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CONTENT

MULTI-ENVIRONMENT EVALUATION OF BARLEY (*HORDEUM VULGARE* L.) GENOTYPES FOR YIELD PERFORMANCE AND AGRONOMIC TRAITS ACROSS EIGHT ROMANIAN EXPERIMENTAL SITES

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Abstract

Barley (*Hordeum vulgare* L.) is a crucial cereal crop for food security and agricultural sustainability. Climate variability significantly impacts crop performance, requiring a comprehensive evaluation of genotype responses to diverse environmental conditions. This study aimed to evaluate barley genotype performance across multiple Romanian environments under variable climatic conditions and identify agronomic traits associated with yield stability and adaptation. The experimental period was characterised by significant climatic variations, with temperatures averaging 3.4°C above long-term means and rainfall below multiannual averages for 6 experimental locations. Monthly average temperatures ranged from -1.8°C to 26.1°C, while rainfall varied from 0.3 to 147.2 mm, creating diverse stress conditions for crop evaluation. Twenty-five barley genotypes (15 winter 6-row barley varieties and 10 winter 2-row barley varieties), including 14 commercial cultivars, 11 advanced breeding lines (of which 5 are obtained using the pedigree method and 6 using the *bulbosum* method were evaluated using a randomised complete block design with three replications per location. Six key agronomic traits were assessed: grain yield (kg/ha), thousand grain weight (g), spike density per square meter, number of grains per spike, grain weight per spike (g), and plant height (cm). Grain yield varied significantly across genotypes and locations (3518-10664 kg/ha, average 6754 kg/ha). Caracal (7639 kg/ha) and Valul lui Traian (7516 kg/ha) were the most productive sites, while Livada (5421 kg/ha) and Turda (5908 kg/ha) showed lower yields due to climatic stress. Key yield determinants were thousand kernel weight (r = 0.34), spike density (r = 0.28), and grains per spike (r = 0.42).

Multi-location testing revealed significant genotype × environment × climate interactions. Several genotypes showed climate resilience with stable yields under temperature stress and irregular rainfall. Advanced breeding lines demonstrated superior adaptation to climatic stress compared to commercial varieties, making them valuable for future breeding programs.

Keywords: *Hordeum vulgare*, climate variability, multi-environment trial, genotype and environment interaction, climate conditions, yield stability, Romanian agriculture

Barley (*Hordeum vulgare* L.) ranks as the fourth most important cereal crop globally, with production exceeding 145 million tonnes in 2023 and cultivation spanning diverse agro-ecological zones (https://www.fao.org/faostat/en/#data/QCL). Its remarkable adaptability to marginal environments, drought tolerance, and shorter growing season compared to other cereals make it a strategic crop for food security and agricultural sustainability (Dawson *et al*., 2015; Mwando *et al*., 2020).

In Romania, barley represents a significant component of the national agricultural economy, cultivated on approximately 516,22 hectares, with production predominantly focused on both feed and malting quality traits (Eurostat, 2025).

Climate change poses unprecedented challenges to cereal production worldwide, with

[1] National Agricultural Research and Development Institute Fundulea,
[2] Agricultural Research and Development Station Turda,
[3] Agricultural Research and Development Station Livada,
[4] Agricultural Research and Development Station Secuieni,
[5] Agricultural Research and Development Station Valul lui Traian,
[6] Agricultural Research and Development Station Teleorman,
[7] Agricultural Research and Development Station Caracal, [8] Agricultural Research and Development Station Brăila

increasing temperatures, erratic rainfall patterns, and more frequent extreme weather events directly impacting crop productivity (IPCC, 2023). These climatic shifts necessitate the development and deployment of resilient crop varieties capable of maintaining stable yields under variable environmental conditions (Ceccarelli *et al*., 2010). Multi-environment trials have become indispensable tools in plant breeding programs, enabling the comprehensive evaluation of genotype × environment (G×E) interactions and the identification of broadly adapted or specifically adapted cultivars (Yan and Kang, 2003; Gauch, 2013).

In Romania, the diversity of soil types, topography, and climatic conditions across agricultural regions creates distinct mega-environments that significantly influence barley performance (Săulescu and Săulescu, 2014). Understanding genotype adaptation patterns across these environments is crucial for developing location-specific variety recommendations and optimizing breeding strategies (Cooper *et al*., 2014).

Previous studies have demonstrated substantial G×E interactions in barley across European environments, emphasizing the need for extensive multi-location testing to identify stable, high-yielding genotypes (Mohammadi *et al*., 2015; Przystalski *et al.,* 2008). The agronomic traits contributing to yield stability and productivity—including, plant height, spike characteristics, and kernel weight—exhibit complex inheritance patterns and are significantly influenced by environmental factors (Akar *et al*., 2020).

Correlation analysis between yield and its components provides valuable insights for indirect selection strategies and helps breeders identify trait combinations that enhance overall performance (Ullrich, 2011). Understanding these relationships under diverse environmental conditions is essential for developing climate-resilient varieties.

MATERIAL AND METHOD

This study aimed to evaluate the yield performance and key agronomic traits of 25 barley genotypes (15 winter 6-row barley genotypes and 10 winter 2-row barley genotypes) across eight experimental sites in Romania during the 2023-2024 growing season. Specific objectives were to: assess genotype performance and stability across diverse environments, quantify genotype × environment interactions for yield and agronomic traits, identify superior genotypes combining high yield potential with adaptation to local conditions, and determine trait associations that contribute to yield performance under variable climatic conditions. The findings will contribute to barley breeding programs by identifying promising genetic materials and providing insights into adaptation mechanisms relevant for future variety development under changing climatic scenarios.

Table 1

Sowing date and soil type for 8 experimental sites

Location	Sowing date	Soil Type	Ph (%)
Fundulea	19.10.2023	Cambic chernozem	6,3-6,8
Turda	18.10.2023	Chernozem	5,8
Livada	9.10.2023	Alluvial soils	5,2
Secuieni	19.10.2023	Cambic chernozem	5,5
Valul lui Traian	19.10.2023	Cambic chernozem	7,5-8,2
Teleorman	17.10.2023	Chernozem	6,5-7
Caracal	18.10.2023	Cambic chernozem	5,4
Brăila	9.10.2023	alluvial soils	7,9-8,4

Table 2

Harvesting plot area

Location	Harvesting plot area (m^2)
Fundulea	4.5
Turda	5
Secuieni	10
Brăila	10
Valul lui Traian	5
Teleorman	5
Caracal	5
Livada	10

During the year of experimentation (2023-2024), at each location, the barley cultivation technology was a classical one, similar to the usual technology practiced on barley-growing farms in Romania (including seedbed preparation, nitrogen-based fertilizer application in spring, weed control, and the application of at least one foliar treatment).

The sowing density was 350 germinable seeds/m², row spacing was 12.5 cm, and sowing depth was 2-3 cm at all experimental locations, to achieve uniform emergence of the experimental plots.

Photo 1. **Experimental plots at NARDI Fundulea (2023-2024)**

The plots were harvested with a combine, and the harvesting area varied according to location (*table 2, photo 1*). The yield was weighted, and the correction factor was used to be expressed at 14% moisture for each plot in every 8 experimental sites, then reported in kg/ha.

After the yield was assessed, samples were prepared in 3 replications and reached the quality laboratory for further analyses: thousand kernel weight (g) and grain weight/spike was assessed using a Contador instrument (set by 1000 grains) followed by weighing on an electronic balance; spike density was assessed counting number of ears/m^2 after heading period; number of grains/spike was assessed by counting seeds of 5 spikes/replication in 3 replications, then the mean was used for data analyses; plant height was determined using scaled ruler (cm) measuring 3 plants in 3 replications from the base of the plant to the top of the spike (excluding awns).

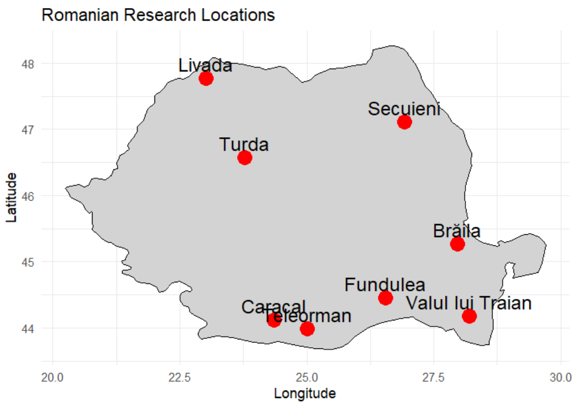

Figure 1. **Experimental sites**

The experimental plots were established in every favorable barley growing condition in Romania, like the Romanian Plain (Caracal, Teleorman, Fundulea, Brăila), Dobrogea Plain (Valul lui Traian), Moldavian Steppe (Secuieni), Transylvania Plain (Turda), and West Plain (Livada) (*figure 1*).

The 2023-2024 growing season was characterized by below-average precipitation across most testing locations. Only two locations recorded rainfall exceeding the multiannual average: Livada exhibited the highest rainfall (697 mm, +31.2% above normal), and Valul lui Traian, 384 mm (+18.9% above normal); the rest of the 6 locations were in water deficit (*figure 2).*

All eight locations showed temperatures in 2024 (red line) consistently above the multi-year normal (blue line) throughout most of the growing season, indicating a warmer year compared with the multiannual average year across all testing environments (*figure 3*).

Multi-environment testing across different pedo-climatic regions remains essential for identifying broadly adapted genotypes capable of maintaining stable performance under increasingly variable and warming climatic conditions.

In all experimental sites in 2023-2024, average temperatures in the locations exceeded the multiannual average from +3°C (Livada) to +4°C (Fundulea), causing heat stress during reproductive stages, particularly when coinciding with water limitation. These findings emphasize the critical importance of developing cultivars with enhanced high draught tolerance, heat stress stress and water-use efficiency.

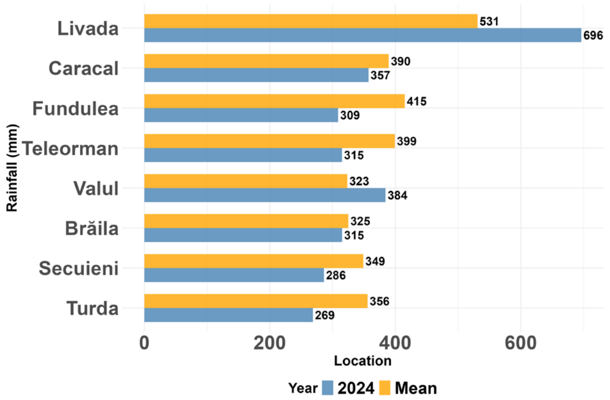

Figure 2. **Rainfall registered in experimental sites during 2023-2024**

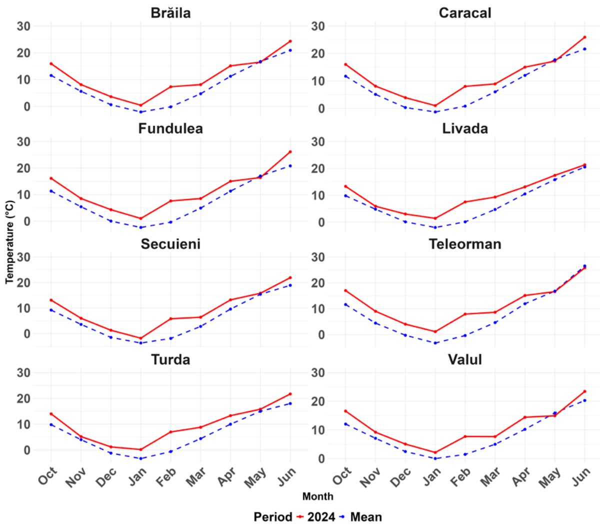

Figure 3. **Average monthly temperatures registered in 8 experimental sites**

RESULTS AND DISCUSSIONS

Analysis of variance (ANOVA) was performed in SPSS Statistics 26 revealed that all probability values are 0.000 ($P < 0.001$)***,** indicating highly significant effects for all sources of variation across all measured traits, including grain yield, thousand kernel weight (TKW), spikes per square meter, grain number per spike, grain weight percentage, and plant height (*table 3*). The significant location effect confirmed substantial environmental variation across the eight experimental sites, reflecting differences in climatic conditions, soil properties, and water availability that collectively influenced crop performance. The highly significant genotype effect demonstrated considerable genetic diversity among the 25 barley genotypes evaluated, indicating exploitable variation for all yield components and morphological traits.

