called "doxing") or slandering. Every modern person should know how to protect their rights on the Internet, how not to become a victim, how to prevent the negative consequences of violations of subjective rights and where to go to restore the violated rights (Myroniuk & Halak, 2021).

At present, statistical data on civil and administrative complaints lodged by citizens concerning infringements of human rights and freedoms in the digital domain indicate that the safeguarding of the rights of Internet users who have been subjected to violations remains severely constrained in Ukraine. This situation calls for the reinforcement of legal frameworks and the implementation of effective mechanisms for the restoration of violated human rights, particularly in instances where the Internet has been the conduit for such infringements (Kurtakova & Usmanov, 2020).

The rights that individuals have offline (e.g., freedom of speech, privacy) are the same as those they have online. However, the way these rights are exercised or how responsibilities are fulfilled can differ between the two settings. The main distinction is not in the rights themselves but in how they are practiced or enforced. For instance, privacy in the offline world might involve physical privacy, whereas online it involves digital data protection. Just like in the offline world, activities conducted online can lead to human rights violations (e.g., online harassment, illegal surveillance). Individuals and entities can be held accountable for these violations, reinforcing that human rights standards apply in both settings.

Some scholars believe that rights in offline mode cannot be compared with rights on the Internet. Thus, Sardak et al. (2021) note that the digital environment creates new challenges that can exacerbate the issue of freedom of speech and privacy. They emphasize that anonymity on the Internet can lead to impunity in cases of slander or threats, which jeopardizes users' responsibility for their actions. Studies conducted by the UN confirm that anonymity on the Internet can interfere with the effective protection of individual rights since sometimes anonymous accounts hide persons who commit crimes in cyberspace.

Hence, the rights that people have offline (for example, freedom of speech, privacy) remain the same in the digital sphere. Nevertheless, the ways of their implementation and responsibility for their violation may differ significantly. In this regard, it is important to ensure proper mechanisms for the realization of users' rights on the Internet and their restoration in case of violation.

The need for regulating relations online

In this regard, a number of new threats are emerging that have not been on the agenda of world organizations, state institutions and civil society until recently. The modern world, like Ukraine, with the technological progress has entered the era of information threats, cyberattacks and, accordingly, information wars. Individual information wars can be much more effective than conventional ground wars with the use of people, territory and weapons, as they affect indefinite areas through the use of information capabilities (Sopilko, 2017). An obvious and horrific example of this is the Russian-Ukrainian war, which clearly shows what information warfare is and how the use of Internet technology for military or criminal purposes can have serious consequences for the information society and access to truthful and verified information from official sources, cyberattacks and other information threats.

With the development and spread of the Internet, more and more countries around the world are aware of the need for its legal regulation. Primarily, this can be attributed to the Internet's significant impact on societal evolution, particularly in regard to its role in facilitating revolutionary changes across all aspects of life. The Internet is a significant factor in social, economic, and cultural development that presents new possibilities for public authorities and ordinary citizens and educators. It has facilitated the creation and dissemination of materials, removed barriers to access, and provided universal access to an expanding array of digital sources (Kovalenko & Turov, 2017). This proves that the range of Internet sources does not mean the criteria of quality or truthfulness, which again opens the problem of regulation of the activities of people and government agencies or institutions on the Internet.

The regulation of the Internet is an issue of significant importance, particularly in view of the necessity to consider the information and communication network as a vehicle for the realization of almost any human right. In any situation wherein rights are acknowledged, responsibilities must also be recognized. It is always possible for these responsibilities to be violated. Consequently, the feasibility of exercising rights and freedoms through digital platforms, along with the prevalence of infringements upon these rights and freedoms, substantiates the imperative for the enactment of diverse levels of legal instruments. Nevertheless, the Internet self-regulating community cannot create a free information environment or set clear rules for Internet users. In particular, the non-binding and non-universal nature of recommendations and resolutions, among other acts, limits the effectiveness of this approach in guaranteeing the aforementioned freedoms.

It has recently become increasingly clear that the regulation of Internet governance requires the adoption of acts that contain international legal norms which bind national legislatures. The framework of international Internet law has developed, with the objective of regulating a series of key issues pertaining to the governance of the Internet. These include relations between states in the digital space, the implementation of controlling measures, and the respect for citizens' rights in this digital age (Sarakutsa & Piliuk, 2021). At the present stage of international cooperation, it is not difficult to develop a universal act to guarantee respect for human rights in the network, it is simplified by the presence of alliances and the number of international agreements with dozens of participating countries.

It should be emphasized that scientists in Western Europe have been analyzing the legal aspects of the Internet information environment for many years. Numerous reports and reports on electronic networks, law and the Internet, prepared at the request of public authorities, have been published in full in France, Belgium, Germany, the U.S. and the UK. Such work is carried out constantly. Its purpose is to study the dynamics of functioning, the development of the Internet as a new way of communication in the world and to develop means of legal and ethical influence on people.

Such analytical work, involving a wide range of scientists and legal experts, should also be conducted regularly in Ukraine and the CIS countries. And this is inevitable, because our market as an integral part of the global market for goods and services is already facing an urgent need for Internet services and is experiencing significant losses due to the lack of scientifically sound and flexible legal regulation of relations arising on the Internet. Thus, creating the concept of information development of Ukraine is critical. There are clearly not enough conceptual acts in this field of informatics and technologies, and there are no special documents dedicated to the Internet at all (Lytvynov, 2013).

Even the simplest, such as defining the legal status and significance of the Internet, is not present in modern domestic acts, let alone a universal act, perhaps even an international one, to be ratified by the Verkhovna Rada of Ukraine. However, these legal documents cannot comprehensively cover the full breadth of online relationships, as well as provide all the prerequisites for protecting and fulfilling human rights online. This once again shows the importance and urgency of establishing mechanisms and adopting regulations, in particular laws and international treaties, that will address the issue of the Internet regulation or will directly regulate these relations.

In the development of modern legislation, we must proceed from the fact that the Internet is a public environment, a public space, and it is used for economic activities and for gathering information. The Internet is changing our space, making it virtual. But in this virtual space, not virtual laws should apply, but the same regulations that govern ordinary space. In light of the ongoing transition toward a more information-centric society, it is necessary to legally enshrine its basic elements (Hlukha, 2020). The components of the Internet correspond to ordinary life, such as the cultural, economic or social spheres, which are directly regulated by legislation, to which must be added the regulation of these rights online.

The Internet is the basis for the development and consolidation of the main directions. Any interference by the state in the network is perceived by the Internet community as a violation of its rights, because currently regulation is through public scrutiny. In order to regulate the network, it is necessary to analyze the trends that are emerging in the online community, consolidating the aspects that it has recognized (Lytvynov, 2013). That is, it is necessary to take into account the opinion of network users, and in general to be guided by the usual principles according to which the Internet operates despite the lack of legal status or regulation.

There is no single special body within the European Union to regulate the Internet. In 2004, the European Network and Information Security Agency (ENISA) was created to act as a consultant and center of advanced technologies in the field of network and information security for the EU member states and institutions. In January 2013, the European Cybercrime Center was established. whose task is to stop the activities of organized criminal networks. The Council of Europe Convention on Cybercrime (2001), the Privacy and Telecommunications Directive (2002), the Directive on measures for a high common level of cybersecurity across the Union (NIS2 Directive) (2016) aim to establish common cybersecurity standards and improve cooperation between EU countries, are in force in the EU (European Parliament, 2016). Although there are documents that directly regulate human rights that can be applied to online relations, most of them apply to international acts that are recognized by most countries in the world, or their region, if it is a regional act (Hutsu, 2018).

The key international instruments guaranteeing human rights and freedoms are the Universal Declaration of Human Rights (1948), the International Covenant on Civil and Political Rights (1966), the International Covenant on Economic, Social and Cultural Rights (1966), the Convention for the Protection of Fundamental Rights and Fundamental Freedoms (1950), the Charter of Fundamental Rights of the European Union (2000), and the Convention on the Rights of the Child (1989). The objective of this initiative is to advance the concept of respecting and safeguarding human rights online. Moreover, it should help international organizations develop and implement a number of recommendations, conventions, guidelines, etc. Documents produced by the United Nations, the United Nations Children's Fund (UNICEF), the Council of Europe, the European Union, and other international organizations focus on the adherence to human rights with the digital setting. States are changing national legislation to realize human rights in the digital space (Voitsikhovskyi, 2018).

The notion of digital rights: challenges and threats

It can be said that the principal task for the observance of human rights and their protection relies on states, which must take international initiatives to legally establish the status of the Internet, enshrine acts in national legislation and cover uniform acts. Thus, the state not only has the rights but also the responsibilities to regulate these areas. This suggests that it is both within the state's power and its obligation to create laws and enforce regulations that govern public communication, including online content. However, there are certain circumstances where the state's regulation might conflict with or infringe upon human rights and freedoms. In other words, the state must do so in a manner that respects and does not unjustly violate fundamental rights and freedoms of its citizens.

State regulation is a definition of clear rules and control over their observance. In this sense and interpretation without regulation it is impossible to do in the field of national use of the Internet as a global information network. If these principles are established taking into account the positive world experience, focusing on democratic principles, then the more detailed and clear these principles will be developed and written, the more transparent will be the processes related to the use of the Internet (Omelchenko, 2014).

At the same time, the Internet can have a detrimental effect on democracy and human rights. This is consistent with the statement that rights are the same online and offline as it emphasizes the importance of the context of their implementation. While rights remain the same, the way they are exercised and protected in the online environment can be more complex due to the specificity of digital technologies. For example, content filtering algorithms used in social networks can create information bubbles in which users receive information confirming their views. This can deepen polarization, radicalize thoughts, and decrease social tolerance (Razmietaieva, 2020).

Thus, the rights that people have online may be at greater risk due to factors such as misinformation, cyberbullying, censorship, and insufficient privacy protections. These risks can undermine the foundations of democracy because they prevent the formation of an objective and diverse information base necessary for an informed civil society. In the face of such a threat, the state protection of human rights in the digital sphere should be strengthened. This may include the development of legislation that regulates issues of privacy and data security, as well as mechanisms that allow the government to effectively respond to rights violations in the digital environment.

Furthermore, in order to ensure rights and freedoms in the digital sphere, it is important to find a balance between protecting these rights and ensuring freedom of speech. In other words, the rules for using the Internet should be aimed at protecting users from abuse, while not restricting their rights to free expression. In this context, it is important to take into account not only the duties of the state to protect the rights of citizens, but also the need to inform society about their rights and ways to protect them in a digital environment.

It is necessary to realize that freedom in the Internet space is one of the most important elements in the creation of acts designed to regulate relations and the exercise of rights in the network. What about digital rights? Analyzing the scientific literature, it is possible to claim that the digital rights encompass several fundamental entitlements, including the freedom and personal security of individuals within the online domain; the right to privacy; the freedom of expression in the digital sphere; the right to peaceful assembly and association; the utilization of digital instruments of democracy; and the prerogative of digital self-determination, or the capacity to disengage from the digital space.

As can be seen from the above, the content of digital rights does not differ significantly from the category of fundamental human rights, except for one – they are all carried out on the Internet, or through its use. It seems quite logical to understand digital rights as a mode of realization of fundamental human rights. From the standpoint of dialectics, basic human rights and digital rights are correlated as content and form (Marushchak, 2021). Therefore, despite the existence of acts regulating fundamental human rights, an important aspect now is the regulation of these same rights online.

The online environment is actively entering the life of the average citizen, through the use of social networks, online platforms, electronic, which indicates that we live in the period of the fourth industrial revolution. However, it has posed a scope of challenges that need to be dealt with immediately, taking into account the core standards of the Council of Europe and the ECtHR case law. The objective is to establish an online environment that safeguards ownership, privacy, and personal data in accordance with the standards of freedom of expression, both in physical and virtual spaces (Sopilko, 2017). Therefore, the importance of the Internet regulation to ensure human rights is immense. The creation of international and national legislation presents a challenge that the world must address comprehensively to uphold human rights against current and future threats.