Table 3

Two-way ANOVA for studied parameters

Source	Yield (kg/ha^{-1})	TKW (g)	Spikes/m^2	Grain number/spike	Grain weight	Plant height
Location (L)	0.000	0.000	0.000	0.000	0.000	0.000
Genotype (G)	0.000	0.000	0.000	0.000	0.000	0.000
L x G	0.000	0.000	0.000	0.000	0.000	0.000

**The mean difference is significant at the .05 level*

Descriptive statistics across the eight testing locations revealed substantial variation in both mean performance and phenotypic stability for all measured traits (*Table 4*). Grain yield (both 6-row and 2-row genotypes) ranged from 5420.7 kg/ha at Livada to 7638.7 kg/ha at Caracal *(figure 4)*. The coefficient of variation (CV%) for yield ranged from 5.9% (Brăila) to 19.9% (Livada), indicating differential genotype response capacity across sites. Turda exhibited the highest spike density (989 spikes/m²) and thousand kernel weight (52.56 g), but achieved only moderate yields, whereas at Valul lui Traian registered the second-highest yield (7515.8 kg/ha) despite having the lowest spike density (506 spikes/m²), compensating through superior grain number per spike (37.81) and optimal grain filling. Coefficient of variation analysis demonstrated that thousand kernel weight (mean CV = 8.5%) and plant height (mean CV = 8.4%) were the most stable traits across environments, while the grain number per spike (average of CV = 25.6%) exhibited the greatest environmental sensitivity, particularly at locations experiencing stress during reproductive development.

Table 4

Main values obtained in 8 experimental sites during 2023-2024 agronomic year

Location	Grain Yield (kg/ha)			TKW (g)			Grains/spike			Spike density (spikes/m²)			Plant height (cm)			Grain weight (g)		
	Mean	SD	CV%	Mean	SD	CV%	Mean	SD	CV%	Mean	SD	CV%	Mean	SD	CV%	Mean	SD	CV%
Brăila	6753.7	397.60	5.9	48.01	5.15	10.7	33.77	12.14	35.9	650	29.34	4.5	117.84	11.98	10.2	1.87	0.67	35.9
Caracal	7638.7	1022.97	13.4	48.97	4.01	8.2	36.84	10.80	29.3	755	99.09	13.1	84.48	7.22	8.5	1.78	0.47	26.2
Fundulea	7149.8	871.04	12.2	36.87	2.65	7.2	36.17	7.88	21.8	932	235.61	25.3	83.23	8.42	10.1	1.67	0.37	22.4
Livada	5420.7	1077.21	19.9	44.01	3.94	8.9	34.68	7.57	21.8	676	111.16	16.4	116.72	9.04	7.7	1.53	0.26	17.0
Secuieni	6458.2	873.07	13.5	46.54	4.69	10.1	36.01	10.38	28.8	537	73.82	13.7	102.42	6.40	6.2	1.66	0.37	22.1
Teleorman	7189.6	653.77	9.1	43.62	4.60	10.5	35.00	7.53	21.5	513	106.68	20.8	94.28	6.73	7.1	1.58	0.23	14.4
Turda	5908.4	650.34	11.0	52.56	5.43	10.3	42.09	15.30	36.3	989	125.26	12.7	94.07	6.64	7.1	2.15	0.68	31.4
Valul lui Traian	7515.8	1257.54	16.7	50.22	1.17	2.3	37.81	3.51	9.3	506	31.59	6.2	114.20	11.31	9.9	1.38	0.10	7.2
Average	***6754.4***	***850.44***	***12.7***	***46.35***	***3.96***	***8.5***	***36.55***	***9.4***	***25.6***	***694.8***	***101.57***	***14.1***	***100.91***	***8.47***	***8.4***	***1.70***	***0.39***	***22.1***

**SD = standard deviation*
**CV% = coefficient of variation*

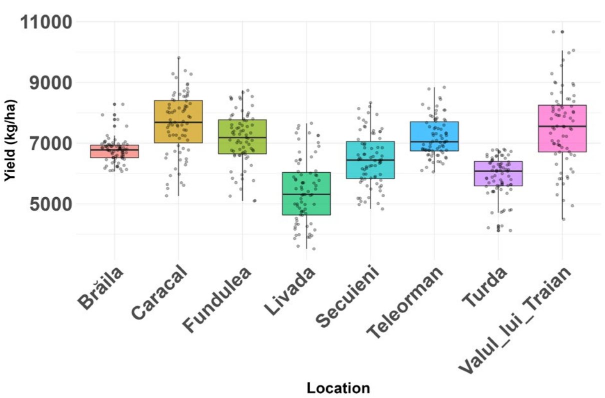

Figure 4. **Average yield registered in 8 experimental sites**

Four locations (Caracal, Valul lui Traian, Teleorman, and Fundulea) exceeded the trial mean, with yields ranging from 7149.8 to 7638.7 kg/ha, representing the most favourable growing environments. Conversely, Turda and Livada recorded the lowest mean yields (5908.4 and 5420.7 kg/ha, respectively), indicating more challenging environmental conditions.

The within-location variability, represented by box height and whisker length, ranged from 2210 kg/ha at Brăila to 6172 kg/ha at Valul lui Traian, reflecting differential genotype responses across environments. The maximum yield of 7515.8 kg/ha was recorded at Valul lui Traian, while the minimum of 5420.7 kg/ha occurred at Livada, representing a difference of 2095.1 kg/ha between high and low yield level. Locations exhibiting high mean yields showed large variability (such as Valul lui Traian and Caracal), while those with consistent performance (such as Brăila, with the smallest amplitude of 2210 kg/ha) provided stable testing environments. These results highlight the importance of multi-location testing for comprehensive genotype evaluation and the critical role of genotype × environment interactions in barley breeding programs.

The performance evaluated separately for 6-row barley genotypes (*figure 6*) and 2-row barley genotypes (*figure 7*) across eight locations revealed substantial environmental variation in all examined agronomic trait.

For 6-row barley genotypes, grain yield ranged from 5583.7 kg/ha at Livada to 8000.4 kg/ha at Valul lui Traian, highlighting the significant impact of environmental conditions on productivity. The locations of Caracal (7862.1 kg/ha), Fundulea (7577 kg/ha), and Teleorman (7071.4 kg/ha) also demonstrated high yield potential, suggesting favourable growing conditions or superior genotype adaptation at these sites.

Spike density exhibited the highest relative variation among locations, ranging from 434.7 spikes/m² at Teleorman to 991.4 spikes/m² at Turda.

Thousand kernel weight (TKW) showed moderate variation across locations, ranging from 36.8 g at Fundulea to 50.2 g at Valul lui Traian, with most locations clustering between 43-50 g. This relatively stable performance suggests that kernel filling was less sensitive to environmental variation compared to spike establishment.

The number of grains per spike ranged from 37.4 at Livada to 53.2 at Turda, indicating location-specific differences in floret fertility and grain set efficiency. The highest-yielding location, Valul lui Traian, achieved its productivity through a balanced combination of three characters: moderate spike density (503.5 spikes/m²), high TKW (50.1 g), and intermediate grain number (39.5 grains/spike), demonstrating an optimal compensation among yield components.

Grain weight per spike, calculated as the product of grain number and individual grain mass, ranged from 1.4 g at Valul lui Traian to 2.6 g at Turda, with considerable variation (1.6-2.3 g) across other locations.

Plant height varied substantially from 82.7 cm at Fundulea to 119.6 cm at Brăila, with no clear correlation to grain yield.

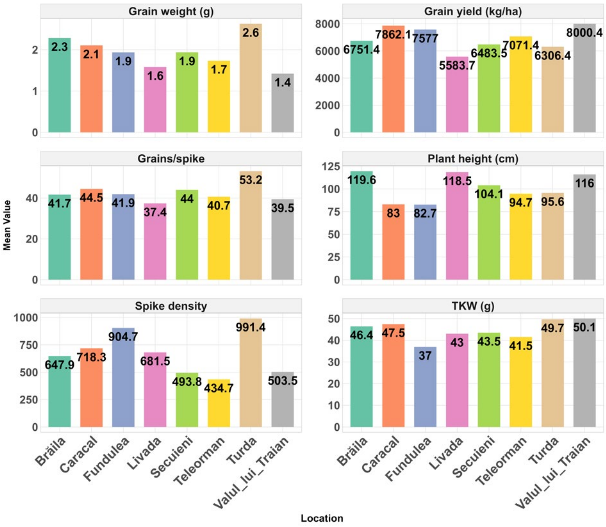

Figure 6. **Mean values of winter 6-row barley genotypes for studied traits during 2023-2024**

In contrast, grain yield as mean for winter 2-row barley genotypes exhibited considerable variation ranging from 5176.3 kg/ha (Livada) to 7366.9 kg/ha (Teleorman), with Teleorman, Caracal (7303.7 kg/ha), and Valul lui Traian (6789.1 kg/ha) demonstrating superior performance, representing approximately 42% higher yields compared to the lowest-yielding genotype Livada, which underscores the critical importance of multi-environment testing for robust cultivar evaluation and recommendation (*figure 7*).

Thousand kernel weight (TKW) ranged from 36.7 g (Fundulea) to 56.8 g (Turda), displaying relatively lower coefficient of variation compared to yield, thereby indicating stronger genetic control and higher heritability, with Turda possessing exceptionally large kernels characteristic of two-rowed spring barley types, while Fundulea's substantially lower TKW suggests either a six-rowed morphology or a compensatory trade-off mechanism with increased grain number per spike.

Spike density showed extreme variation from 510.5 spikes/m² (Valul lui Traian) to 986.3 spikes/m² (Turda), reflecting nearly doubled differences in tillering capacity attributable to genotypic responsiveness, environmental conditions, with Turda and Fundulea (975.3 spikes/m²) achieving exceptional spike populations that may indicate vigorous vegetative growth under favorable conditions, whereas Valul lui Traian's reduced spike density likely necessitates compensation through enhanced individual spike productivity to maintain competitive yields.