Digital rights protection in the EU, U.S., and Ukraine

To deepen the analysis of digital human rights, it is essential to explore how different countries regulate these rights and deal with the emerging problematic aspects of the digital era. For instance, a comparison of the GDPR and the CCPA highlights significant differences in legal frameworks. While the GDPR provides a comprehensive, centralized approach to ensuring individuals' privacy rights, the CCPA offers a more fragmented, state-level regulatory mechanism. The GDPR is known for its stringent requirements, such as obtaining explicit consent before processing personal information and ensuring the right to be forgotten, thus empowering European citizens to control their digital presence. In contrast, the CCPA affords California residents the right to be informed as to the nature of the data being collected and the option to decline participation in data sales. However, it lacks the broader enforcement mechanisms found in the GDPR.

Moreover, the enforcement of these regulations differs significantly. The GDPR has the power to impose heavy fines on companies that fail to comply. The potential penalties for noncompliance can reach up to four percent of a company's global annual revenue. This has led to a higher level of compliance and awareness among European businesses about data privacy. Meanwhile, the CCPA's penalties are more limited, and enforcement primarily depends on the actions of the Attorney General of California, leading to uneven enforcement and compliance across different sectors. These contrasts illustrate not only the diversity in legal approaches but also the varying degrees of protection provided to individuals' rights online, depending on the jurisdiction in which they reside (European Parliament and the Council of the European Union, 2016).

In addition, a study on the role of Internet during the pandemic underscores the global need for stronger digital rights protections. In countries like South Korea, where technology was effectively used to trace and control the spread of the virus, the balance between public health measures and privacy rights became a focal point of legal debates. Meanwhile, in Ukraine, the use of social media platforms during the Russian-Ukrainian war to document human rights violations has prompted discussions about the need for international legal standards that ensure the right to free expression online while mitigating the risks of disinformation and privacy breaches.

The synthesis of these comparative perspectives and case studies reinforces the argument that legal frameworks must evolve to address both the opportunities and threats posed by the digital space. The effective regulation of digital rights is not only a national issue but a global one, requiring coordinated international efforts (Bocharova, 2021; Razmietaieva, 2020). By bridging the gap between theoretical approaches and practical case studies, it becomes evident that the upholding human rights on the Internet requires a comprehensive, multilayered legal response.

Conclusions

Since today the information and communication sphere and the Internet are a means of realizing almost any human rights and freedoms, the range of violations of these rights and freedoms is increasing as the digital age of mankind develops. Therefore, thanks to legal regulation, the Internet should not become a sphere of breach of human rights and freedoms, but a sphere of cross-border guaranteed, safe and free space for the development of the person.

The importance of the Internet for the military situation in Ukraine cannot be overestimated, as it is an opportunity to disseminate and transmit important, strategic and sometimes vital information, military strategy, fundraising and volunteering, collecting information and evidence of Russian war crimes in Ukraine, military medical training of the population, psychological support of victims and a number of other important aspects. inadequate legal regulation deprives human rights of protection and guarantee, so the improvement and evolution of digital legislation must always remain alive.

This study makes a significant contribution to the field of legal regulation of digital rights, in the context of upholding human rights on the Internet. The comparative analysis shows that regulatory approaches differ significantly, regarding privacy and personal data protection. The study also emphasizes the importance of international cooperation and harmonization of legal standards for more effective guarantees of human rights in the digital sphere. The example of Ukraine demonstrates the need to strengthen legal regulation in times of war, when the Internet is essential in protecting the rights of citizens.

However, the study has certain limitations. The main one is that it is based on secondary data and comparative analysis of legal acts, which does not take into account the details of their practical application in specific cases. In addition, the study is limited to a few jurisdictions, so further research could focus on analyzing regulatory approaches in other countries or regions to provide a more global picture.

Suggestions for future research include conducting empirical studies covering the practical aspects of the application of digital rights in different jurisdictions. It is also worth focusing on the role of international organizations in shaping common standards for upholding human rights in digital environment.

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Organizational Culture and Leadership for Sustainability from a Work and Organizational Psychology perspective

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Abstract

In the past two decades, sustainability has gained significant attention, influencing global agendas. This paper examines the relationship between Governance for Sustainability (GfS) and organizational dynamics through the lens of Work and Organizational Psychology (WOP). While existing literature predominantly focuses on macro-level governance, this study addresses the overlooked micro and meso levels. By exploring dimensions such as culture and leadership, it sheds light on critical issues for organizations navigating sustainable change. Emphasis is placed on the "human factor" and its connection to WOP. Implications for research and practice are discussed, with a focus on advancing the GfS field through WOP themes.
Keywords: Governance for Sustainability; Work and Organizational Psychology; Organizational culture; Leadership; Sustainability; Governance.

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1. Introduction

Over the last two decades, the topic of sustainability has increasingly attracted the attention of academics, policy makers and practitioners,

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sparking an interdisciplinary discourse that now influences strategic agendas at a global level (Di Fabio, Rosen, 2018). The concept of sustainability goes beyond the traditional focus on environmental and ecological aspects and embraces a comprehensive and integrated approach that also includes social and economic dimensions (Kuhlman and Farrington, 2010), addressing the well-being of individuals, organizations and society in general. In this scenario, where environmental awareness, social responsibility, and economic governance are central, organizations play a crucial role in promoting a sustainable future.

This paper attempts to unravel the intricate interplay between governance for sustainability and organizational dynamics by delving into the field of Work and Organizational Psychology (WOP). In the literature, the focus is usually on the macro level, i.e. the highest levels of governance systems and dynamics, while little attention is paid to the micro and meso levels (Perkins and Nachmany, 2019; Schill et al., 2019).

Based on this consideration, our paper examines the importance of dimensions such as organizational and individual behavior, organizational culture, and leadership, drawing on the existing literature in the field of organizational studies on sustainability and in the context of WOP. First, the topics of sustainability and GfS are examined with a special focus on their often neglected "human factor" and its connection to WOP. Subsequently, the topic of organizational culture and leadership in connection with GfS will be examined in greater depth. The aim is to present key issues for organizations dealing with sustainable change and for research in this area, addressing aspects such as complexity, change, and inclusion in their interaction with organizational culture and leadership. Finally, implications for research and practice are presented. The focus of this paper on the fundamental role of WOP themes in sustainability, such as organizational culture and leadership, contributes to the further development of the GfS field.

In fact, as organizations increasingly grapple with the complexities of a rapidly changing global landscape, the need for a governance for sustainability which encourages and enables sustainable practices should be an ethical obligation and a strategic imperative. Indeed, organizations are increasingly seeking to measure, report and highlight their concrete commitments to combating climate change and promoting sustainability. At a global level, for example, 61% of companies have obtained an Environmental, Social, and Governance (ESG) committee (CECP, 2020), a recognized framework that organizations use to disclose their sustainability performance. However, it is important that these types of certifications and the visibility they can provide do not become the ultimate goal of organizational efforts to conform to a bureaucratic culture. Rather, certifications should only be a tool for transparency, accountability and benchmarking in the pursuit of common sustainability goals. Organizations' actions should be embedded in an authentic sustainability culture and driven by coherent leadership capable of communicating values, beliefs, and norms, influencing decision-making processes and stakeholder engagement in the adoption and implementation of sustainable governance practices (Aguinis and Glavas, 2019; Schein, 2010).

2. Governance for Sustainability and Work and Organizational Psychology

2.1 Sustainability

Although the term "sustainability" is being used more and more frequently, there is some confusion about its meaning. Sustainability is commonly defined as «the degree to which a process or enterprise is able to be maintained or continued while avoiding the long-term depletion of natural resources» (Oxford English Dictionary, 2022), has been articulated in more than 300 different ways in the literature (Maggiolini and Tecco, 2019). For several years, attempts have been made to narrow down and decode the word sustainability (e.g. Brown, et al., 1987).

The first definition of sustainable development can be found in the report "Our Common Future" (also known as the Brundtland Report, after the name of the head of the commission), produced by the World Commission on Environment and Development (WCED) in 1987. They were faced with the challenge of reconciling global aspirations for a better life with limited natural resources and the dangers of environmental degradation. Their solution was formulated as sustainable development, defined as progress that meets the needs of the present while ensuring the ability of future generations to meet their own needs (Kuhlman and Farrington, 2010). Despite its vagueness, the Brundtland definition of sustainability is often used because it has a broad scope and introduces the fundamental theme of intergenerational equity (Emas, 2015; Tenuta, 2009), focusing on the conservation of resources, the improvement of quality of life, and equitable access to environmental resources for future generations (Tenuta, 2009).

Since the Brundtland Report, sustainability has been conceptualized in terms of three interconnected dimensions – social, economic, and environmental – which must be in balance (Kuhlman and Farrington, 2010). Various models such as the "triple bottom line" by Elkington (1994) illustrate the connection between these areas of sustainability (Maggiolini, Tecco, 2019). Kuhlman and Farrington (2010) take a critical look at the effects of a three-dimensional approach to sustainability. They argue that a three-dimensional model gives too little weight to the environmental dimension, as both the social and economic dimensions are related to human well-being and thus conflict with environmental priorities. In contrast, the authors propose replacing the traditional social and economic dimensions of sustainability with a single dimension, "well-being", in order to bring transparency to the policy formulation process by clearly distinguishing between the two concerns of well-being and sustainability. The debate on the conceptualization of sustainability is therefore complex and still open, and it is intertwined with the "human factor" and the concepts of well-being and happiness.

The human factor in all aspects of sustainability requires an appropriate culture and effective leadership to guide sustainable transformations, especially with regard to the sustainability of organizational life (Di Fabio and Rosen, 2018, Molino et al., 2019, Baumgartner, 2009).

In WOP research, the concept of sustainability is often declined as sustainability of organizational life and linked to the topics of well-being and quality of working life. Sustainability in organizational life means promoting well-being and healthy cultures, emphasizing meaningful work experiences and positive narratives that can inspire hope and success, and changing cultures to promote diversity and enhance performance (Di Fabio, 2017). Addressing unsustainable dynamics in organizations, such as negative leadership styles, is critical to ensuring employee well-being under changing work conditions (Molino et al., 2019). Considering organizational life as a component of the corporate sustainability framework seems particularly crucial for workplace psychologists to create organizations in which sustainability is a fundamental value of organizational culture and thus permeates all processes and levels of the organization, including those related to the sustainability of organizational life.

2.2 Governance for Sustainability

According to scientific literature, governance plays a very important role for organizations embarking on the path to sustainability. The concept of governance can be defined as «the sum of the many ways individuals and institutions, public and private, manage their common affairs including both formal, i.e., codified, and informal mechanisms» (Commission on Global Governance 1995, p. 4). Governance, in other words, is «a set of regulations, stakeholder engagement, and procedures aimed at achieving a shared objective» (van Zeijl-Rozema et al., 2008, p. 411). Governance, as sustainability, inherently encompasses multiple dimensions and involves different decision makers, stakeholders, processes and hybrid practices (Glass and Newig, 2019; Kemp et al., 2005). In contrast to government, which implies static, easily identifiable, and formal structures that rule over people, governance emphasizes the importance of both formal and informal arrangements where power is exercised through a network of interconnected actors who use knowledge resources, financial means, and rights granted to them (Kemp et al., 2005). This comparison implicitly recognizes the need to move from an outdated form of government to a more adaptable and flexible model of governance capable of managing the diverse debates of contemporary society. This need for change is repeatedly emphasized in discussions of governance (Kemp, Martens, 2007; Kemp et al., 2005).

On the one hand, effective governance can contribute to the sustainability performance of organizations. The study by Gueney (2017) describes the positive effects of governance on sustainable development that can be observed in both developed and developing countries. According to the author, the improvement of governance levels is crucial for the protection of resources and wellbeing. On the other hand, governance can be explicitly dedicated to sustainability, which is defined as Governance for Sustainability (GfS) or similar terms. Several authors have attempted to codify the characteristics that GfS should have in order to achieve effective and efficient outcomes. The key components listed by Kemp and colleagues (2005) are based on the concept of good governance defined by the European Commission, which emphasizes openness, participation, responsibility, effectiveness, and coherence. At the same time, they take into account the requirements of sustainable development, including collaboration not only with formal but also with informal institutions, a coherent vision, involvement, and the ability to coordinate and realign. On the basis of these fundamental indications, some characteristics of the GfS are outlined below.

- Policy Integration: essential in order to address common problems and implement coordinated solutions, counteracting the prevailing trend of sectoralization and specialization. This includes vertical and horizontal aspects such as the consideration of environmental impacts, dialog systems, sectoral strategies, long-term sustainability planning, governing bodies, communication programs, evaluation, and conflict resolution.
- Common Objectives, Criteria, Trade-offs, and Indicators: key tools for applying policy on a large scale and promoting sustainable behaviors. These include common sustainable goals at different levels, sustainability criteria for planning, explicit negotiation rules, and indicators that drive

sustainable development efforts and promote education and empowerment.

- Information and Incentives for Practical Implementation: integrated, context-adapted tools are critical for sustainability-oriented decision-making that uses information to create systems that incentivize sustainable behaviors.
- Programs for System Innovation: transitioning to innovative systems is crucial for long-term sustainability. Anticipatory governance focused on learning and innovation should revolutionize knowledge, rules, roles, linkages and organizations, with an emphasis on reflexivity.

In addition, Glass and Newig (2019) examined empirical data and theories to develop a list of characteristics, some of which overlap with those of Kemp et al. (2005), that GfS must have in order to contribute effectively to achieving the SDGs.

- Participation: intrinsic to the definition of governance, forming the basis for the development of a collaborative governance model, which is essential for tackling complex problems such as the SDGs.
- Policy Coherence: linked to the need to coordinate policies in order to harmonize the actions of different actors and achieve the overall goals.
- Reflexivity and Adaptation: previously mentioned in Kemp's typology, they are central to the development of critical self-awareness and the ability to change existing ways and behaviors.
- Democratic Institutions: elements that characterize such institutions include freedom of expression, electoral processes, access to and diverse contributions to information, recognition of civil rights, political freedom, and the power of the law.

Although there is a growing body of literature on GfS, particularly in the area of corporate governance and sustainability (Naciti et al., 2022), research in this area often neglects the human, psychological, and relational aspects of the phenomenon (Pfeffer, 2010). Baker-Shelley and colleagues (2017) conducted a study examining sustainability governance and transformation in higher education, using a comprehensive framework that encompasses the macro, meso, and micro levels of analysis. Their study highlights the complex relationships between individual behavior, organizational dynamics, and external influences at these different levels, and underlines the urgent need to pay more attention to the micro and meso levels, which are often overlooked in research (Pfeffer, 2010). Psychology emerges as a key tool to study these overlooked dimensions, especially with regard to individual behavior, organizational dynamics, and their interplay (Baker-Shelley et al., 2017).

Furthermore, the link between topics traditionally explored in psychology, such as emotions and affect, and those in WOP, such as participation and team cohesion, also extends to the macro level of interorganizational connections, as demonstrated by the research of Perkins and Nachmany (2019). This study highlights the social and emotional dynamics inherent in networking endeavors and their influence on climate governance. It suggests that recognizing the emotional and affective dimensions of participation in such initiatives can deepen our understanding of people's motivation to take climate action. Furthermore, the study highlights the importance of capturing the psychological aspects of esprit de corps and collective identity within transnational network initiatives to foster commitment, dedication, and action towards achieving national climate goals (Perkins and Nachmany, 2019).

Although several researchers argue that governance and sustainability are inherently «a very human business» (Perkins and Nachmany, 2019), ideally suited for examination through the WOP perspective, especially in the context of organizations, the discourse on GfS in the academic literature continues to emphasize mainly the managerial aspects. As a result of this trend, there is no structured collection of WOP knowledge on GfS.

2.3 Work and Organizational Psychology and Sustainability

Although WOP does not yet have a firm place in the GfS academic literature, psychology more broadly has quite a rich history in the study of sustainability and governance. Di Fabio and Rosen (2018) speak of the "psychology of sustainability and sustainable development" as a new area of research within sustainability science that contributes to the transdisciplinary approach by providing a stable, integrated, and non-occasion-specific key to interpreting phenomena from a psychological and behavioral perspective. This perspective is also fundamental with regard to environmental sustainability, as psychological processes guide and support environmental choices and behaviors, influence the diffusion of a culture of sustainability, and highlight the importance of the construction of representations and meanings related to the ecological transition (Di Fabio and Rosen, 2018).

In addition to its contribution to the scientific and research dimension, Vlek (2000) emphasizes the practical role of psychology in shaping environmental policy, especially with regard to complex long-term environmental issues. The collaboration of psychologists with scientists from other fields dealing with environmental issues is based on an awareness of the limitations and potential risks associated with the promotion of environmental policies based solely on technical or economic strategies: this awareness must therefore be acquired by local and international decision-makers in order to assess problems with an integrated approach and to design flexible and complex solutions.

Furthermore, Coglianese and Starobin (2020) emphasize the importance of social sciences, including psychology, in studying and addressing environmental policy issues.

The systematic review recently published by Freschi et al. (2023) reports on 52 studies dealing with climate change governance and psychology. The study distinguishes three main thematic clusters, each emphasizing different psychological aspects: determinants of pro-environmental behavior, individual perceptions and perspectives, and group-based processes. Key psychological theories and frameworks include the Theory of Planned Behaviour, Model of Private Proactive Adaptation to Climate Change, construal- level theory, theory of social representations, the social norm paradigm from the theory of normative conduct, and decision-making theories. Despite the extensive analysis of the relationship between psychology and sustainability, this review does not consider the contribution of WOP to GfS. Instead, it focuses on the broader contribution of psychology to addressing the challenges of climate change, making evident a lack of WOP's contributions and themes to GfS.

Just as there is a need for in-depth analysis of the micro and meso levels by psychological disciplines in the study of GfS (Baker-Shelley et al., 2017), psychological studies on sustainability also lack an examination of these levels and their interrelationships, which lends itself to analysis by WOP.

The starting point for this paper is therefore a gap in the academic literature, which lacks structured and codified attention to WOP models and dimensions, especially organizational culture and leadership, when addressing GfS issues. Currently, there is still no systematic theoretical and empirical corpus on culture and leadership for sustainability (Baumgartner, 2009; Ketprapakorn and Kantabutra, 2022), although they play an essential role in sustainable transformation. In particular, a systematic proposal that incorporates the perspective of work and organizational psychology is lacking (Sacchi et al., 2023), as evidenced by the difficulty in identifying specific contributions in the databases, even when combining different keywords. Our contribution aims to address this gap and contribute to the development of organizational thinking, research, and practice in these dimensions.

3. Organizational culture and leadership in Governance for Sustainability through the Work and Organizational Psychology lens

The importance of WOP for GfS can be seen in some of its most important fields of action: leadership, organizational behavior, organizational culture, complexity, communication, and change management, which are located at a middle – meso – level, between the micro level of individuals and the macro level of connections between organizations (Baker-Shelley et al., 2017). These objects of action and research serve as an intersection, located in organizations, between what happens in people's mental world, how they act, and how their behavior can impact society. When discussing barriers to action on climate change, it is important to consider the complex relationship between psychological tendencies, social relationships, and societal structures (Schmitt et al., 2020). Psychologists engaged in climate change action should broaden their perspective beyond individual consumer behavior and household contexts to conduct psychological research that challenges current power dynamics and opens up the potential for transformative social change (Schmitt et al., 2020). To contextualize behavior change and its effects, meso-level factors at the community or organizational level must also be considered by drawing on disciplines such as psychology and addressing areas such as governance (Newell et al., 2021).

Tackling climate change requires significant changes in behavior that go beyond individual consumer actions: individuals also act as investors, producers, and participants in emissions-intensive organizations, thereby influencing organizational decisions and political structures. However, existing behavioral models are often reductionist and individualistic and lack a broader perspective that takes into account the societal and organizational context, which requires the attention of organizational psychologists (Whitmarsh et al., 2021; Nielsen, et al., 2020).

Given the importance of GfS at the meso-level, it is therefore essential for WOP (Nielsen et al., 2020) to integrate it into its framework in order to make a meaningful contribution to sustainability and climate issues, acknowledging the complementarity between individual-oriented analyzes and the study of organizational and political actions. In our operationalization of the meso-level, represented by organizations, key WOP topics such as leadership, organizational behavior, culture, communication, and change management play a central role.

Young et al. (2015) examined pro-environmental behaviors in the workplace and identified several important variables, of which only leadership (referred to as "management support" in the study) and organizational culture closely aligned with the framework proposed in WOP. In addition, Baumgartner had pointed out in 2009 that the relationship between organizational culture, leadership and corporate sustainability is underestimated in the discussion on sustainable development. Linked to this is a lack of attention to the role of culture in sustainability by those with governance roles. On the other hand, culture would be crucial for GfS, especially if it is able to integrate sustainability values into the corporate vision and strategy.

Based on these considerations, we focus primarily on the dimension of organizational culture and leadership within organizations to understand its interplay with all other variables mentioned and their influence on the promotion of sustainable practices, fostering organizational values of sustainability, and driving change toward sustainability goals. By focusing on the dynamics of culture and leadership within organizations, WOP can effectively analyze and intervene in the complex interplay between individual behaviors, organizational structures, and social impacts to ultimately facilitate the transition to more sustainable practices in organizations and society at large.

Because of their central importance to GfS, organizational culture and leadership are the cornerstones on which we build our perspective for examining GfS through the lens of WOP. In the following sections, we draw on relevant position papers and research that address the human and relational aspects of sustainable change in the organizational context and highlight key themes for developing a self-reflection tool to guide organizations undergoing this change towards informed GfS practice. Our presentation aims to advance the discourse on GfS in WOP literature, which remains underdeveloped and lacks structure. Our proposal focuses on the topics of organizational culture and leadership and extends to other aspects of WOP, such as organizational values, complexity, organizational change, reflexivity, and inclusion, all of which are geared toward promoting GfS.

3.1. Key themes for approaching GfS from a WOP perspective

3.1.1 Organizational culture for GfS

Sustainability – also from the perspective of those who observe Organizations and Organizing, and of those who build and define them (Weick, 1992) – has the multi-layered and complex meaning of social sustainability (in relation to the socio-legal context in which it operates), environmental sustainability (in relation to the territory in which it is located), economic sustainability (in relation to its economic framework)

(Kuhlman and Farrington, 2010), and organizational sustainability in the narrower sense (in relation to the people who work in that context).

This specific content focuses on organizational sustainability and in particular on the interdependent relationship between leadership, those who exercise leadership on a daily basis, and organizational culture (Baumgartner, 2009). Namely, between the leaders (this is not just about hierarchical responsibility) who help to build, disseminate, and pass on values, «the way we work around here», and finally the assumptions that give meaning to action (Schein, 1999) and that are associated with sustainability. Organizational culture is the DNA of Weick's concept of Organizing (1992): it is generated, transmitted, and becomes an action through the concatenated and recursive behaviors of all people working in an Organizing. Culture – constantly and in every role – determines and is determined by leadership, which is expressed and accepted in daily actions (Schein, 2019). Furthermore, organizational culture is an essential part and at the same time a guiding pattern of the framework of meaning (Wieck, 1995) that people build and use on an individual, team, organizational, and even cultural and more abstract level. They need culture to explain what they do, what they see, what they want to do, and, above all, to explain their enactments, namely the changes that they take from their environment (Weick, 1992) and which are observed again.