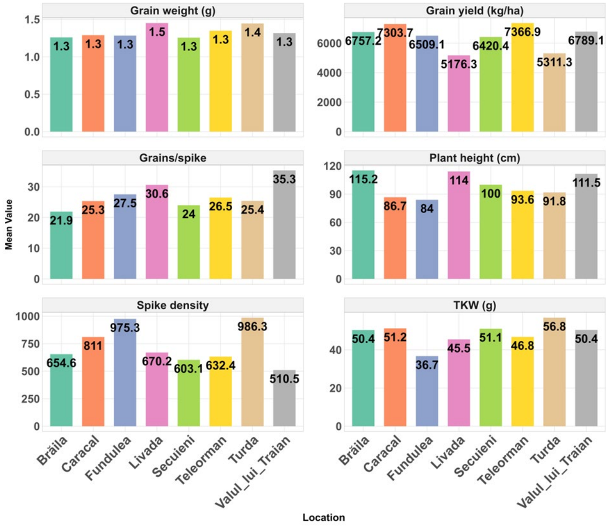

Figure 7. **Mean values of winter 2-row barley genotypes for studied traits during 2023-2024**

Grains per spike demonstrated moderate variation ranging from 21.9 (Brăila) to 35.3 (Valul lui Traian), with Valul lui Traian and Livada (30.6) exhibiting superior floret fertility while Brăila's substantially lower grain number suggests potential stress during critical reproductive phases such as booting or anthesis, or reflects inherent genotypic limitations in spikelet development, emphasizing the trait's sensitivity to environmental stress and moderate heritability.

Grain weight per spike exhibited remarkably low variation, ranging narrowly from 1.3 g to 1.5 g (Livada and Turda), with most genotypes clustering around 1.3 g, indicating strong homeostatic regulation of individual spike productivity through compensatory mechanisms balancing grain number against kernel weight, wherein genotypes with higher spike densities necessarily produce lighter individual spikes to maintain physiological equilibrium and optimize whole-plant yield potential.

Plant height showed substantial genotypic diversity spanning from 84 cm (Fundulea) to 115.2 cm (Brăila). At Fundulea and Caracal (86.7 cm) confers agronomic advantages including enhanced lodging resistance and improved harvest index, which are critical traits for sustainable intensification under high-input management systems, whereas taller genotypes like Brăila and Livada (114 cm) may possess competitive advantages for biomass accumulation but face increased lodging risk under adverse weather conditions or excessive nitrogen fertility.

The top 3 performing winter barley genotypes registered during agronomic year 2023 – 2024 are highlighted in *figure 8*. At Brăila, the 6-row genotype DH 403-12 emerged as the top performer with 7332 kg/ha, closely followed by the 2-row variety Diana (7217 kg/ha) and 6-row genotype Lucian (7205 kg/ha).

Caracal exhibited the most clearly visible genotype differentiation, with 6-row variety Lucian achieving an exceptional 9229 kg/ha, the highest absolute yield recorded across all location-genotype combinations in this study.

At Fundulea, three 6-row genotypes dominated the top rankings: Expert FD (8620 kg/ha), Cadril (8490 kg/ha), and Agil (8136 kg/ha), without 2-row genotypes among top performers. This clear dominance of 6-row types, with advantages exceeding 484 kg/ha over the third-ranked genotype, suggests that Fundulea's growing conditions particularly favour 6-row barley.

Livada demonstrated relatively modest absolute yields compared to other locations, with the 6-row barley variety Iulian leading at 7252 kg/ha, followed by F8-1-2020 perspective line (6530 kg/ha) and Expert FD (6198 kg/ha).

At Secuieni, the top performers included 6-row genotypes F8-1-2020 (7939 kg/ha), Expert FD (7828 kg/ha), and the 2-row Diana variety (7411 kg/ha). The presence of two breeding lines (F8-1-2020 and the established variety Expert FD) among the elite genotypes indicates this location may serve as an effective environment for selecting superior breeding material.

Teleorman's top performers included 2-row Diana (8706 kg/ha), 6-row Lucian (8225 kg/ha), and 2-row Artemis (8048 kg/ha), representing the only site where 2-row genotypes occupied both first and third positions. At Turda, three 6-row genotypes demonstrated clear superiority: F8-22-2018 perspective line (6785 kg/ha), F8-1-2020 (6715 kg/ha), and Cardinal FD (6657 kg/ha) variety, with only 128 kg/ha separating these top performers. Valul lui Traian exhibited the highest overall productivity, with 6-row Agil achieving an outstanding 9767 kg/ha—the highest single genotype-location yield recorded in this study. This was followed by 6-row Iulian (9056 kg/ha) and 6-row F8-1-2020 (8664 kg/ha), with all three genotypes surpassing 8600 kg/ha.

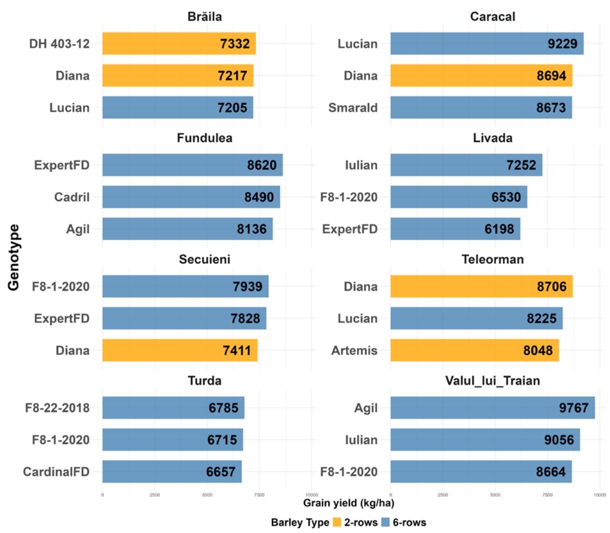

Figure 8. **Highest registered yield (kg/ha) for 8 experimental sites during 2023-2024**

The outstanding performance of Agil, surpassing 711 kg/ha beyond the second-best genotype, indicates exceptional specific adaptation to this water-limited environment. The strongest positive correlation observed between grain number per spike and grain weight per spike (r=0.85) would indicate that grain weight per spike is the product of grain number and individual grain mass (*figure 9*).

The negative correlation between spike density and plant height (r=-0.36) suggests that taller genotypes tend to produce fewer spikes per unit area, possibly reflecting resource allocation conflicts between vegetative extension growth and tiller production. This relationship supports breeding strategies emphasising moderate plant stature to optimise both standability and tiller fertility.

Figure 9. **Correlations between studied parameters**

CONCLUSIONS

These results provide several critical insights for breeding programs and variety recommendation systems. First, the identification of broadly adapted genotypes (Diana, Expert FD, Lucian, F8-1-2020) that consistently perform well across diverse locations indicates successful breeding for stable, high-yield potential and suggests these varieties should form the foundation of regional variety recommendations.

Second, the location-specific superior performance of certain genotypes (Agil at Valul lui Traian, Iulian at Livada, DH 403-12 at Brăila) highlights opportunities for targeted variety deployment where specific adaptation mechanisms match particular environmental conditions, potentially maximizing productivity in defined production zones.

Third, the competitive performance of 2-row Diana across multiple locations, including environments where 6-row types generally dominate, demonstrates that well-bred 2-row varieties can approach or occasionally exceed 6-row yields while maintaining quality advantages, supporting continued breeding investment in both barley types.

These findings emphasize the necessity of multi-location testing to identify genotypes with stable, high-yielding performance and to understand the environmental factors driving trait expression.

ACKNOWLEGMENTS

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YIELD PERFORMANCE AND ADAPTABILITY OF SUNFLOWER HYBRIDS IN THE REPUBLIC OF MOLDOVA

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Abstract

The present study summarizes the results obtained from multi-year trials on sunflower hybrids under different agro-ecological zones of the Republic of Moldova. The research was conducted during 2022–2024, under the conditions of the Republic of Moldova, involving 10 sunflower hybrids. On average, the seed yield of sunflower ranged from 1.96 to 2.69 t/ha, while the environmental condition index fluctuated between +0.66 t/ha (northern zone) and 0.39 t/ha (central zone). The highest yields of the hybrids were recorded in the northern zone (3.15 t/ha), with variations between 2.75 (FSL-1) and 3.44 t/ha (control – LG 5555 CLP). In the central zone these values averaged 2.10 t/ha, ranging between 1.95 (FSL-1) and 2.21 t/ha (FSS-8), whereas in the southern zone the mean yield was 2.23 t/ha, with fluctuations between 1.19 t/ha (FSL-1) and 2.43 t/ha (FSS-8). On average, across three years of research, the highest productivity was shown by the hybrids LG 5555 CLP (control) with 2.60 t/ha and FSS-8 with 2.69 t/ha. The greatest stress tolerance ($Y_{min} – Y_{max}$) was observed in the variants FSE-9 (–0.83 t/ha) and FSP-2 (–0.87 t/ha). A high level of genetic flexibility (($Y_{min} + Y_{max}$)/2) was recorded in the hybrids LG 5555 CLP, control (2.79 t/ha), and FSS-8 (2.82 t/ha). The selection index (*Sc*) of the hybrids ranged from 0.85 to 1.74, with FSC-6, FSE-9 (1.72), and FSS-8 (1.74) showing the highest selection values. The adaptability coefficient values varied between 0.79 and 1.08, with the control LG 5555 CLP (1.05) and FSS-8 (1.08) standing out with the highest values. The linear regression coefficient (*bi*) of sunflower hybrid yields ranged from 0.80 to 1.49. Most of the studied sunflower hybrids exhibited high ecological plasticity (with *bi > 1.0*). The yield depression index for sunflower ranged between 28.4 and 56.7%, with the lowest values recorded in the hybrids FSP-2 and FSE-9, both at 28.4%. The values of phenotypic stability for yield varied from 1.40 to 2.31, with the lowest stability recorded in the hybrid FSL-1 (2.31).

Key words: Hybrids; Sunflower; Yield; Stress tolerance; Stability.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is widely used in human food, as a raw material in industry and in animal feed. The oil extracted from the seeds is of high quality, with low cholesterol content.

Sunflower is the main oilseed crop in the Republic of Moldova, with an average annual area in the last three years (2022-2024) of 370 thousand hectares, with an average seed production of 1.66 t/ha [National Bureau of Statistics of the Republic of Moldova, 2022-2024].

Due to the growing market demand for sunflower seeds for oil, cultivated varieties and hybrids that combine high biological, economic, technological properties and at the same time have high stability and flexibility to environmental conditions, which are of great importance for farmers, are currently in demand [Detsyna A. A. et al., 2019; Detsyna A. A. et al., 2020].

Sunflower, due to its well-developed root system, is more resistant to drought compared to other field crops, however, seed production is below the potential of the genotype [Lekarev A.V., et al., 2022]. Among abiotic factors, drought is the main factor limiting the productive potential of sunflower varieties and hybrids. When introducing new sunflower hybrids into production in a particular region, it is necessary to take into account their adaptability to local environmental conditions.

The purpose of the research was to investigate the production and assess the adaptability of new sunflower hybrids to the conditions of the Republic of Moldova.

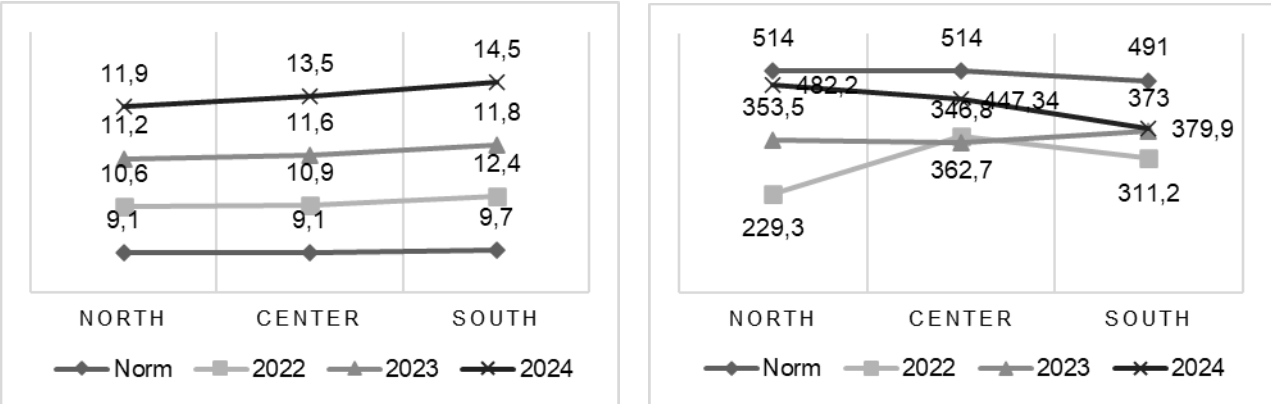
MATERIAL AND METHOD

Research on the production and adaptability indicators of new sunflower hybrids was carried out in the period 2022-2024. Nine sunflower hybrids were selected in the study (ESL-1, ESP-2, ESP-3, FSX-4, FSF-5, FSC-6, FSI-7, FSS-8 and FSE-9), and the control was the approved hybrid LG 5555

CLP. The preceding crop was winter wheat. Sowing rate - 55,000 viable seeds/ha, sowing being carried out in the optimal period (1st-2nd decade of April) for the area. The cultivation technology was conventional, and as a starting fertilization, 250 kg/ha of ammonium phosphate (ammophos) was administered under cultivation, before sowing. The experiment was conducted in five replications, with plots systematically arranged, each plot having an area of 15 m².

The soil in the experimental plots was represented by a leached chernozem (northern area) and carbonate chernozem (central and southern areas). The harvest data were analyzed using the analysis of variance (ANOVA) method proposed by B. A. Dospekhov [Dospekhov B. A., 1985].

During the study years, the average temperature conditions in the republic were 1.9 °C (2022), 2.4 °C (2023) and 3.9 °C (2024) higher than the multiannual average (9.4 °C). The precipitation deficit per year was 205.2 mm (2022), 148.5 mm (2023) and 69.8 mm (2024), being 40.5-13.8% lower than the norm (506.3 mm), figures 1 (a, b).



a) Temperature (^{0}C)

b) Atmospheric precipitation (mm)

The stress tolerance and genetic flexibility of the hybrids were determined according to the method of A. A. Rossielle and J. Hemblin [Rossielle A.A., Hemblin J., 1981], cited by A.A. Goncharenko [Goncharenko A. A., 2025; 2016; Dubiț D. et al., 2025; Burdujan V., et al., 2025]. The adaptability coefficients and the environmental index were determined according to the method of A. A. Jivotkov [Jivotcov L. A. et al., 1994; Jivotcov L. A., 1990]. The plasticity coefficient (*bi*) was calculated by the Eberhard and Russell method, cited by V. V. Pakudin and L. M. Lopatina [Pakudin V. V., Lopatina L. M., 1984]. Phenotypic stability (SF) was calculated according to the D. Lewis method [Lewis D., 1954].

REZULTS AND DISCUSSIONS

During the years of research, the highest seed production of the studied sunflower hybrids was obtained in the northern zone of the Republic of Moldova, on average 3.15 t/ha (table 1). In this zone, the highest production was provided by ESP-3 (3.34 t/ha), FSI-7 (3.36 t/ha), FSS-8 (3.42 t/ha) and the control hybrid LG 5555 CLP (3.44 t/ha).

In the central zone, the average sunflower production in the experiment was 2.10 t/ha, 1.05 t/ha lower than in the northern zone. The highest production, in the center of the republic, was obtained by the hybrids FSX-4 (2.13 t/ha), LG 5555 CLP (2.14 t/ha) and FSS-8 (2.21 t/ha).

The average sunflower seed yield in the southern zone was 2.23 t/ha, 0.92 t/ha lower than in the northern zone and 0.13 t/ha higher than in the central zone. The highest seed yields were recorded for the hybrids FSC-6 (2.36 t/ha) and FSS-8 (2.43 t/ha), which significantly exceeded the control hybrid LG 5555 CLP (2.22 t/ha) by 0.14 and 0.21 t/ha, respectively.

The average yield of the sunflower hybrids studied in the country was 2.49 t/ha, with variations between hybrids ranging from 1.96 t/ha (ESL-1) to 2.69 t/ha (FSS-8). The highest seed yields were recorded for the FSX-4 (2.57 t/ha), LG 5555 CLP (2.60 t/ha) and FSS-8 (2.69 t/ha) variants. The ESL-1 hybrid had the lowest productivity (1.96 t/ha), yielding to the control variant (2.60 t/ha) by 0.64 t/ha.

The Republic of Moldova belongs to the region with insufficient humidity for agricultural crops, in which hybrids with resistance to the limiting factor are of particular importance. The stress adaptability of the studied sunflower hybrids was assessed using stress tolerance, which is the difference between the minimum and maximum seed yield. The smaller the difference, the higher the stress tolerance of the hybrid. In our research, this indicator ranged from -0.83 (FSE-9) to -1.56 (ESL-1). High stress tolerance was provided by the FSE-9 (-0.83 t/ha) and ESP-2 (-0.87 t/ha) hybrids, while low stress tolerance was provided by the FSI-7 (-1.38 t/ha) and ESL-1 (-156 t/ha) hybrids.

Genetic flexibility, which reflects the average yield of sunflower genotypes under contrasting climatic conditions, is an important indicator of the adaptive qualities of a genotype. This indicator reflects the compensatory ability to regulate productivity under stressful growing conditions. In the group of sunflower hybrids studied, the values of this indicator (table 2) ranged from 1.97 t/ha (ESL-1) to 2.82 t/ha (FSS-8).

Table 1

Seed yield of sunflower hybrids in the areas of the Republic of Moldova, t/ha (2022-2024)

Hybrids	North		Center		South		Mean		Harvest index, t/ha
	t/ha	± control	t/ha	± control	t/ha	± control	t/ha	± control	
LG 5555 CLP (control)	3,44	-	2,14	-	2,22	-	2,60	-	+0,11
FSL -1	2,75	-0,69	1,95	-0,19	1,19	-1,03	1,96	-0,64	-0,53
FSP-2	2,96	-0,48	2,09	-0,05	2,21	-0,01	2,42	-0,18	-0,07
FSP-3	3,34	-0,10	2,10	-0,04	2,02	-0,20	2,49	-0,11	0
FSX-4	3,29	-0,15	2,13	-0,01	2,29	+0,07	2,57	-0,03	+0,08
FSF-5	2,95	-0,49	1,93	-0,21	2,25	+0,03	2,38	-0,22	-0,11
FSC-6	3,04	-0,40	2,09	-0,05	2,36	+0,14	2,50	-0,10	+0,01
FSI-7	3,36	-0,08	1,98	-0,16	2,28	+0,16	2,54	-0,06	+0,05
FSS-8	3,42	-0,02	2,21	+0,17	2,43	+0,21	2,69	+0,09	+0,20
FSE-9	2,92	-0,52	2,09	-0,05	2,21	-0,01	2,41	-0,19	-0,08
Mean	3,15		2,10		2,23		2,49		
Environmental index	+0,66		-0,39		-0,26				

Table 2

Harvest and statistical data on the adaptability of sunflower hybrids to environmental conditions, 2022-2024

Hybrids	Harvest			$Y1 - Y2$	$\frac{V1 + V2}{2}$	SF	SC	Adaptability coefficient (AC)	Ecological plasticity (*bi*)	Yield depression (D%)
	Y1 min	Y2 max	Mean							
LG 5555 CLP (str.)	2,14	3,44	2,60	-1,30	2,79	1,55	1,68	1,05	1,49	37,8
FSL -1	1,19	2,75	1,96	-1,56	1,97	2,31	0,85	0,79	1,14	56,7
FSP-2	2,09	2,96	2,42	-0,87	2,53	1,42	1,71	0,97	0,83	28,4
FSP-3	2,02	3,34	2,49	-1,32	2,68	1,65	1,51	1,00	1,30	39,5
FSX-4	2,13	3,29	2,57	-1,16	2,71	1,55	1,66	1,03	1,06	35,3
FSF-5	1,93	2,95	2,38	-1,02	2,44	1,53	1,56	0,96	0,93	34,6
FSC-6	2,09	3,04	2,50	-0,95	2,57	1,46	1,72	1,01	0,88	31,3
FSI-7	1,98	3,36	2,54	-1,38	2,67	1,70	1,50	1,02	1,30	41,1
FSS-8	2,21	3,42	2,69	-1,21	2,82	1,55	1,74	1,08	1,17	35,4
FSE-9	2,09	2,92	2,41	-0,83	2,51	1,40	1,72	0,97	0,80	28,4
Mean			2,49							

Most of the sunflower hybrids studied were inferior in genetic flexibility to the control hybrid LG 5555 CLP (2.79), with the exception of the FSS-8 variant (2.82 t/ha).

The indicator stability factor proposed by D. Lewis [Lewis D., 1954] represents the ability of a genotype to form a certain range of phenotypes depending on the cultivation conditions.

In research, the values of the stability factor ranged from 1.42 (ESL-2) to 2.31 (ESL-1), indicating a practically identical phenotypic stability of the sunflower hybrids studied, under the conditions of the republic. However, the highest phenotypic instability was identified in the ESL-1 hybrid, with a value of 2.31.

The selection value indicator (SC) of a hybrid was calculated by comparing the seed yield under limited and optimal growing conditions, taking into account the average yield values [Mazalov V. I., et al., 2025; Kurasova L. G. et al., 2022; Madyakin E. V., Goryanin O. I., 2022]. In agroecological studies of the country, the selection value indicator (SC) for experimental variants ranged from 0.85 (ESL-1) to 1.74 (FSS-8). Calculations revealed that the studied sunflower hybrids possess a high and stable selection value, with values exceeding 1. The highest values were provided by the ESP-2 (1.74), FSC-6 and FSE-9 (1.72 each) and FSS-8 (1.74). Relatively low selection value was recorded for the ESL-1 hybrid (0.85).

The adaptability coefficient (CA) varied between the experimental variants from 0.79 (ESL-1) to 1.08 (FSS-8 -8). The highest CA values were recorded by the control variant LG 5555 CLP (1.05) and FSS-8 (1.08). Most of the sunflower hybrids studied responded positively to the ecological conditions of growth (medium), with adaptability index values above 1. Relatively weaker success in ecological conditions was in the variants FSE-9, ESP-2 (0.97 each), FSF-5 (0.96) and ESL-1 (0.79).