Sustainability in this historical moment is just that: an enactment, a clue drawn from the flow of social, political, scientific, task-environment-related, and managerial-related experience, which is re-observed to create sense and meaning of each Organizing, for each Organization. We can hypothesize about the framework of Meaning that drives people to (also) extract sustainability issues – oriented by organizational culture – from their context. One of the most typical guiding patterns concerns problems of external survival (Schein, 1999, 2019) and how they are addressed and solved at a deeper level (Mission, Strategy, Objectives, Means, Error Assessment), within the assumptions related to «human relationships with nature».

This perspective allows us to observe and understand some alternative ways of dealing with the issue of sustainability. Greenwashing, for example, is an approach to adaptation problems: adapting to current trends without corresponding changes in cultural orientation or genuine sustainability-oriented measures. In these cases, the organization's mission, goals, strategies, and means remain largely unchanged, while only the image of services and products is altered. In other cases, some organizations are primarily concerned with bureaucratic compliance just to obtain sustainability certifications (e.g. ESG reports). However, there are cases where it is possible to observe changes in strategy and investments modifications, oriented to meet the social, environmental, and political (*polis*-related) demand for sustainability.

The other cultural guiding pattern that – also – guides the elaboration of sustainability is the one associated with problems of internal integration (language, borders and group identity) (Schein, 1999, 2019). Within this framework, assumptions about the «nature of authority and relationships» can be identified, primarily recalling the role of leadership (including role responsibility) in promoting, interpreting, and proposing the issue of sustainability within the organization. In a leadership culture focused on power and purpose, outcome and role (Schein, 2019), sustainability is integrated into the organizational culture, transforming it into a culture of change if it aligns with the leader's interests and objectives. In a culture of participative leadership and followership, geared towards trust and empowerment, sustainability is collectively elaborated within the organizational culture by engaging in collaborative and intentional sensemaking activities aimed at shaping the future. In organizational terms, we don't believe that the culture of sustainability can be limited to reducing document printing; instead, we believe it translates concretely into a broad and articulated journey towards a People-Oriented Organizing. This means, for example, that leaders and managers, starting with HR, must promote a talent management system that fosters diversity and talents of all employees.

Sustainability must therefore be understood through culture and promoted by leaders: sustainability leaders as leaders of cultural change and learning (Schein, 2019). Only recently, some authors have proposed a systematic reflection on an organizational theory of sustainable culture (Ketprapakorn and Kantabutra, 2022), built around the dimensions of values and beliefs, vision and communication. In summary, sustainability is interpreted and enacted in very different ways in each Organizing. Its meaning and impact vary in each context due to the unique interdependence and expression of culture and leadership. However, leadership plays a central role in organizational sustainability (Baumgartner, 2009), the discussion of which is about addressing the shift to sustainability: a new approach to solving the challenges of adaptation that encompasses both issues of external survival and internal integration.

3.1.2. GfS Leadership

Leadership is an important factor for sustainability: it influences the communication of the organization's commitment to sustainability, the development of sustainable practices, and their implementation (Epstein, 2008). Effective and consistent leadership can align organizational goals with social and environmental concerns, and the internal credibility that good leadership brings serves as a driver for the transition to a more socially and environmentally sustainable management style (Epstein, 2008). Furthermore, leadership is the organizational lever that can change the corporate culture, which in turn affects the behavior of individual employees, as well as the ability to integrate sustainability into management decisions at all levels of the organization (Epstein, 2008).

Moreover, a link between leaders' values, democratic leadership and the implementation of sustainable measures was observed in Swedish and Austrian organizations (Nedelko and Potocan, 2021). Effective and coherent leadership facilitates the harmonization of business objectives with social and environmental concerns (Epstein, 2008).

Participation is also a key element in improving sustainability, but bottom-up initiatives must be supported by top management to be legitimized and formalized (Richardson and Lynes, 2007; Lozano, 2006). Top management should make decisions related to sustainability by clarifying policy goals and timetables for action, considering development at different levels and in different contexts, setting innovative and proactive long-term goals, collaborating with scientists (Kemp and Martens, 2007), and relying on complexity and solidarity (Martínez de Anguita et al., 2007).

Leadership also has a link to GfS: it is able to drive sustainability frameworks within corporate governance, highlighting vision, mission, and leadership as key factors (E-Vahdati et al., 2018). However, leadership can also be seen as a potential weak point in establishing ethical foundations within organizations: for this reason, strong leadership – in combination with governance and ethics – is required to effectively manage the complexity of GfS (Bloomfield, 2022).

In the discourse on leadership, it is of course fundamental to focus on positive behaviors (Monzani and Van Dick, 2020) that contribute to organizational sustainability, i.e. the leadership actions that are aligned with the vision of sustainability and lead people towards this "goal". However, it is equally important to be aware that those who hold leadership roles in organizations do not always exert a positive influence: studies on destructive leadership have shown that hypercontrol, micromanagement and unsupportive behaviors, which are far from rare in organizations (Dolce et al., 2020), are associated with significant unsustainability in organizational life (Molino et al., 2019) and can be detrimental to sustainable transformation.

Numerous authors have suggested leadership traits that are conducive to sustainability. Mahran and Elamer (2023) conduct a systematic literature review to provide a comprehensive examination of the relationship between

CEO personality and environmental sustainability. Most of the studies examined were based on the Upper Echelons Theory (Hambrick, Mason, 1984), according to which the characteristics of top managers tend to influence strategic decisions at the organizational level. The 139 articles examined from the last ten years deal with demographic factors (such as age, background, and experience), aspects of compensation, and psychological characteristics (such as emotional intelligence, narcissism, humility, reflective capacity, and overconfidence). Interestingly, the empirical results show that the correlation between CEO demographic characteristics and a company's environmental performance or disclosure practices is of greatest interest.

However, there are only a limited number of studies, 18 to be exact, that look at the psychological characteristics of CEOs, suggesting that this is an area that needs to be further researched and understood. The research into the psychological traits of CEOs found that narcissism, hubris, and overconfidence were each examined in three separate studies, while traits such as aggressiveness, extraversion, emotional intelligence, humility, and reflective capacity were only examined in one study each. Further research on how psychological traits of CEOs influence environmental performance is essential for a comprehensive understanding in this area (Mahran and Elamer, 2023). Furthermore, the review does not present studies that consider leadership styles and other constructs typical of WOP, and the lack of focus on governance is evident.

When examining the leadership characteristics typical of WOP that are suitable for supporting GfS, an interesting result emerges in relation to governance of common pool resources and voluntary leadership, that is «the actions of individuals who voluntarily take the initiative to speak up and propose a course of action for the group» (Andersson et al., 2020, p. 27293). This type of unselfish leadership has proven to be effective in promoting GfS for sustainable resource management. In particular, unselfish leadership can: improve group consensus on rules; change group dynamics through enhanced information exchange, reciprocal collaboration, and trust within the group; and exert greater influence under conditions of increased biophysical and social uncertainties. This type of leadership has been particularly important for the creation and institutionalization of rules and governance in relation to sustainability (Andersson et al., 2020).

The proactive and empowering nature of voluntary leadership corresponds at the organizational level to the dynamics that often prevail in employee-owned organizations. Yetim and Gur (2023) use the instrument of interviewing leaders from such organizations to explore the development of environmentally conscious decision-making. The results show that transparency and delegated authority are key mechanisms driving environmentally conscious decision-making processes in employee-owned organizations. Thus, the first salient features that emerge from the overlap between leadership and GfS are voluntariness, unselfishness, delegation, and transparency. These elements emerged in studies dealing with non-hierarchical contexts.

Thinking about more focused leadership by the top management of an organization, meaning by the CEO, and its impact on governance, there is an interesting and counterintuitive finding regarding narcissism. In the study by Lin and colleagues (2020), a positive relationship was found between green marketing programs and narcissistic traits of the CEO. The premise was that sustainable action can be elicited by CEOs' need to enhance their image and gain attention (Petrenko et al., 2016). The empirical results showed that CEO narcissism has a significant positive impact on the implementation of the green marketing programs, with the mediation of the environmental strategy. These results are an important point of reference for decision makers involved in the implementation and governance of green marketing. While considering the negative implications of narcissism, it is important to consider that this characteristic of CEOs can encourage reflection and integration of sustainability issues. For this reason, it is important to build a governance system that guides these types of CEOs (Lin et al., 2020).

Furthermore, Lungeanu and Weber (2021) have shown that when we think about how to make companies more sustainable, we need to consider how leaders make decisions and where they put their efforts to maximize their positive impact on the world. In fact, leaders are critical to where a company puts its money, particularly on social and environmental projects. They looked at how CEOs engage in corporate social responsibility and how they donate to charity. They found that CEOs can switch their focus between these two areas to adjust their efforts to have the greatest positive impact on society and the environment (Lungeanu and Weber, 2021), resulting in balanced social and environmental sustainability.

Finally, when involved in sustainability decision-making, leaders must consider whether their organization is self-determined to implement sustainable actions (intrinsic motivation) or driven by circumstances (extrinsic motivation). Such differences in self-determination depend on the underlying psychological needs of organizations for competence, autonomy, and relatedness and are evident in leadership decisions about sustainability initiatives (Shah and Arjoon, 2015).

Thus, when thinking about leaders in organizations, it is necessary to consider both their characteristics and personal inclinations (such as narcissism, which can nevertheless be conducive to sustainability), their orientation in decision-making (which should balance the needs of the organization with different types of sustainability, depending on the circumstances of the context), and the psychological characteristics of the organization itself (e.g., intrinsic or extrinsic motivation, the needs on which it depends, and the type of governance in which it results).

GfS without leadership is therefore not enough. In our opinion, leadership makes it possible to grasp certain human and relational factors that relate to the meso level, which connect individual perception with macro-dynamics and ultimately characterize sustainability.

3.1.3. GfS Leadership's interplay with values and culture

The first and most important relationship of GfS-oriented leadership that we examine because of its prominent role in WOP is with the values and culture of the organization (Schein, 1992). Values and culture are intertwined in several famous organizational theories (Schein, 1992; Trice and Beyer, 1984), one being a subset of the other. According to Schein (1992), values represent an intermediate level of organizational culture, while Trice and Beyer (1984) refer to them as judgments of preferability with deontological valence, capable of distinguishing the right from the wrong. In the context of leadership, values therefore prove to be an important organizational element for GfS, both in the individual and collective sense of the organization.

First, some organizational studies have highlighted the influence of the values of CEOs and directors, who are considered leaders, on environmental sustainability (Prömpeler et al., 2023). The value systems fundamental to their impact on sustainability are biospheric values, which incentivize pro-environmental beliefs and actions, and egoistic values, which constrain them (Steg and Bolderdijk, et al., 2014). However, the consequences of the presence of such values can be more complex, as in the findings collected by Prömpeler et al. (2023), who examined the relationship between the values of the leaders and sustainability: counterintuitively, when the CEO was selfish, directors focused even more on sustainability, likely because directors play a critical role in monitoring the CEO's decisions from a governance perspective and therefore, when directors care about the environment, they counteract the CEO's selfishness by prioritizing sustainability more.

Shifting the focus on the collective dimension of values, we come across the issue of organizational culture and its relationship to GfS leadership. Culture is defined as «a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation or internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think and feel in relation to problems» (Schein, 1992, p. 12). To promote sustainability, it is important to understand the values that shape an organization's culture and to identify which of these values can be aligned with sustainability (Marques et al., 2021). Adebayo and colleagues (2020) point to the central role that organizational culture and values play in aligning with sustainable development: the dominant values, as reflected in culture, influence individuals' behaviors and actions, contributing to more sustainable organizational performance. In particular, sustainable organizations need to develop an organizational culture that is sensitive to social and environmental concerns (Leon, 2013), which can manifest itself, among other things, in the support of top management – leaders – for sustainability (Lo et al., 2012). Bergman and colleagues (2017), in a review of conceptualizations of corporate sustainability, describe one that refers to corporate sustainability as an ethical approach that is primarily concerned with the morality of corporate behavior, which should therefore prioritize values over profits. This view encompasses the concepts of leadership and corporate culture, as the values of individual decision-makers are reflected in the culture of their organization and determine its focus on sustainability.

The cultural change required for the implementation of GfS is therefore closely linked to the elements of leadership, values, and organizational culture (Sacchi et al., 2023), which in turn are interrelated and interdependent (Schein, 1992).

In summary, values (both personal and shared) and organizational culture are not only important for GfS, but are also related to a broader leadership orientation. Therefore, to effectively support GfS, leadership must favor a style that promotes the establishment of a culture of sustainability and pro-environmental values. The characteristics of this type of leadership and their interrelationships can and should be explored further.

3.1.4. GfS Leadership's interplay with complexity and change

The idea of sustainability implicitly and explicitly presupposes change: the change in environmental, social, and economic conditions requires a change in human systems in order to adapt. The future of humanity depends on the ability of people to make a radical and systemic change that encompasses profound values and beliefs, social behavior patterns, and the way different levels of reality are governed and managed (Westley et al., 2011).

The need for change also extends to the organizational (meso) level, where the key role of governance emerges, namely the attempt to develop a comprehensive approach that addresses the need to change thinking, tools, and methods in order to effectively manage change and implement new sustainable lifestyles (van Zeijl-Rozema et al., 2008). Change is thus both a cause and a consequence of sustainability and is framed as organizational and not just technical change at the macro level of international relations, the meso level of organizations and the micro level of individuals: in fact, if innovation only concerned the technical and technological sphere, humanity would risk increasing environmental risks, which is why such change must be accompanied by a change in thinking, decision-making, and culture (Westley et al., 2011).

The concepts of transformation and change have permeated research into approaches that are useful for the implementation of sustainability. An expression of this orientation is the proliferation of studies on sustainable transitions (Koehler et al., 2019) and transition management, which considers change in a participatory, adaptive, iterative, and forward-looking manner, proposing long-term strategies, optimizing contextual initiatives, and anticipating and adapting to tensions between change and conservation (Kemp et al., 2005; Kemp and Martens, 2007). Transition management is considered to be a suitable approach for the implementation of GfS (Loorbach, 2010; Kemp et al., 2005; Sacchi et al., 2023).

Organizational change is an important object of study in WOP, which views it as the «movement of an organization away from its present state and toward some desired future state to increase its effectiveness» (George, Jones, 2012, p. 533). In classic WOP theories, change is also associated with leadership and other organizational elements such as organizational culture and interpersonal relationships (Schein, 1992; Lewin, 1951). To achieve organizational change that leads to sustainability, an important aspect is leadership commitment (Eccles et al., 2012; Maimbo and Zadek, 2017), which together with governance can have a significant impact on organizational transformations (Doppelt, 2017). The study by Sancak (2023) has identified different phases of sustainable transformations characterized by environmental, social, and governance (ESG) factors, of which governance has the greatest influence. Leadership plays an important role in each of the described steps towards sustainable transformation.

Organizational change is therefore a figure of departure into sustainability. This change is in turn influenced and influences GfS and can be managed effectively through good leadership. However, change is only one element of the complexity that leaders must take into account when promoting GfS. Sustainability and sustainable transition are indeed a complex matter, and this is also true for research and study on sustainability (Ahuerma et al., 2018; van Kerkhoff, 2014; Peter and Swilling, 2014).

Edgar Morin (1993), a renowned philosopher and sociologist, describes complexity as the paradigm for the interpretation of today's world, from biological life to social phenomena, which «certainly cannot obey principles of intelligibility less complex than those now required for natural phenomena» (Morin, 1993, p. 11). With a WOP lens, to navigate complex systems, where complexity amplifies deviations and makes it impossible to reconstruct causal chains (Weick, 1969), it becomes essential the ability to dwell in uncertainty and lack of meaning, what Lanzara (2016) calls "negative capability".

Kirschke and Newig (2017) have addressed the complexity of sustainability issues by drawing on research in psychology and using the instrument of governance, which must prove flexible, incorporate different elements and move along a continuum of 'density', meaning the degree of rigidity of rules and information exchange. Within this framework, GfS leadership is therefore responsible for governing and navigating through complexity. In order to make effective environmental management decisions in a complex landscape such as sustainability, the multiplicity of decision makers involved must be taken into account and the different disciplines integrated to achieve coherence between the different levels of decision-making for the management of environmental issues (Martinez de Anguita et al., 2008).

Indeed, in systems characterized by complexity, traditional top-down leadership models may be less effective and leaders of complex systems need to focus on collaboration, learning and innovation of all actors in the system (McKim and Goodwin, 2021). According to McKim and Goodwin (2021), this type of complexity-oriented leadership is able to promote change and sustainable practices.

In complex situations characterized by «uncertainty, instability, uniqueness, and values conflicting» (Schon, 1983, p. 23), the usefulness of another leadership trait becomes apparent: reflexivity. The "Reflective Practitioner", theorized by Donald Schön (1983), is a professional who reflects during action or after action (reflection-in-action or reflection-on-action) on his actions and their consequences, attributing value to the process and work practices and being capable, in this way, of truly learning from their mistakes. Among the WOP themes related to leadership that prove to be useful for the promotion of GfS, reflexivity proves to be suitable to support the analysis of complexity necessary for sustainable development.

Reflexivity is also seen as a central feature of governance that is geared towards the management of sustainable development and related issues. In the view of Voß and colleagues (2006), reflexive governance has the capacity to create interactions between different rationalities, to take into account the complexity of linkages between sustainability spheres, to address the uncertainty associated with systemic dynamics, and the ambiguity of sustainability criteria. Reflexive governance models are characterized by continuous and situated learning in the course of action, rather than complete knowledge or control maximization. The authors describe reflexive strategy as «the phenomenon whereby thinking and acting regarding an object of governance also influences the subject and its governance capacity» (Voß et al., 2006).

Kemp and Martens (2007) affirm that sustainable development requires the renewal of institutional governance and that such change should be carried out using reflexive methods that anticipate problems and allow for adequate analysis of progress-oriented actions. The authors argue that governance models need to be made more reflexive to ensure that the policies implemented are truly sustainable.

In summary, complexity and change in addressing sustainability issues are key elements that need to be considered when implementing an effective GfS. Leadership that is able to promote GfS must therefore be able to deal with uncertainty and a multitude of variables in a reflexive, flexible and adaptive manner.

3.1.5 GfS Leadership's interplay with inclusion

Inclusion is a central theme in most of the SDGs, but especially in Goal 8: 'Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all', which refers to inclusion in the workplace (https://sdgs.un.org/goals). Diversity and Inclusion in the workplace are increasingly becoming the is emerging as a significant focus in both research and organizational approaches, as studies such as those by Adamson et al. (2021) show. Inclusion can also be a goal of leaders in the workplace, who can make it a priority and act as inclusive leaders. Inclusive leadership is «leadership that stimulates the exchange, discussion and utilization of employees' diverse features, as well as supporting the full participation of all employees in order to satisfy needs of individuation and belongingness» (Ashikali, 2019, p.8).

Inclusive leadership can have an impact on sustainability in a broader sense within organizations, as some studies show. Bhutto et al. (2020) see inclusive leadership as an important driver for sustainability in organizations. Their study examines the relationship between green inclusive leadership and green creativity. They found that green inclusive leadership has a positive impact on green psychological climate, green work engagement, and ultimately green creativity in both the manufacturing and service sectors. Therefore, the adoption of inclusive leadership practices can promote sustainability in organizations, especially in the tourism and hospitality industry. Elmagrhi et al. (2018) investigated the impact of governance structures on environmental performance, focusing in particular on the influence of gender diversity on the corporate board on environmental aspects improvement. Their study shows that the proportion and age of female board members have a positive impact on the overall environmental performance of companies as well as on environmental strategy, implementation, and disclosure. These findings underscore the importance of inclusive leadership, such as gender-diverse boards, for the advancement of GfS in organizations.

However, the topic of work inclusion is reminiscent of the field of social sustainability and, in particular, the sustainability of organizational life, a relevant area to WOP (Di Fabio, 2017, Molino, et al., 2019). Inclusive leadership can indeed promote career sustainability, which is characterized by individual agency, which gives meaning to the person, through the mediation of supervisor developmental feedback and thriving at work (Fang et al., 2021). According to Feng and colleagues (2021), leaders must achieve corporate sustainability by supporting employees in improving their career sustainability and recognizing individual sustainable development as a fundamental source of sustainability in both society and enterprises. Furthermore, inclusive leadership is also positively related to sustainable employability, that denotes the degree to which an individual has the ability, motivation, and opportunities to engage in work both currently and in the future (Gürbüz et al., 2022). Inclusive leadership and high-involvement HR practices are associated with sustainable employability. Furthermore, inclusive leadership and high-involvement human resource practices exhibit an indirect association with sustainable employability, mediated by the utilization of strengths at work, which are defined as inherent qualities enabling outstanding performance or optimal functioning (Gürbüz et al., 2022).

Finally, inclusive leadership is positively related to perceived insider status and negatively related to employee withdrawal, thereby enhancing sustainability in employee relationships (Shah et al., 2022).

Thus, inclusive leadership and inclusion in general can promote organizational sustainability and sustainability of organizational life, and therefore leaders who wish to implement a GfS must be mindful of promoting inclusion in their organization.

4. Conclusion

4.1. Implication for practice

Some practical conclusions can be drawn from the above issues to focus the attention of organizations not only on governance, but also on culture and leadership in order to strengthen their commitment to sustainable governance and improve the effectiveness of their actions.

First of all, as we have argued in this paper, leadership plays a critical role in governance for sustainability; therefore, great efforts in leadership development are needed. Organizations should invest in programs that specifically focus on fostering leadership skills that are aligned with sustainable governance and aim to integrate environmental, social and governance considerations into decision-making processes. Particular attention should be paid to the development of leadership styles in organizations, such as unselfish leadership, which are able to disseminate values and norms to create a culture of sustainability, responsibility and accountability. At the same time, it is important that organizations recognize the presence of destructive leadership, its antecedents and consequences, through a specific corporate analysis (Ghislieri, in press). As for the behavior of leaders, the consequences of their actions should be considered at all levels, from the environmental impact of the organizations they work for to the well-being of the people they work with (Piao et al., 2022).

Secondly, training programs should also be developed for employees to improve their understanding of sustainability, governance practices and their environmental, economic, and social impacts. In addition, sustainability could be incorporated into performance evaluations to incentivize employees and teams to engage in sustainable practices (Eccles and Serafeim, 2011). To foster the development of a sustainability culture, transparent communication both internally and externally is also necessary to build trust and encourage a shared commitment to sustainable goals among employees and stakeholders. As Taljaard and de Beer (2019) emphasize, communication plays an important role in GfS, as dialogical interaction between stakeholders in decision-making can lead to better environmental outcomes (Newig et al., 2018). Leaders promoting GfS should address communication models, while promoting sensemaking activities that allow the complexity of events to be given order, albeit partial and fragmented, and reduce the ambiguity created by the multiplicity of conflicting information in complex systems. Sensemaking helps to develop a shared ideology that can be seen as an alternative source of organizational structure (Weick, 1995). Communication and sensemaking can also be considered means of conflict resolution and negotiation and are also a fundamental part of group functioning.

Finally, as mentioned in the introduction to this paper, certifications cannot be the primary goal. However, the introduction of standardized ESG reports facilitates comparability and transparency and increases the credibility of sustainability initiatives.

4.2 Implication for research

Implications must also be described from a research perspective in order to contribute with valuable insights to the evolving field of WOP in the context of sustainability. To this end, it is necessary to build a new body of knowledge on this topic and raise awareness of the role of WOP practitioners and researchers within the scope of governance for sustainability. Indeed, there are already some contributions in the literature on how to promote sustainability in organizations, but awareness of the potential role of WOP is still lacking. Therefore, more evidence-based contributions are needed to empirically demonstrate the validity of the main dimensions of WOP in promoting sustainability at all levels. Longitudinal studies could be useful to assess the impact of governance practices for sustainability on the environment, society, organizational performance, and people's well-being over time. Case studies may be the best suited to observe the effects of sustainable actions or certain leadership approaches in specific organizational contexts. Cross-cultural studies can also be valuable, especially when examining cultural differences in perceptions and practices related to sustainable governance and gaining insights into the effectiveness of different governance approaches (Doh, and Guay, 2006). Studies should also involve employees to understand how they perceive and respond to sustainability practices (Aguinis and Glavas, 2019) and what is most effective in promoting their engagement and commitment to sustainability goals.