The assessment of the adaptability properties of hybrids in terms of seed yield is determined based on ecological plasticity (*bi*) or the linear regression coefficient, which characterizes the response of the hybrid to ecological conditions. For the studied sunflower hybrids, the linear regression coefficient ranged from 0.80 (FSE-9) to 1.49 (LG 5555 CLP, control). When the *bi* value >1, a high reaction of the genotype to improved cultivation conditions is observed.

Most of the studied sunflower hybrids recorded a positive value of the plasticity coefficient (*bi* = 1.06 -1.49), and the results of the analysis allowed to identify the hybrids FSI-7 and ESP-3 (*bi* = 1.30, each) and the control LG 5555 CLP (*bi* = 1.49). Low reaction to improving growing conditions and the formation of seed crops was provided by the hybrids FSF-5 (*bi* = 0.93), FSC-6 (*bi* = 0.88), ESP-2 (*bi* = 0.83) and FSE-9 5 (*bi* = 0.80).

The adaptability of the sunflower hybrid to specific environmental conditions is also characterized by the yield reduction index. In the variants of the experiment, the values of this indicator ranged from 28.4% (ESP-2, FSE-9) to 56.7% (ESL-1). Growing conditions caused the greatest yield depression in the FSI-7 (41.1%) and ESL-1 (56.7%) hybrids. For most of the sunflower hybrids studied, yield depression ranged from 28.4% to 39.5%.

CONCLUSIONS

Research conducted over the years of research has shown that the highest yield of sunflower hybrids was achieved in the northern area of the Republic of Moldova, with an average of 3.15 t/ha. In the southern area, an average of 2.23 t/ha of sunflower seeds was obtained, and in the central area 2.10 t/ha.

The highest average seed yield in the research areas was provided by the FSS-8 hybrids (2.69 t/ha) and the control LG 5555 CLP (2.60 t/ha). The FSE-9 (-0.83 t/ha) and ESP-2 (-0.87 t/ha) hybrids demonstrated the highest stress tolerance, and the LG 5555 CLP (2.79 t/ha) and FSS-8 (2.82 t/ha) hybrids demonstrated the highest genetic flexibility.

Increased yield phenotypic instability was observed in the ESL-1 hybrid (2.31), and the FSE-9, FSC-6 (1.72) and FSS-8 (1.74) hybrids demonstrated a high selection value. The LG 5555 CLP (1.05) and FSS-8 (1.08) hybrids demonstrated the highest adaptability coefficient.

High linear regression coefficient was calculated for the FSI-7 and ESP-3 hybrids (*bi* = 1.30) and the control hybrid LG 5555 CLP (*bi* = 1.49), and the lowest degree of seed yield depression was in the ESP-2 and FSE-9 hybrids (28.4%).

The conducted research identified sunflower hybrids FSS-8, FSI-7 and FSX-4 with high yield and adaptability, which are promising for the conditions of the Republic of Moldova.

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THE QUALITY INDICES OF THE BIOMASS FROM *BROMUS INERMIS* AND *PHLEUM PRATENSE* UNDER THE ENVIRONMENTAL CONDITIONS OF THE REPUBLIC OF MOLDOVA

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Abstract

The aim of this study was to evaluate the quality indices of green mass and silage prepared from smooth brome, *Bromus inermis* and timothy grass, *Phleum pretense* and cultivated in the experimental plot of the "Alexandru Ciubotaru" National Botanical Garden (Institute) MSU, Chisinau. It has been determined that the dry matter of whole plants contained 99-104% CP, 33.6-37.2% CF, 9.4-11.1 % ash, 36.9-41.7 % ADF, 62.9-73.4 % NDF, 2.3-3.6 % ADL, 6.5-13.5% TSS, 33.0-39.1 % Cel, 26.0-31.7 % HC, 58.6-60.2% DDM, 9.40-9.88 MJ/kg ME, 5.24-5.79MJ/kg NEl. The biochemical composition and nutritive value of prepared silage was: 9.9-10.9 % CP, 34.5-35.6% CF, 8.8-9.8 % ash, 35.9-40.2 % ADF, 61.5-71.0% NDF, 2.3-3.3 % ADL, 32.6-37.9 % Cel, 25.6-37.9 % HC, 57.6-60.9% DDM, 9.60-10.18/kg ME, 5.41-5.90 MJ/kg NEl. The estimated biochemical biomethane potential of substrates from smooth brome and timothy grass varied from 351 to 369 l/kg ODM.

Key words: biochemical biomethane potential, biochemical composition, *Bromus inermis*, green mass, nutritional value *Phleum pratense*, silage

Plants of the family *Poaceae* Barnhart are well known for their multiple uses: they provide food for humans, fodder and shelter for various species of animals, birds and insects, and hold high socio-economic value. They are used in the production of building materials and handicrafts, and in recent years, have become increasingly important as a source of biofuels and raw materials for the circular economy. Grasslands typically supply the majority of forage for domestic livestock, thereby supporting the production of livestock-based goods and contributing to rural agricultural and economic development. Temperate forage grasses are key components of grasslands, which cover approximately 40.5% of the world's terrestrial surface and 30-40% of Europe's agricultural land. The species and genotypes (cultivars) of grasses significantly affect total biomass yield, forage quality indices, and the overall efficiency of grassland utilization.

At the global level, the genus *Bromus* L. includes approximately 170 accepted species, both annual and perennial, of which around 10 are cultivated for forage purposes. The genus *Bromus* in Romania consist from 18 species, while in the Republic of Moldova, 11 species have been identified (Marusca T., 1999; Pînzaru P., 2023). One of the most widely used species is smooth brome (*Bromus inermis* Leyss.), also known by several synonyms: *Bromopsis inermis* (Leyss.) Holub, *Festuca inermis* (Leyss.) DC., *Forasaccus inermis* (Leyss.) Lunell, *Schedonorus inermis* (Leyss.) P. Beauv. and *Zerna inermis* (Leyss.) Lindm. Smooth brome is a perennial, cool-season, rhizomatous grass. It features erect stems that are glabrous or retrorsely hairy below the nodes, reaching heights of up to 150 cm. The leaves are greyish-blue on the upper surface and green on the underside. Leaf sheaths are glabrous or sparsely hairy, while the leaf blades are flat, 15-40 cm long and 5-10 mm wide, with both surfaces and margins being scabrid, glabrous, or sparsely ciliate. Leaf tips are acuminate, and the ligules measure 1-2 mm. The inflorescence is an open panicle, 5-20 cm in length, bearing 1 to 4 branches per node. Spikelets are purple-brown, typically 15-30 mm long, and contain 6-12 florets. Rachilla internodes are 2-3 mm long and spinulose. Glumes are lanceolate with membranous margins; the lower glume is 4-7 mm long and 1-veined, while the upper glume is 6-10 mm long and 3-veined. Lemmas are oblong-lanceolate, 8-12 mm long, 5-7-veined, glabrous, scabrid at the base, and have obtuse or emarginate apices. They may be awned (up to 3-4 mm) or awnless. Paleas are shorter than the lemmas and have ciliate keels. Anthers are 3-4 mm in length. *Bromus inermis* is an open-pollinated, self-incompatible species. Flowering occurs from late May to early July. The caryopses are elliptical, 5-8 mm long, and range in colour from pale yellow to dark brown. The weight of 1000 seeds ranges from 2 to 3 grams. Chromosome numbers include 2n = 14, 28, or 56. Seeds remain viable for 6-10 years. The species reproduces by

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seeds, tillers and rhizomes. Smooth brome thrives in well-drained soils with a pH of 5.5-8.0, but it is tolerant of both acidic and poorly drained conditions. It performs well in areas with annual precipitation exceeding 380 mm. Its notable drought tolerance is attributed to a deeply penetrating root system and vigorous rhizome development. The species has excellent seedling vigour and establishes quickly when sown in early spring. In subsequent years, growth resumes early in spring and continues into late autumn. Smooth brome is one of the most important grasses used for pastures, hayfields, soil erosion control, and land reclamation. It is often sown in mixtures with perennial legumes, which typically improves both yield and forage quality. Modern cultivars of smooth bromegrass are highly productive, yielding 13-20 t/ha of dry matter. Currently, the *Bromus inermis* species is extensively studied and cultivated across several continents (Albayrak S. *et al*. 2011; Maruşca T. *et al.* 2011; Ünal S., & Mutlu Z., 2015; Tana T. *et al.* 2017; Kazarina A.V. *et al.* 2019; Sokolović D. *et al.* 2019; Karbivska U.M. *et al*. 2020; Feoktistova N.A. & Leonidov Y.E., 2022; Baykalova L.P. & Serebrennikov Y.I., 2022; Bozhanska T. *et al*. 2022, 2024; YANG et al., 2023; Ankuda J. *et al*. 2023; Mackiewicz-Walec *et al*. 2024; Rojas-Sandoval J. 2024; Waliszewska B. *et al.* 2024; Vozhehova R.A. *et al*. 2025).

The genus *Phleum* includes 18 accepted species names, native to Europe, Asia, North Africa, North and South America. In the spontaneous flora of the Republic of Moldova, there are 4 species. Timothy grass *Phleum pratense* L. (syn. *Phleum nodosum* L., *Phleum parnassicum* Boiss. & Heldr. ex Nyman*, Phleum praecox* Jord., *Plantinia pratensis* (L.) Bubani, *Stelephuros pratensis* (L.) Lunell) being the most popular and used species. It forms sparse tufts, grows 48-150 cm tall, the culms are erect and thicker at the base, the leaves are flat, 25-40 cm long and 6-10 mm wide, gradually narrowed, the ligule 3-7 mm long, slightly toothed, with three larger teeth; the sheaths – smooth, glabrous, with transverse striations. The inflorescence is a spike-like, cylindrical, dense panicle, 7-15 cm long, greenish in colour, with spikelets containing a single flower, glumes 2-3 mm long, linearly elongated, truncated, with a long, rigidly ciliated keel, ending in an 1-2 mm long awn, the lower palea half as long as the glumes, translucent, truncated and slightly denticulated at the tip. It blooms in May-June, bears fruit in July-August. The seed – oval or convex caryopsis, covered by the lower palea, colourless, truncated at the tip and slightly dentate, finely porous on the veins, whitish-silver, the caryopsis is often glabrous. The seeds are 1.5-2.0 mm long and 0.4-0.6 mm wide. The weight of 1000 seeds is 0.30-0.52 g. The seed yield is 600-800 kg/ha. The chromosome number 2n = 42 (but different ploidy levels are also known). Timothy grass (*Phleum pratense*) has been cultivated since the early 20th century and is among the most important forage grasses in temperate regions worldwide. It is commonly used in pasture mixtures on wetland soils and for erosion control. *Phleum pratense* exhibits excellent resistance to low temperatures compared to other forage grasses; however, it is sensitive to prolonged drought and high temperatures due to the limited absorptive capacity of its root system.

Smooth brome has been studied and cultivated for various uses, including forage and energy biomass (Mähnert P. *et al.* 2002; Hetta M. *et al.* 2003; Tran G. & Lebas F. 2015; Huuskonen A. &Pesonen M. 2017; Chornolata L.P. *et al.* 2018, 2020; Țîțe V. &Roșca I. 2021; Bužinskienė R. 2024; Maruşca T. *et al.* 2011; 2025).

Smooth brome (*Bromus inermis*) and timothy grass (*Phleum pratense*) are often grown in mixtures with perennial leguminous species for the establishment of temporary grasslands.