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The contribution of short proximity chains to the development of romania's food and nutritional security

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Abstract

Reality confirms that globalized supply, food security and especially their social dimension do not take precedence over the food and nutrition requirements of all communities in general, because the external extensions of chains and networks only pursue the efficiency of distribution, the sustainability of agri-food and nutritional products and services for profits. The regional/national agri-food potential represented by local and seasonal sources can be exploited in combination with the activities of large chains and networks in the field. The aim of the article is to better understand sustainable agri-food structures in the competitive business environment, to critically evaluate the vision of short proximity chains combined with long chains and agri-food networks. A considerable fragmentation of the food supply base, especially domestic, has an impact both upstream and downstream, on the entire processing, distribution and marketing chain of agri-food products. The effect on supply from small organizations in the field is still unclear, as they often do not have the coordinates or

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quantified influence on downstream chains and large agri-food networks, usually being disconnected from them. Food insecurity will increase due to inadequate market infrastructures and socioeconomic vulnerabilities in the most densely populated regions of the world. Global agricultural systems will be increasingly affected by the negative effect of climate change, water scarcity and price volatility The authors propose transdisciplinary collaboration in the field of food and nutrition security for Romania, with a focus on technologies that allow achieving security in the field.
Keywords: food security, short proximity chains, agri-food networks, food products
JEL Classification: I31; Q02; Q13; Q18

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Introduction

As the world's population grows and incomes rise, it is estimated that food demand will increase by 70% by 2050. However, food supply will remain relatively constant. The world population, which currently stands at over 7.8 billion (of which about 49% live in rural areas), will grow to over 9 billion by the middle of the 21st century, and this growth (about 95%) will occur in 50 of the world's least developed countries. From a nutritional point of view, it is found that 21% of the population consume more calories than necessary, 63% can eat three full meals, and 15% are malnourished.

Some manufacturing entities from developed countries provide substandard food products through exports to less developed countries, the same labels under the same brands having lower nutritional qualities.

It is also estimated that by 2050 the total EU population will reach over 515 million inhabitants, which means an increase of only 5% compared to the value in 2008. One of the countries affected by this trend is Romania, where the total population is expected to decrease by 10% compared to 2011 and reach approximately 18 million inhabitants by 2050. In terms of food demand, there will be serious implications, as limited expansion possibilities are expected on European markets.

Internationally, agri-food and nutritional product chains, as well as integrated supply networks, are dominated by large production and distribution organizations (Global supply). They practice monitoring and control through the economic criteria of efficiency, considering in real time the demand and the variation of consumer prices. In general affairs worldwide, Small and Medium Enterprises (SMEs) continue to play a predominant role in the social system, in the productive-economic and service structures (Hervás-Oliver, J.L., et al., 2021).

In the EU, more than 90% of the total companies represent productive-industrial, economic and micro-scale business entities (there are over 25 million SMEs), with almost 45 million employees (32% of the workforce) and bring a contribution of 21% added value for the European economy (Kotsios, P., 2023).

As such, micro-businesses, public policies in the food sector must no longer be researched purely descriptively, only in relation to their constituent elements, but it is necessary to systematically identify the availability of interaction between large chains and networks with local agri-food actors, at micro-scale level. For the agri-food sector in Romania, these aspects represent an opportunity as well as a challenge.

1.The purpose and objectives of the research

Mainly, the purpose of the article is to explore different understandings of small proximity chains, sustainability, especially considering sustainable development, measuring the circulation flows of aliments along the supply chain / on the value chain, emphasizing the tendency to collaborate between entities and agro-industrial sectors in Romania. In this paper we focus on the conceptualization of the proximity approach for understanding the new collaboration models in the structures of the agri-food and nutritional system in the context of ensuring food security in Romania.

The main objective of this study was to investigate the factors that contribute to the establishment of short agro-industrial chains of proximity contributing to ensuring food security. We set out to find out if the proximity situation is suitable for studying the association trends of actors in the agri-food sector. Agri-food and nutritional security in Romania aims at the conception, design, implementation, testing, development and dissemination of new proximity chains in/between localities in various areas, with effective and efficient tools, methodologies and formulas for access and participation in production and capitalization continuous production of agro-food products, meeting the nutritional levels demanded by consumers.

The facilitation and promotion of access to and participation in the agri-food processes of SMEs, chains and networks is carried out with the aim of obtaining, processing and valorizing by them some products with maximum nutritional values, to which is added the awareness, information and dissemination of the benefits, of the optimal and efficient formulas of a methodological nature for the integrated operation in the field.

The purpose of the proposal for the formation of short proximity agri-food chains in Romania is to determine the tendency of different actors and local entities to interact in the long term, through commitments directly related to the national agri-food business environment, supported by viable public policies, visions and sustainable applications.

The development of a category of medium-sized agricultural holdings and local agri-food processors must be through actions that stimulate capital formation through increased access to both the market and financing. Various limitations are considered obstacles that small farmers and agro-processing entities are currently facing.

The development of local producer groups for the processing of raw materials, as well as the creation of short food chains, will help farms to integrate more easily into the national and European market. In this regard, investments in the development of local infrastructure and marketing networks are imperative. It is important for local producers in Romania to plan their supply and adapt to market demand (quantity, rhythm, quality and short delivery times, compliance with traceability principles, etc.) given the trend of concentration of the supply of agri-food products at EU level.

Our recommendation is to correlate the need to prepare the process of combining with the technological changes given by the dynamics of companies in the field, the trends and the impact of ethnic progress.

We emphasize that it is necessary to change the mentality in terms of managerial training regarding the importance of short proximity chains for their complementary or combined operation with long chains and agri-food networks that are currently dominant in the business environment on a national and global level.

2. Review of the scientific literature

In general, the specialized literature examines the structures and role of agri-food chains, including short proximity ones, with reference to: a) food delivery, b) activation of delivery systems and c) the use of a multitude of criteria for control and monitoring processes in the field. Martens, K., et al. (2023), points out that the current agri-food system still belongs to public and private national and transnational entities, which are rigid institutions, they pursue a relatively strict supply only by themselves, only sufficient with food for consumption. It is found that the inter-organizational and logistic proximity (Twaróg S., Wronka-Pośpiech M., 2023), is a subject that highlights the theoretical and practical implications arising from the research of the modern agri-food field, while short supply chains reposition themselves in the turbulent global environment, characterized by exogenous productive-economic influences, unstable and uncertain economic conditions (Tsoulfas G. et al., 2023).

Gori F., Castellini A. (2023), highlights that short supply chains connect producers with food consumers more directly, thus registering a minimum number of intermediaries. Some research on the environmental impact of short food supply chains focuses on assessing greenhouse gas emissions when consumers are directly connected to local farmers (more intensive transport, larger size and number of local food hubs, additional processing processes, preserving the quality of food products along the entire supply chain) (Cui Y. et al., 2027).

Favargiotti, S., et al., (2024), bring into analysis the "analytical hierarchy" process, using decisions with several criteria for logistics, distribution mode and the dynamic climate of food production in a local, decentralized profile, and Cole M.B. et al., (2018), report on local opportunities to reduce food loss and waste. The authors link food security to agricultural productivity, food safety, health and nutrition, processing and short supply chain efficiency. At the same time, it is recognized that digitization, information technology has the potential to integrate and connect the different steps in the short chain of supply, production, processing, distribution and consumption of foods with high nutritional value, all viewed as a combined cross-functional approach (Krupitzer C. and Stein A., 2023).

Food and nutrition insecurity, according to Mrabet R. (2023), is also influenced by climate change disrupting the total supply chain, and Gupta R. and Shankar R. (2024), points out that the operational inadequacies of poor security in the field are given at the local level by disorganized interactions between stakeholders in the food supply chain, which affect the social, economic, environmental aspects of a nation. Therefore, through their study, the authors conclude that it is appropriate to use the blockchain in the implementation of the food traceability system.

Many studies suggest that new ways of transformation are needed for the food and nutrition security system, by resorting to bioeconomy, ecological agriculture, digitization, agro-ecology, along with the calibration of the relationships between the agri-food chains of food production, distribution and consumption.

3. Characterization of Romania's agri-food and nutritional security

The agri-food sector and agriculture in Romania play an important role, in relation to employment and the size of the rural population. Compared to EU member states where 23.6% of the population lives in rural areas, in Romania the proportion is approximately 45.7% and 30% of the population is employed in agriculture, compared to only 2% in EU member states (Leoveanu-Soare B.E. et al., 2020). Agricultural lands occupy almost 62% of Romania's surface (2/3 of this is arable). Compared to the other EU member states, Romania is notable for a large gap in the ratio between the number of large and small farms, as well as for, the share of subsistence/semi-subsistence agriculture, and comparatively it has the most pronounced structural division of agricultural land.

The structure of farms analyzed according to their economic size highlights the underutilization of local agricultural potential for the production of food products. Farmers' prosperity is influenced by long distribution chains that place farmers in a captive relationship between their suppliers and customers. The interposition of at least two intermediaries between the producer and the consumer (wholesaler + retailer) in current practice determines an inequitable distribution of benefits, with a smaller proportion reaching farmers. This inefficiency directly influences the productivity and motivation to invest of farmers, mainly those with semi-subsistence farms. Farms with a standard production of less than 2,000 Euros are common, and 50% of the total standard production is obtained by farms that generate less than 8,000 Euros annually.

Between 2005 and 2023, Romanian agriculture shrank by 400,000 farms. The number of young farm managers increased (compared to 2005 when only 17% of farmers were under 45, between 2005 and 2023 the share increased to 23%). However, the average farm size registered a modest increase (from 3.11 ha in 2002 to 3.6 ha in 2023). For the main agricultural products in Romania, average agricultural yields are only 1/3 or ½ of those recorded in the EU: 2.6 t/ha for wheat, compared to 6.1 t/ha, 3.2 t/ha, compared to 8.7 t/ha for corn and 1.3 t/ha, compared to 2.4 t/ha for oilseeds.

For products of animal origin, yields are reduced (for example, for dairy products 2.9 t/ animal in Romania compared to 6 in the EU) (De Moura G.B., Saroli L.G., 2021).

Current milk production is mostly carried out in about 800 thousand farms that have a staff of only 1 or 2 cows (and the standards are met by only 80% of raw milk).

It is estimated that climate change in the medium and long term will affect Romania more and more, especially its agricultural sector. In Romania, the food industry with a turnover of 9.7 billion Euros is among the largest manufacturing sectors and with 186 thousand employees becomes the most important employer. Registered agri-food companies operating in the food industry in 2023, accumulated about 7-8% of Romania's total exports (Andrei T. et al., 2023).

Before and after joining the European Union, perhaps the most important challenge of the Romanian agri-food sector was compliance with European nutritional standards for food safety and quality, throughout the agri-food chain (a major impact was in the meat and milk industry because the standards are stricter).

The degree of utilization of processing capacity for animal products was low due to fragmented demand (the local industry processing only 22% of total milk production). As for the meat industry, it is faced with both considerable fragmentation and a lack of processing capacity (there is a lack of specialized slaughterhouses). In family households, pig breeding is predominant and only 47% of total pig production reaches the agri-food chain. In the last 10 years, thanks to major investments from programs offered by foreign investors, modern agri-food product chains have developed rapidly. Foreign retailers have also made large investments in supermarkets and other forms of retail. Unable to keep up with the demands of the standards, some small processing units have ceased operations because they could not cope with the rising prices of primary resources or ran out of raw materials.