Currently, there are no registered varieties of smooth brome (*Bromus inermis*) or timothy grass (*Phleum pratense*) in the Catalogue of Plant Varieties of the Republic of Moldova, although such varieties are registered in Romania, 5 varieties of *Bromus inermis* and 5 varieties of *Phleum pratense*.

The goal of this study was to evaluate the quality indices of green biomass and silage produced from *Bromus inermis* and *Phleum pratense*, both as fodder for livestock and as substrates for biogas production.

MATERIALS AND METHODS

The local ecotype of smooth brome, *Bromus inermis* and the cultivar *'Tirom'* of timothy grass *Phleum pratense*, created at the Research and Development Institute for Grasslands, Braşov, Romania, and grown in monoculture in the experimental sector of the National Botanical Garden (Institute) of Moldova MSU, Chişinău, served as research subjects.

The experimental design was a randomized complete block design with four replications, and the experimental plots measured 10 m^2. Plant samples of smooth brome (*Bromus inermis*) were collected in the second year of growth, while samples of timothy grass (*Phleum pratense*) were collected during the third growing season. The first harvest was performed at the pre-flowering stage. Harvested plants were chopped into 1.5–2.0 cm pieces using a laboratory forage chopper. Dry matter (DM) content was determined by drying the samples at 105°C to a constant weight. For ensiling, the chopped plant material was further shredded and tightly packed into sealed containers. After 45 days of fermentation, the containers were opened, and the silage was evaluated for sensory and fermentation characteristics in accordance with standard laboratory procedures and the Moldovan standard SM 108 for forage quality analysis. For chemical analyses, the plant samples were dried in a forced-air oven at 60 °C, then milled in a beater mill equipped with a sieve with mesh diameter of 1 mm. Some of the main biochemical parameters were assessed: crude protein (CP), ash, acid detergent fibre (ADF), neutral detergent fibre (NDF) and acid detergent lignin (ADL), total soluble sugars (TSS), digestible dry matter (DDM) were determined by the near infrared spectroscopy (NIRS) technique using the PERTEN DA 7200 NIR analyser, at the Research and Development Institute for Grasslands, Braşov, Romania. The concentration of hemicellulose (HC), cellulose (Cel), digestible energy (DE), metabolizable energy (ME), net energy for lactation (NEl) and relative feed value (RFV) were calculated according to standard procedures. The mass samples were collected in the early flowering stage. The carbon content of the substrates was determined using an empirical equation according to Badger C.M. et al., (1979). The biochemical methane potential was calculated according to Dandikas V. et al. (2015).

RESULTS AND DISCUSSIONS

The analysis of the agrobiological characteristics revealed certain differences in the growth and development patterns of the studied grass species. *Bromus inermis* exhibited a more rapid growth rate, with inflorescence emergence occurring 8-10 days earlier than in *Phleum pratense*. At the time of mowing, during the pre-flowering stage, smooth brome plants reached a height of 99-109 cm, while timothy grass reached 107-118 cm. The dry matter content of the green biomass was 269.7 g/kg for smooth brome and 257.1 g/kg for timothy grass. The analysis of the nutrient composition of the dry matter in the studied grasses (Table 1) revealed that the forage contained 99-104% CP, 33.6-37.2% CF, 9.4-11.1% ash, 36.9-41.7 % ADF, 62.9-73.4 % NDF, 2.3-3.6% ADL, 6.5-13.5% TSS, 33.0-39.1 % Cel, 26.0-31.7 % HC. An optimal level of crude protein, total soluble sugars, ash and a lower content of structural carbohydrates was found in the fodder from *Bromus inermis* plants. The concentration of nutrients influences on the digestibility of forage and energy value. Thus, the green fodder from *Bromus inermis* had 602 g/kg DMD, 11.89 MJ/kg DE, 9.76 MJ/kg ME and 5.79 MJ/kg NEl, while the forage from *Phleum pratense* – 586g/kg DMD, 11.23 MJ/kg DE, 9.22 MJ/kg ME and 5.24 MJ/kg NEl.

Table 1.
The nutrient composition and the feed value of the green mass from studied grasses

Indices	*Bromus inermis*	*Phleum pratense*
Crude protein, g/kg DM	124	95
Crude fiber, g/kg DM	336	372
Ash, g/kg DM	94	111
Acid detergent fiber, g/kg DM	369	417
Neutral detergent fiber, g/kg DM	629	734
Acid detergent lignin, g/kg DM	36	26
Total soluble sugars, g/kg DM	135	65
Cellulose, g/kg DM	330	391
Hemicellulose, g/kg DM	260	217
Dry matter digestibility, %	60.2	58.6
Digestible energy, MJ/kg DM	11.89	11.23
Metabolizable energy, MJ/kg DM	9.76	9.22
Net energy for lactation, MJ/kg DM	5.79	5.24
Relative feed value	90	72

The specialized literature provides various data on the green mass quality of the studied grasses. Thus, Burlacu G. *et al.* (2002) revealed that, the green forage from *Bromus inermis* contained 250 g/kg DM, 10.2% CP, 3.1% EE, 34.2% CF, 45.1% NFE, 7.4% ash, 37.8% ADF, 28.3% Cel, 16.0% HC, 18.3 MJ/kg GE, while *Phleum pratense* – 265 g/kg DM, 7.8% ash, 8.7% CP, 2.8 % EE, 32.5% CF, 49.5% NFE and 18.4 MJ/kg GE, respectively. Hetta M. *et al.* (2003) remarked that the *Phleum pratense* first-cut green mass contained 182 g/kg DM with 12.4% CP, 54.5% NDF, 9.2% WSC and 11 MJ/kg ME. Tomić Z. *et al.* (2007) mentioned that the *Phleum pratense* had 8.36-13.95 % CP and 26.92-29.36 % CF. Utyamishev I.I. & Reznicenko V.G. (2009) reported that *Bromus inermis* during the earing stage of plants contained 15.16% CP, 2.49% EE, 28.88% CF, 46.27% NFE, 1.12% starch, 1.95% sugars, 7.2% ash, 18.50 MJ/kg GE, and 9.43 MJ/kg

ME; at the flowering stage, values shifted to 7.42% CP, 1.67% EE, 30.63% CF, 54.57% NFE, 4.80% starch, 4.01% sugars, 5.33% ash, 552 g/kg DMD, 18.14 MJ/kg GE, and 9.11 MJ/kg ME. Albayrak S. *et al.* (2011) remarked that that brome had 10.45-11.30% CP, 57.85-59.70% NDF, 41.75-43.50% ADF, 45.16-47.45% TDN and RFV 85.57-88.11. Naydenova Y. (2012) mentioned that the green mass of *Bromus inermis* harvested in the heading period contained 16.55-20.29 % CP, 27.83-30.04 % CF, 33.45-41.62 % ADF, 59.44-64.12 % NDF, 2.71-5.85% ADL, 22.50-26.00% HC, 30.74-35.77% Cel, 58.04-70.38 % IVDMD, 54.17-68.65 % IVOMD, 10.45-11.04 MJ/kg ME and RFV=132-172, while the forage cut in the flowering period – 14.11-15.23 % CP, 30.99-33.97 % CF, 42.50-43.54 % ADF, 66.00-67.37 % NDF, 6.29-7.06% ADL, 23.50-23.83% HC, 36.21-36.48% Cel, 44.44-49.68 % IVDMD, 41.66-47.30 % IVOMD, 7.96-8.72 MJ/kg ME and RFV=122-126. Albayrak S. & Türk M. (2013) found that *Bromus inermis* plants contained 8.5-8.7% CP, 61.1-61.3% NDF, 44.6-46.4% ADF, RFV=80-82. Wang P. *et al.* (2014) reported that the timothy grass had the following quality indices: 124-133 g/kg DM, 13.6-17.4% CP, 3.5-4.6% EE, 32.3-36.0% ADF, 58.1% NDF, 6.1-8.3% WSC, 20.2-20.3 MJ/kg GE. Tod M.A. *et al.* (2015) found that the studied cultivars of *Phleum pratense* first-had 11.1-13.0% CP, 29.0-34.8 % CF, 33.3-37.5 % ADF, 54.5-63.3 % NDF, 3.5-4.1% ADL, 55.3-63.6 % DMD, 56.1-62.1 % OMD. Tran G. & Lebas F. (2015) indicated that timothy grass dry matter had 7.6-22.3% CP, 2.0-2.6 % EE, 21.5-33.1 % CF, 49.5-63.5 % NDF, 25.4-44.7% ADF, 1.4-3.2 % lignin, 4.9-11.8 % ash, 1.2-1.6 g/kg Ca, 1.4-2.5 g/kg P, 43.0-83.3% ODM, 58.0-76.9% DDM, 18.2-18.8 MJ/kg GE, 11.6 MJ/kg DE, 9.6 MJ/kg ME. Ünal S. & Mutlu Z. (2015) reported that studied *Bromus inermis* genotypes were 45.66- 87.86 cm, 77.1- 269.6 kg/da hay with nutritive value 17.79-21.93% CP, 34.41-37.67% ADF, 61.79-66.43% NDF, 59.54- 62.09% DDM and RFV=107.64-120.24. Tana T. *et al.* (2017) mentioned that *Bromus inermis* green mass contained 362.7/kg DM 10.17 % CP, 39.71 % ADF, 61.45 % NDF, 11.13% WSC. Chornolata L.P. *et al.* (2018) reported that the timothy grass dry matter had 16.05% CP, 4.23% EE, 23.10% CF, 50.45% NDF, 24.82% ADF, 42.26% NFE, 1.88% starch, 14.60% Cel, 15.80% HC, 6.10% lignin. Janković V. *et al*. (2018) found that timothy grass dry matter had 13.20-14.52% CP and 24.30-26.98% CF. Tenikecier H.S. & Ates E. (2018) remarked that *Bromus inermis* harvested in full bloom stage had 14.23 % CP, 55.11 % NDF, 30.19 % ADF, 3.88 % calcium and 0.22 % phosphorus. Türk M. *et al.* (2018) reported that the forage from *Bromus inermis* contained 8.91% CP, 59.55 % NDF, 45.11 % ADF, 43.11% TDN, RFV=83.96, but in variants with different nitrogen doses 8.88-12.02% crude protein, 51.49-58.01 % NDF, 36.38-43.34 % ADF, 45.40-54.38% TDN, RFV=88.40-109.38. Bandanova A.V. & Butukhanov A.B. (2019) found that brome forage quality in earing stage was 16.3% CP, 2.9% EE, 34.0% CF, 36.8% NFE, 5.3% ash, 1.32% calcium, and 0.37% phosphorus, but in flowering period respectively 14.8% CP, 3.0% EE, 37.8% CF, 37.0% NFE, 7.53% ash, 1.40% calcium, and 0.30% phosphorus. Kazarina A.V. *et al.* (2019) reported that local varieties of *Bromus inermis* had 13.56–16.39% CP, 8.26–13.37% sugars, and 102.6–174 mg/kg carotene. Pavlova S.A. *et al.* (2019) stated that the forage value of *Bromus inermis* grown in monoculture was 10.6% CP, 1.7% EE, 35.0% CF, 47.5% NFE, 8.5 MJ/kg ME, 0.58 nutritive units/kg, and 63.7 g digestible protein per nutritive unit. Soković D. *et al.* (2019) revealed that the nutrient composition of *Bromus inermis* 'Kruševački 46' at first cut was 11.61% CP, 33.23% CF, 3.09% EE, 60.19% NDF, 40.33% ADF, and 7.69% ash, and at the second cut 13.51% CP, 30.57% CF, 5.39% EE, 57.26% NDF, 36.34% ADF, 11.51% ash. Chornolata L.P. *et al.* (2020) found that crude protein content in budding-flowering stages in smooth brome forage was 6.15-8.92%, while in timothy grass 6.17-8.09%. Karbivska U.M. *et al.* (2020) mentioned that the chemical composition and energy nutritional value of dry matter from *Bromus inermis* plants was: 10.6-14.8% CP, 3.34-3.4% EE, 29.8-30.2% CF, 43.2-47.9% NFE, 8.3-8.4 % ash, 0.41-0.4% Ca, 0.33-0.34% P, 55-56% DDM, 0.69-70 fodder units/kg DM, 8.0-8.1 MJ/kg ME, 107-147 g DP/nutritive unit, while – from *Phleum pratense* 10.7-14.2% CP, 2.8-2.9 % EE, 28.6-29.0% CF, 45.9-51.35% NFE, 7.4-7.5 % ash, 0.40-0.45% Ca, 0.25-028% P, 58-59% DMD, 0.70-0.71 fodder units/kg, 8.1-8.3 MJ/kg ME and 107-144 g DP/fodder unit. Reiné R. *et al.* (2020) reported that *Phleum pratense* plants had 377 g/kg DM with 7.6% CP, 3.9% ash, 2.1% EE, 68.5% NDF, 34.0% ADF, 4.0% ADL, 62.4% DDM. Ţîţei V. *et al.* (2022) found that the forage dry matter of timothy grass had 10.4-12.4% CP, 28.9-35.1% CF, 7.5-8.5 % ash, 31.4-36.8 % ADF, 49.5-58.9 % NDF, 3.6-4.1 % ADL, 27.8-37.4 % Cel, 18.1-27.7 % HC, 56.9-61.4% DMD, 54.9-60.0% OMD, RFV=95-121, 9.78-10.38 MJ/kg ME, 5.81-6.42 MJ/kg NEl. Becker T. *et al.* (2023) mentioned that the forage value of *Phleum pratense* was 18.7% CP and 6.1MJ/kg NEl. Coşman S. *et al.* (2023) remarked that the nutrient content of timothy grass forage was 244 g/kg DM with 6.69% CP, 2.80% EE, 35.71% CF, 41.75% NFE, 8.11% ash, 0.25% Ca, 0.18% P. Baykalova L.P. & Serebrennikov Y.I. (2022) reported that the studied cultivars of *Bromus inermis* had17.5-25.5% CP, 24.13-28.4% CF, and 1.7-1.9 MJ/kg ME in fresh mass. Feoktistova N.A. & Leonidov Y.E. (2022) noted that forage from *Bromus inermis* 'Gvardeets' is characterized by a 38-50% foliage content, 7.0-12.0%CP and the fiber content was in the range 28.2-34.0% CF. Bozhanska T. et al. (2022, 2024) remarked that *Bromus inermis* plants contained 13.26-15.27% CP, 2.17-2.31% EE, 34.30-41.23% CF, 35.51-41.78% NFE, 5.67-6.71 % ash, 0.9-2.78% Ca, 0.06-0.21% P, while *Phleum pratense* – 9.49% CP, 4.01% ash, 2.20% EE, 40.56% CF, 34.32% NFE. Acatrinei (Dumitru) S. *et al.* (2023) reported that the Romanian cultivars of *Bromus inermis* yielded 10-20.3 t/ha dry matter with 12.74-14.66 % crude protein content. Waliszewska B. *et al.* (2024) reported that the dry matter from *Bromus inermis* contained 38.65 % cellulose, 14.89 % lignin, 68.40 % holocellulose, 29.75 % hemicellulose and 8.57 % ash. Vozhehova R.A. *et al.* (2025) remarked that forage quality of smooth brome was 17.54% CP, 3.88% EE, 26.57% CF, 42.09% NFE, 9.92 % ash, 18.42 MJ/kg GE, 10.53 MJ/kg ME, 0.70 nutritive units/kg.

Grasses preserved as hay or silage provide an important source of feed for livestock during periods when pasture growth and harvested green forage are insufficient — particularly during the winter, when animals are housed indoors. These preserved forages are also essential in confinement feeding systems. Ensiling perennial grasses is one of the most effective methods of forage conservation, as it helps maximize both the quantity and quality of the resulting bulky feed. Compared to traditional haymaking, ensiling significantly reduces losses in yield and nutrient content.

The results regarding the biochemical composition and nutritive value of the silages prepared from the studied grasses are presented in Table 2. The silages contained the following ranges of nutritional components: 9.9-10.9 % CP, 34.5-35.6% CF, 8.8-9.8 % ash, 35.9-40.2 % ADF, 61.5-71.0% NDF, 2.3-3.3 % ADL, 32.6-37.9 % Cel, 25.6-37.9 % HC. The silage made from *Bromus inermis* was characterized by a higher crude protein content, a lower concentration of cell wall components (ADF and NDF), and superior digestibility and energy value compared to that of *Phleum pratense*.

Table 2.
The fermentation profile, the nutrient composition and the feed value of the silage from the studied grasses

Indices	*Bromus inermis*	*Phleum pratense*
Crude protein, g/kg DM	109	99
Crude fibre, g/kg DM	345	356
Ash, g/kg DM	99	88
Acid detergent fibre, g/kg DM	359	402
Neutral detergent fibre, g/kg DM	615	710
Acid detergent lignin, g/kg DM	33	23
Total soluble sugars, g/kg DM	41	27
Cellulose, g/kg DM	326	379
Hemicellulose, g/kg DM	256	308
Dry matter digestibility, g/kg DM	609	576
Digestible energy, MJ/kg DM	12.03	11.44
Metabolizable energy, MJ/kg DM	9.88	9.40
Net energy for lactation, MJ/kg DM	5.90	5.41
Relative feed value	92	75

Several literature sources have described the quality of silage made from these species. For example, Burlacu et al. (2002) reported that silages produced from timothy grass contained: 200-220 g/kg DM with 7.3-8.0% ash, 10.0-11.2% CP, 3.3-4.0 % EE, 25.4-32.4% CF, 47.0-51.4% NFE, 18.4-18.8 MJ/kg GE. Hetta M. *et al.* (2003) reported that timothy silage had pH=4.64, 3.17% lactic acid, 2.88% acetic acid, 2.34% butyric acid, 168 g/kg DM, 12.4% CP, 52.7% NDF, 0.5% WSC. Coşman S. *et al.* (2023) remarked that the silage from smooth brome contained 316.9 g/kg DM with 9.88% CP, 3.34% EE, 30.71% CF, 42.77% NFE, 7.75% ash and from timothy grass – 244 g/kg DM, 6.88% CP, 3.25% EE, 41.29% CF, 38.76% NFE, 6.09% ash. Wang P. *et al.* (2014) reported that quality indices of timothy silages were: pH=4.46-4.75, 15.9-35.3 g/kg lactic acid, 24.7-36.9 g/kg acetic acid, 0.1-0.3 g/kg butyric acid 134-138 g/kg DM, 13.4-17.1 % CP, 9.96-13.51 % DP, 5.4-5.7 % EE, 35.9-38.4 % ADF, 56.4-61.2 % NDF, 1.6-1.8 %WSC, 20.2-20.3 MJ/kg GE and 13.3-15.1 MJ/kg DE. Tahir M.N. *et al.* (2013) mentioned that timothy silages contained: 238-286g/kg DM with 5.8-6.2 % ash, 12.9-16.7 %CP, 1.8-2.7 %EE, 48.2-58.7 %NDF, pH= 3.7-4.0, 83-

55g/kg lactic acid, 16-23 g/kg acetic acid, 69.9-80.5% OMD, 10.2-11.3 MJ/kg ME. Tran G. & Lebas F. (2015) revealed that timothy silage contained 30.8% DM, 13.9% CP, 34.6% CF, 56.2 % NDF, 36.9% ADF, 3.7 % lignin, 8.2 % ash, 7.9% TS, 6.2%WSC, 64.2% ODM, 18.2 MJ/kg gross energy, 11.1 MJ/kg DE, 8.9 MJ/kg ME. Huuskonen A. &Pesonen M. (2017) found that, depending of cuts, the silage from *Phleum pratense* contained 222-326 g/kg DM with 91.7-94.5% OM, 68.5-74.0% DOM, 14.7-18.6% CP, 3.2-3.5% EE, 44.0-59.2% NDF, 6.5-14.8% WSC, pH=3.90-4.56, 3.2-4.9% lactic+formic acids, 11.0 -11.2 MJ/kg ME. Tana T. *et al.* (2017) mentioned that *Bromus inermis* silage was characterized by: pH= 4.2, 370.8 g/kg DM with 8.06 %CP, 39.71 %ADF, 61.69 %NDF, 2.05% WSC. Richard A-M *et al.* (2020) found that the silage dry matter of timothy grass contained 916 g/kg OM, 154 g/kg CP, 583 g/kg aNDF, 385 g/kg ADF, 86.3% IVTD and 1.23 Mcal/kg NEl. fermented fodders were characterized by 345.6-570.0 g/kg DM with 1.64-3.93% lactic acid, 0.15-0.19% acetic acid, 11.47-11.77% CP, 2.51- 2.86% CP, 35.03-35.27% CF, 44.13-44.39% NFE, 3.26-5.11% sugars, 0.93-1.20% starch, 27.75-33.75 mg/kg carotene, 18.50-18.80 MJ/kg GE 8.50-8.51MJ/kg ME. Ţîţei V. *et al.* (2022, 2023) revealed that fermented fodders from *Bromus inermis* were characterized by 345.6-570.0 g/kg DM with 1.64-3.93% lactic acid, 0.15-0.19% acetic acid, 11.47-11.77% CP, 2.51- 2.86% CP, 35.03-35.27% CF, 44.13-44.39% NFE, 3.26-5.11% sugars, 0.93-1.20 % starch, 27.75-33.75 mg/kg carotene, 18.50-18.80 MJ/kg GE and 8.50-8.51MJ/kg ME, while fermented fodders from *Phleum pratense* contained 12.9-27.7g/kg lactic acid, 1.6-6.9 g/kg acetic acid, 9.0-9.5 % CP, 6.7-8.4 % ash, 40.8-41.6 % ADF, 68.1-71.6 % NDF, 2.9-3.8 % ADL, 37.0-38.3 % Cel, 27.3-30.0 % HC, 65-131 g/kg TSS, 51.7-56.0% DMD, 46.7-46.9% OMD, 11.24-11.36 MJ/kg DE, 9.23-9.33 MJ/kg ME, 5.25-5.34 MJ/kg NEl.