The insufficient promotion of local food products has causes, such as: the difficulty of supplying large and constant volumes, the variable quality of food over longer periods of time, the weak presence of some domestic distributors on the international market, unconvincing or non-existent branding in the field (Speciality Traditional Guaranteed /STG, Protected Designation of Origin /PDO, Protected Geographical Indication /IGP, certification, etc.).

In fact, the essential cause of these non-fulfilments is given by the weak association between producers. The intelligent and sustainable exploitation of the agri-food potential in Romania is based on the European financial programming 2014-2020, as a commitment to contribute to the achievement of the CAP (Common Agricultural Policy).

Compared to the basic reference of 100% for Romania, statistical data confirmed by opinions collected between March 2021 and April 2022 based on questionnaires from 39 managers in the local agri-food sector are identified (Table 1).

In Romania, 35 billion Euros/year are spent on the procurement of food and consumer goods, of which 73% go to the most important chains on the market with foreign ownership. Some large chains, which already use Artificial Intelligence (AI) to avoid food waste, (Ștefan I., 2024), are creating proximity stores in Romania for the aggressive coverage of secondary areas: Carrefour has 162 stores proximity, Mega Image 518, Auchan has 382, Metro has the La Doi Pași franchise with over 2,300 stores (Dragomir A., 2023). A number of only 10 entities with Romanian capital have a market share of only 2-3%, while the rural environment with agri-food production is seriously ignored by retail conglomerates that operate mainly in urban areas.

Table 1 - Statistical data and confirmation opinions through assessments regarding the economic-productive environment related to agri-food structures in Romania (%)

Priority	Consolidation of land, farms and the elimination of constraints on the land market	34,4
	Capitalizing on the country's agricultural potential	22,1
	Reducing rural poverty	16,5
Competitiveness	Regionally specific products	19,5
	Agri-food chains – through the development of associative forms (market organizations and associations)	14,1
	Intensification of production, (paying attention to animal husbandry)	10,6
Constraints in rural space	Insufficient access to financing	44,9
	Land fragmentation	14,7
	The aging population	11,5
	Lack of skills	9,33
Rural poverty	Lack of employment opportunities	30,1
	Reduced access to credits for productive activities	27,8
	Aging of the rural population	22,8
Institutional and policy framework	Cooperation between farmers	30,8
	The efficiency of the agricultural/agri-food administration	26,2
	Modernization through research-education and consulting services in the rural environment	23,4

Source: systematization of data from INS Bucharest, 2022; responses from questionnaires

It is concluded that local entrepreneurship needs support for the development of retail networks (Deleanu C., 2024). Romania has more than 4,500 hypermarkets, supermarkets, stores for trade and about 32,000 companies of retail activities in small grocery stores through chains and local retail networks.

4. Data description and methodology

For food and nutritional security in Romania and on the European level, there is a need to define some forms of collective action, to evaluate and implement the combination of large agri-food chains and networks with short regional, local agri-food proximities chains. In fact, it is a coordinated alignment of commitments to include SMEs (even independent ones) in the sustainable, quasi-complete environment of agri-food and nutritional businesses under operational incidences through marketing carried out by public, private governmental actors or non-governmental associations in the field.

SMEs in the agri-food sector are, as a rule, autonomous, have individual management based on independent thinking, own motivations and direction for mutual recognition between entities, lifestyle and family orientation.

The present research is based on the study of data from the official statistics in the field, the processing and interpretation of the answers from 39 decision-making managers and strategy developers regarding the content, role and significance of short chains in the formalization of food security in Romania, the methodological evaluation of the process of forming these chains, respectively the order-of-magnitude proposal regarding their configuration in the 8 development regions of the country. We find, however, that short proximity chains are permissive to external coordination when a framework is created in which they operate resiliently, capitalizing efficiently and accelerated their own production.

The attempt to engage domestic agri-food SMEs in the sense of collaboration with large chains and agri-food networks represents the practical challenge of a top-down approach (government policies, subsidies) but especially from the bottom up (associations, incubators, parks processing technologies, procurement and distribution groups, etc.). Often, tender requests capture the potential of SMEs or the collective potential of independent entities for common visions regarding agri-food and nutritional security (with examples from Romania through Râureni, Topoloveni, Napolact, Covalact, Albalact, Unicarm, Agricola, Vincom, Boromir, Argus, Avicola, Dobrogea etc.).

In fact, strategists and practitioners, based on the conclusions of this article, can resort to sustainable collaboration through exercises of bottom-up centralization, interconnection, loose organizational and activity object articulations for valorization and gratification in food proximity. local markets in the field.

As such, it is fully justified to investigate the multitude of forms of commitments for the establishment of short chains of agro-industrial and nutritional proximity for the largest and densest possible territorial coverage of markets with additional local resources generating, in essence, the collective competitiveness of the field.

5. Results and discussion

5.1. Architecture proposal and ordering of short agri-food proximity chains

Food production/processing is mainly found in rural areas, so the proximity approach is natural for the conceptual study of social innovation processes, for the promotion of local public-private collaboration models. As such, we suggest that policy makers and practitioners resort to alternative strategies to promote short proximity chains for obtaining and capitalizing on local food products.

With this paper, we contribute by adding value to knowledge at multiple levels, create a rationale for considering and promoting short proximity agri-food chains, and define the capacity for organizational rethinking through associations.

It is necessary to generate the climate of success through which different actors are together and thus mastery of the emerging challenges for food security is envisioned. Considering the oscillatory cycles with limited frequencies and amplitudes for the short chains of production and agro-food exploitation in the economic environment in Romania, we found that, in the context, spontaneous synchronizations appear that represent the premises for the formalization of at least a local network, of proximity between the entities new or existing ones.

Functional oscillations take place according to directions related to reference systems, characterized by circumstances (type of food products and demand), by the lack of agri-food and nutritional security, with moments, reduced or increased speed for the initial phase of the local network body. In this way, the pre-clusterization of the local agri-food environment, respectively the relational concentration, is produced, which contributes to the construction of the network of short proximity chains in the field (fig. 1).

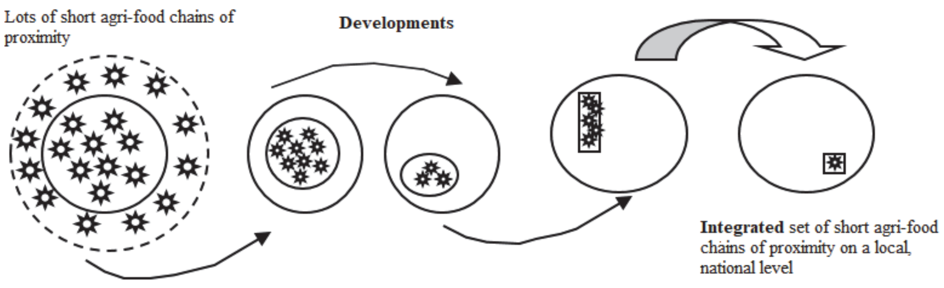

Figure 1 - Relational concentrations of short proximity chains for formation of local agro-food networks
Source: authors, processing after Gâf-Deac, I.I, 2010

In the initial architecture of the network, the fixed points or those with fixed stability are identified, respectively the locations in/between which entities of agrarian culture and product processing can be found, and the local plan offers the levels of concentration (attractiveness) that suggest links (connections). The maximum relevance for each chain results from the examination of the collective network behavior, respectively highlighting the ability of the processors to participate resiliently in generalizations for activities of distribution and valorization of local products on the agri-food markets.

A proximity chain is considered in a static state when each point (node) is fixed/stable and does not present more attraction capacity. Agri-food nodes/locations are in this type of state when they are in the coexistence phase. The local network dominated by uncertain stable equilibrium is considered frustrating for large agri-food chains. If a node (point/location, processor) has the potential of attraction through increasingly amplified operations, the state of the network in that area is dynamic, and the connections contribute to the more stable formalization of the local network architecture. With the help of this type of networks, synchronizations are achieved from operational symmetries and asymmetries, food processing and valorization applications being found in multidirectional flows in the local area.

The ordering of the architecture represents the operational goal of the specific management in the field of short, proximity agri-food chain networks (fig. 2).

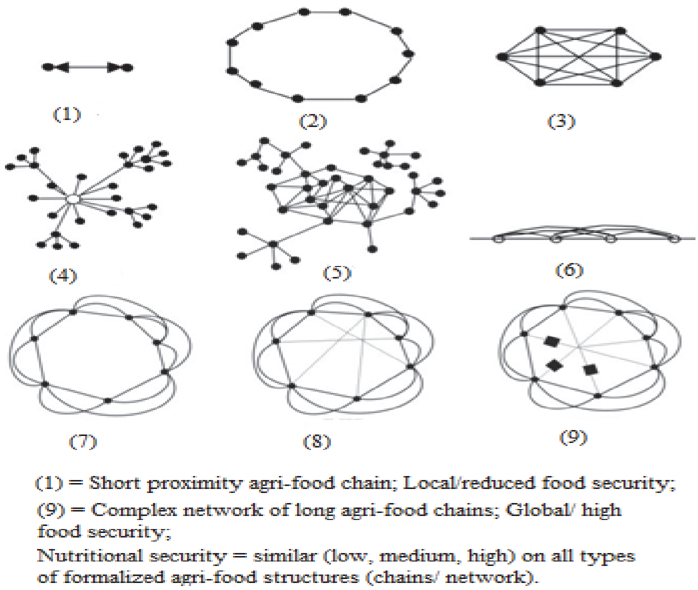

Fig. 2 - The formation of networks of short local proximity chains with multivalent architecture, favorable to complementarity and/or their inclusion in long chains and large agri-food networks
Source: the authors, after Gâf-Deac, I.I, 2010

To solve network problems, we suggest using the *probability density* and the parameters to express the self-consistency of the respective network. By using *ordered graphs,* considering a number N of locations/agri-food entities, they can have *n* potential links with other entities in the field, in which case $(1/2N \cdot n)$ there are links between the number of SMEs considered in relation to the whole set of SMEs from Romania.

For a number S of degrees of separation between all N locations/agri-food entities, it follows that:

$$n^S = N \quad (1)$$

$$S = \log N / \log n \quad (2)$$

which shows that there is a logarithmic increase in the number of degrees of separation in relation to the size of the network.

Equally, the suggested cluster areas can be expressed in the form of complex networks. It is thus possible to form different types of networks including specificities for local and overall agri-food production and utilization. Such a vision confirms that short proximity chains in the agri-food and nutritional field can be found, after all, in a *complex social business network*, real and all-encompassing, with holistic contributions to food and nutritional security for human communities in Romania and in Europe.

6.2 Network effects and applications of short proximity chains in the structure of food security in Romania

The ratios/relationships between two nodes (local agri-food processing entities) in a large chain or complex network show that in the process of establishing links, the sources of errors cannot be eliminated (*there are no pure links*). Between a processor and another agri-food processor, the local or global business environment intervenes, "screens" that represent relational "intermediaries" for food products.

We believe that short proximity chains contribute decisively to the expansion and consolidation of the agri-food market, to reaching the level of food security considered a commendable, required, imposed value (Fig. 3).

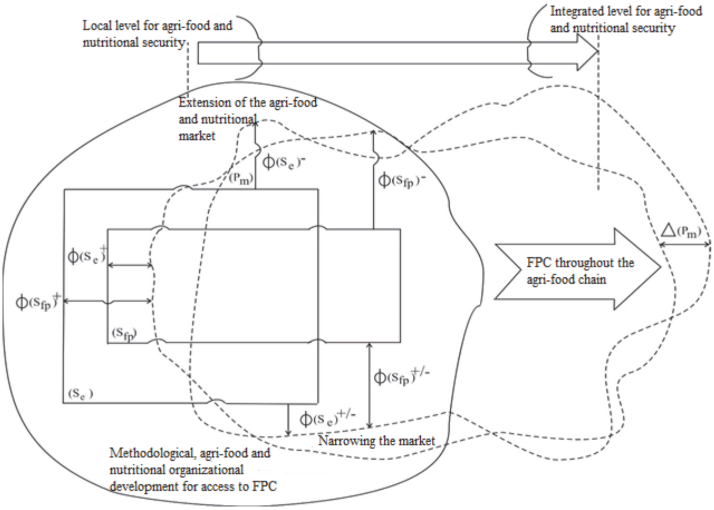

Fig. 3 - The expansion of the agri-food market and developments towards ensuring food security in Romania
Source: authors, 2023

(P_m) = the local/global market of food products with nutritional content;
(S_e) = knowledge system of short proximity chain, long chain and network concepts;
(S_{fp}) = the professional training system for establishing short proximity agro-food chains;
$\Delta(P_n)$ = dynamics of the local/global market of food products with nutritional content;
$\Phi(S_e)^+$; $\Phi(S_{fp})^+$ = positive correlations of the knowledge system, respectively of the professional training system and the food market;
$\Phi(S_e)^+$; $\Phi(S_{fp})^-$ = negative correlations of the knowledge system, respectively of the professional training system and the food market;
$\Phi(S_e)^{+/-}$; $\Phi(S_{fp})^{-/+}$ = mixed correlations of the knowledge system, respectively of the professional training system and the food market.

In the agro-food processing industry in Romania, the increase in the number of short proximity chains has the potential for operationalization on a multitude of 12,585 companies with over 148 thousand employees (Table 2).

The main observation is that the production of bakery products and flour products has the largest number of companies, and the production, processing and preservation of meat and meat products has the largest number of employees (Fig. 4).

Table 2 - The potential of the agro-food processing industry in Romania for processing operations of forming short local chains

Code	Number of companies	Number of employees	Specifications
101	1.126	43.425	Production, processing and preservation of meat and meat products
102	65	1.630	Processing and preservation of fish, shellfish and molluscs
103	1.158	5.255	Processing and preservation of fruits and vegetables
104	157	3.176	Manufacture of vegetable and animal oils and fats
105	727	10.058	Manufacture of dairy products
106	666	6.835	Manufacturing of milling products, of starch
107	7.026	61.803	Manufacture of bakery products and flour products
108	1.428	12.884	Manufacture of other food products
109	232	1.670	Manufacture of preparations for animal feed

Source: from INS Bucharest data, 2024

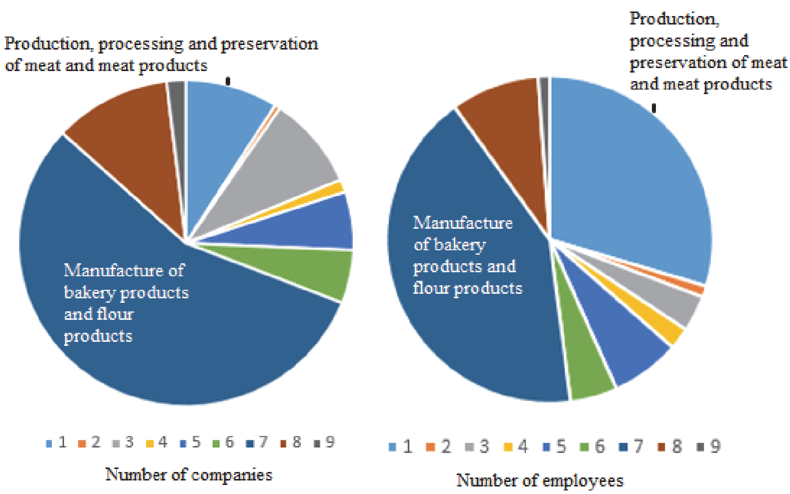

Fig. 4 - The areas with the most significant valences for the formation of short chains of local agro-food processing, of proximity in Romania
Source: processing carried out by the authors according to INS Bucharest, 2024

From field observations, researching the responses of decision-makers, producers, processors and consumers in the agri-food environment in Romania (interviews in 2023-2024), it follows that the proximity approach has simultaneous influences, without excluding each other, factors such as: a) geographical distances, b) local social similarities and differences, c) institutional complementarities, d) levels of mutual knowledge between entities and d) perspectives organizational. We found from the answers that the identification of short chains of proximity has the highest importance weight coefficient (0.88) for the specific category “Participants” (the essential condition of the existence of participants for expressions of interest is met).

The most relevant obstacle (difficulties) comes from the need for “Complementarity with the dominant large chain networks” (coefficient 0.24, the lowest in terms of optimism among the total coefficients obtained from the interview responses) (Table 3).

Table 3 - The matrix of the formalization of short chains of proximity and appreciations through importance coefficients from the answers to the interviews with decision-makers, strategists and practitioners in the field

1. Identification of short proximity chains	1.1 Participants	1.2 Commitments					
	(+)	(+)					
	.88	.79					
2. Formation of short proximity chains	2.1 Chain definition	2.2 Complementarities with large chains	2.3 Complementarities with large networks				
	(+)/(-)	(+)	(-)				
	.53	.67	.24				
3. Driving the implementation of commitments	3.1 Selection of large chains	3.2 Common understandings of articulation/ complementarity	3.3 Application of commitments	3.4 Commitment report	3.5 Lessons learned		
	(+)/(-)	(+)/(-)/(-)	(+)/(-)	(+)	(+)		
	.57	.50/ .48	.56	.67	.79		
4. Specific management	4.1 Critical report		4.2 Guide to making commitments	4.3 Collective learning		4.4. Diagnostics	4.5. Critical evaluation
	(-)		(+)/(-)	(+)		(+)	(+)/(-)
	.39		.55	.66		.69	.58
		4.1.1 Collaboration Instructions			4.3.1 Best practices		4.5.1 Social innovation
		(+)/(-)			(+)/(-)		(-)/(+)
		.59			.51		.49/ .50

5. Communication	5.1 Communication plan	5.2. Communication tools	5.3 Stakeholder meetings	5.4. Cooperation/collaboration with other fields in the economic environment			
	(+)/(-)	(+)/(-)	(+)	(-)/(+)			
	.59	.55	.89	-48/ .50			
6. Interpretation/dissemination	6.1 Exploitation/dissemi-nation operation plan	6.2. Dissemination materials	6.3. Dissemination/ learning events	6.4. Specific guidelines	6.5 Replica-tion/multi-plication formulas		
	(-)/(+)	(+)/(-)	(+)	(+)	(-)/(+)		
	-49/ .51		.78	.79	.46/ .50		

Source: authors, 2023-2024

Participants, engagements, complementarities with large chains, engagement report, lessons learned, diagnosis, collective learning, stakeholder meetings, dissemination/learning events and specific guidelines have specific direct inputs on decisions to establish short proximity chains. Exemplary cases encountered in the south of Romania, in the Bărăgan Plain, show that between two neighboring/adjacent territorial administrative locations, proximity complementarities, aspirations and similar visions for the production and valorization of food products are shared, which motivates the proposals collected from the responses aimed at establishing short proximity chains in the development regions of Romania. (Table 4)

The significant finding from our scientific investigations shows that starting from 2025, in the early phase, on the national territory it is possible to highlight a number of 49 agri-food SME brands that can be operational on the surfaces of 93 groups of agro-food culture characterized by trust. If production and consumption take place in different, often widely dispersed locations, this aspect is perceived as an obstacle to shortening food value chains. Farmers and processors still tend to prefer individualism and independent action when their businesses are in the public concern. However, when other business opportunities arise, the actors in question are inclined to join collectively organized institutions that accept the shortening of food value chains.

In Romania, we believe that it is necessary to increase the level of awareness of the problem of establishing local food strategies, together with the dramatic increase in the demand for high-quality food products.

Table 4 Proposals identified for the establishment of short proximity chains in the Development Regions of Romania

Proposed areas for the formation of short proximity agri-food chains								
	Region North-East, 30.949 km². 3.674.367 people	**Region West** 32.034 km². 1.958.648 people	**Region North-West** 34.159 km². 2.740.064 people	**Region Center** 34.100 km². 2.523.021 people	**Region South-East** 35.770 km². 2.848.291 people	**Region Muntenia – South** 34.450 km². 3.379.406 people	**Region Bucureşti-Ilfov** 1.821 km²/ 2.226.457 people	**Region South-West Oltenia** 31.211 km². 2.330.792 people
A. Mediators/ Triggers of short proximity agri-food chains								
1	6	9	3	4	6	9	4	5
2	11	14	7	7	9	11	7	8
3	3	3	2	2	3	3	5	3
4	2	2	2	2	3	3	2	2
1= Identification of agri-food SME brands; 2 = Spin-off for new brands; 3 = Learning specific marketing through forums for products, processing and selling; 4 = Research for the new collective procedural state (from chain links)								
B. Agro-industrial and nutritional environment to support the joint operation of large chains and networks with short proximity chains								
1	18	19	8	7	11	13	8	11
2	4	2	2	2	3	4	2	3
3	2	2	2	1	3	2	3	1
4	6	7	4	3	8	8	5	6
5	2	2	2	2	2	2	2	2
6	2	3	3	2	3	3	4	3
7	1	2	2	1	3	2	4	2
1 = Agri-food culture groups characterized by trust; 2 = Interaction with other factors outside the business environment; 3 = Informal events (fairs, exhibitions, etc.); 4 = Joint promotion of food products; 5 = Subsidies, tax breaks, local circumstances; 6 = Associated food services; 7 = Association and sharing resources.								

Source: authors, 2023-2024

Conclusions

Small and medium-sized agri-food enterprises in Romania must quickly become important targets for public policies and local business practices with an impact on the national economy. The weak presence or lack of short proximity chains formed by entities with local agri-food micro-businesses shows the lack of sustainable food and nutritional security in Romania, the need to resort to food imports with often substandard nutritional characteristics.

The independent agri-food SMEs and associated local enterprises, not really and sufficiently incorporated in the national effort to increase their individual adaptation capacity, determine food insecurity and cause the risks of not maintaining the sustainable collective competitiveness of the field in Romania. The formation and commissioning of short proximity chains leads to the increase of the capacities and capabilities of local agri-food entities for their self-organization at the micro-scale, the operation amplified with collective resources, increases the predisposition to cooperate with each other, dysfunctions are more easily identified resorting to critical analysis of existing best practices. Typically, impact criteria from activities in agri-food chains are recognized and future policy directions are indicated.

Romania, through the ports on the Black Sea and the Danube, has easier access to world markets, the strong domestic demand is only partially satisfied by national production and imports of processed food products are practiced. Also, among the European countries with the most favorable soil and climatic conditions, Romania has a favorable potential for obtaining quality agri-food production in sufficient quantity to cover domestic demand.

For small producers, it is necessary to stimulate association and improve access to loans for investments, to regain the status of net agri-food exporter. In this way, the spatial distribution of agricultural product processing units on short proximity chains attests to the model of secure supply sources, significantly functional food security at the local and national levels.

The authors recommend that central and territorial government decision-makers formulate sets of instructions for the development of commitments for collaboration between agri-food entities in chains, guidelines for the application of good practices of interaction of chains and networks, collective learning, diagnostics for sustainable actions of competitive collaboration, critical assessment of social innovation investments and policies.

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...Un orologio, metafora del tempo, scandisce l'inizio di una sequenza catartica...
I valori, la conoscenza, la partecipazione e l'ambiente come i meccanismi di un orologio antico sono a vista, correlati e perfettamente sincronizzati tra di loro, e come gli ingranaggi di un meccanismo funzionante essi sono posti a sostegno del futuro dei giovani.
È così che il volto del giovane, ormai uomo, reso forte ed ottimista per la conoscenza acquisita, guarda verso il futuro, verso i suoi obiettivi, qui rappresentati dalla stella e dall'orizzonte: egli è pensoso ma anche sereno, poichè è certo di poterli raggiungere.
L'elemento acqua-mare, sintetizzato con due lievi onde marine, è l'ambiente ideale in cui tutti vorremmo perderci entro una dimensione temporale illimitata che va oltre la realtà.

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