Table 3.
The biochemical composition and biomethane production potential of the substrates from the studied grasses

Indices	*Bromus inermis*		*Phleum pratense*	
	green mass	silage	green mass	silage
Crude protein, g/kg DM	124.00	109.00	95.00	99.00
Ash, g/kg DM	94.00	99.00	111.00	88.00
Nitrogen, g/kg DM	19.84	17.44	15.20	15.84
Carbon, g/kg DM	503.33	500.56	493.89	506.67
Ratio carbon/nitrogen	25.37	28.70	32.49	31.99
Acid detergent lignin, g/kg DM	36.00	33.00	26.00	23.00
Hemicellulose, g/kg DM	260.00	256.00	317.00	308.00
Biomethane potential, L/kg DM	318.00	318.00	324.00	337.00
Biomethane potential, L/kg VS	351.00	353.00	364.00	369.00

Biogas (or biomethane) is a renewable energy source that can significantly reduce fossil fuel emissions in sectors such as transport, heating, and electricity generation. Its use plays a vital role in climate change mitigation and in meeting renewable energy targets. In recent years, the production of biogas directly from harvested and chopped green biomass has gained considerable attention across Europe as a sustainable energy solution. Utilizing grasses as feedstock for anaerobic digestion has also been recognized as a promising strategy for rural development and diversification. The results concerning the biochemical methane potential of the studied grass substrates are presented in Table 3. The nitrogen content in the tested substrates ranged from 16.20 to 19.84 g/kg, while the estimated carbon content varied from 493.89 to 503.33 g/kg, resulting in a carbon-to-nitrogen (C/N) ratio between 25.37 and 32.49. Among the tested species, smooth brome substrates demonstrated an optimal C/N ratio for efficient anaerobic digestion. Significant differences were observed in acid detergent lignin (ADL) concentrations among the studied grasses. As noted previously, timothy grass substrates contained lower ADL levels and higher hemicellulose content, which may positively influence the activity of methanogenic bacteria.The estimated biochemical methane potential of smooth brome and timothy grass substrates ranged from 351 to 369 l/kg ODM. The superior methane potential was in *Phleum pratense* substrates.

There are different results reported in research studies conducted by other authors. Mähnert P. *et al.* (2002) reported that *Phleum pratense* fresh mass co-substrate had 148 g/kg DM with 90.1% ODM and the measured gas production was 733-828 l/kg VS over 28 days. Kaiser F. & Gronauer A. (2007) reported that the specific methane yields of timothy grass were 345-375 l/kg VS or 4500-4800 m^3/ha. Żurek G. & Martyniak, M. (2020) reported that the *Bromus inermis* substrate produced a biogas yield of 518.3 l/kg VS with methane content 50.4%, *Bromus catharticus* substrate yielded 485 L/kg VS biogas with 50.23% methane and *Lolium perenne* substrate – 611.9 l/kg VS biogas with 54.8% methane, respectively. Zhang Y. *et al.* (2021) reported that the methane potential of timothy grass substrates, determined through biochemical methane potential (BMP) and long-retention batch tests, ranged from 308 to 365 l/kg VS. According to Bužinskienė R. (2024), the biomethane yield of the biomass substrate from timothy grass ranged from 151 to 322 l/kg or 1362-5800 m^3/ha. Waliszewska B. *et al.* (2024) reported that *Bromus inermis* substrates contained 38.65% Cel, 29.75% HC, 14.89% lignin, and 8.57% ash, resulting in a biogas yield of 429 L/kg and a methane potential of 232 L/kg.

CONCLUSIONS

The local ecotype of *Bromus inermis* and the cultivar *'Tirom'* of *Phleum pratense* are suitable for restoration and creation of sown meadows and the collected biomass may be served as forage for farm animals, and also as feedstock for biogas reactors in methane production as a source of renewable energy.

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EVALUATION OF THE QUALITY OF FRESH AND ENSILED MASS OF *MALVA CRISPA* AND *ALCEA ROSEA* AND THEIR POTENTIAL APPLICATION IN MOLDOVA

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Abstract

The goal of this study was to evaluate the productivity and quality indices of harvested whole plants and ensiled mass of Malva crispa and Alcea rosea grown in experimental plots at the National Botanical Garden (Institute) of Moldova State University, Republic of Moldova. The results showed that the dry matter of the harvested whole plants contained: 159-182 g/kg CP, 9.6-10.4 g/kg ash, 308-363 g/kg ADF, 453-540 g/kg NDF, 50-51 g/kg ADL, with nutritive and energy values 60.6-64.9 % DDM, RFV=104-133, 11.98-12.75 MJ/kg DE, 9.91-10.47 MJ/kg ME and 5.86-6.49 MJ/kg NEl. The ensiled mass from the studied species is characterized by specific smell and color. Its dry matter contained 176-178 g/kg CP, 132-141g/kg ash, 269-357 g/kg ADF, 440-540 g/kg NDF, 24-50 g/kg ADL, with 61.1-67.9 % DMD, RFV=105-144, 9.91-10.91 MJ/kg ME, 5.93-6.93 MJ/kg NEl. The substrates prepared from the studied species for anaerobic digestion had optimal carbon to nitrogen ratio and the biochemical methane potential varied from 329 to 376 l/kg VS.

The studied species – Malva crispa and Alcea rosea – have optimal nutrient content, and they can be used as an alternative forage source for ruminant animals, or as substrates for biomethane production.

Key words: Alcea rosea, biochemical methane potential, ensiled mass, fresh mass, Malva crispa, nutritional value

The family *Malvaceae* Juss., according to The Plant List (2013), comprises 245 genera and at least 4,465 species, widely distributed across the globe, with a notable concentration in tropical regions. Several *Malvaceae* species hold significant economic value and have been introduced and cultivated globally. They are used for the production of food, beverages, fibers, pharmaceuticals and construction materials, they also serve ornamental purposes, are used in traditional medicine and provide sources of bioenergy.

The genus *Alcea* includes 77 species of annual, biennial, and perennial plants native to Europe and Asia. Likewise, the genus *Malva* encompasses 29 species of herbaceous annuals, biennials, and perennials, and is broadly distributed across the temperate, subtropical, and tropical regions of Africa, Asia, and Europe.

Alcea rosea L. (syn. *Alcea biennis* Winterl, *Althaea chinensis* Wall., *Althaea rosea* (L.) Cav., *Malva rosea* Garsault, *Malva hortensis* K.F. Schimp. & Spenn.), commonly known in English as hollyhock, hock herb, or round dock, is referred to in Romanian as *nalbă de grădină* and in French as *alcée*, *alcée rose*, *althée rose*, *mauve rose* or *pass-rose*. It is a biennial or short-lived perennial herb, native to regions extending from the eastern Mediterranean to Central Asia. The plant has an erect, simple or sparsely branched stem, growing 1.5 to 3.0 m tall, growing best in full sun. Its leaves are large, rounded and 3-5-lobed, with hairs on both surfaces. The flowers are showy and large, measuring 5-8 cm in diameter, typically purple, rose or white in colour, borne on short pedicels and arranged in long terminal racemes. Flowering occurs in mid-summer, and the species is cross-pollinated. The seeds are brownish-black, kidney-shaped, approximately 6 mm long, rugose, and fringed with hairs along the margins. *Alcea rosea* prefers well-drained, moderately acidic soils and is propagated by seeds or root division.

Several pharmacological studies have reported that *Alcea rosea (Althaea rosea*) possesses anti-inflammatory, antibacterial, analgesic and anticancer properties (Al-Snafi A.E., 2013; Parry R.A. *et al.* 2025)

Malva crispa L. (syn. *Malva verticillata* subsp. *crispa* (L.) Tzvelev), commonly known as curly mallow, is an annual, monocarpic, herbaceous plant native to East Asia. The stem is slightly pubescent with scattered hairs, irregularly rounded, slightly branched and reaches a height of 200-270 cm. The leaves are light green, 5-lobed, and have wavy (curly), serrated edges. They are borne on long petioles. The small, numerous flowers are arranged in groups of 3 to 10 in the axils of the leaves, forming whorls. The flowering period lasts 12 to 25 days. The fruit is a capsule composed of 10 to 12 transversely wrinkled seeds. The ripe seeds tend to fall off easily. They are brownish in colour, with blunt edges. The weight of one thousand seeds is approximately 2.68 g. (Rakhmetov D.B., 2001ab; Kshnikatkina A.N. *et al.* 2005; Ţîţei V., Teleuţă A., 2018ab, Cerempei V. *et al.* 2023)

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The main objectives of this study were to evaluate the productivity and quality parameters of whole harvested plants and ensiled biomass of *Malva crispa* and *Alcea rosea*, with the goal of evaluating their potential as forage for livestock and as feedstock for biomethane production.

MATERIALS AND METHODS

The local ecotype of hollyhock (*Alcea rosea*) and the Ukrainian cultivar 'Rada' of curly mallow (*Malva crispa*), grown in monoculture in the experimental sector of the National Botanical Garden (Institute) of MSU, Chişinău, were used as research subjects. The traditionally cultivated forage crop – maize (*Zea mays*) served as control.

The experiment followed a randomized complete block design with four replications, using plots of 10 m² each. Plant samples from the studied Malvaceae species were collected during the flowering stage, while maize was harvested at the kernel milk stage. All harvested plants were chopped into 1.5-2.0 cm pieces using a laboratory forage chopper. Dry matter content was determined by drying the samples at 105°C until a constant weight was achieved. Silage was prepared from whole chopped plants, which were packed and compressed into glass containers. These containers were sealed and stored for 45 days. Afterward, they were opened for organoleptic evaluation and analysis of organic acid composition, following the Moldavian standard SM 108*. For chemical analysis, both fresh plant samples and silages were dried in a forced-air oven at 60°C, then ground using a beater mill fitted with a 1 mm mesh sieve. Key biochemical parameters were assessed, including crude protein (CP), ash, acid detergent fiber (ADF), neutral detergent fiber (NDF), acid detergent lignin (ADL), total soluble sugars (TSS) and digestible dry matter (DDM). These were measured using near-infrared spectroscopy (NIRS) with a PERTEN DA 7200 NIR analyzer at the Research and Development Institute for Grasslands in Braşov, Romania. Additionally, values for hemicellulose (HC), cellulose (Cel), digestible energy (DE), metabolizable energy (ME), net energy for lactation (NEl) and relative feed value (RFV) were calculated using standard methods. The carbon content of the substrates was estimated using an empirical equation from Badger et al. (1979), and the biochemical methane potential (BMP) was calculated following the method described by Dandikas V. et al. (2015).

RESULTS AND DISCUSSIONS

As a result of our research, we found that at the time of mowing, *Alcea rosea* plants had reached a height of 274 cm, with a green mass yield of 3.74 kg/m² and a dry matter content of 23.71%. *Malva crispa* plants reached a height of 227 cm, with a green mass yield of 4.37 kg/m² and a dry matter content of 24.47%.

According to Grevtsova S.A. (2002), the productivity of *Malva crispa* can reach 73.2 t/ha of green mass and 2.36 t/ha of crude protein. Heneman P. and Červinka J. (2007) reported a dry matter yield of *Malva* species at 13.40 t/ha. Rakhmetov D.B. and Rakhmetova S.N. (2011) noted that when *Malva* plants were mown during the budding stage, yields ranged from 22–25 t/ha of green mass. When harvested at the early fruiting stage, yields increased to 50–60 t/ha of green mass, 10–12 t/ha of dry matter, and 1.8–2.2 t/ha of protein. Trots V.B. et al. (2014) observed that *Malva meluca* productivity can reach 100–120 t/ha of green mass and 1,200–1,800 kg/ha of digestible protein. Kasarin V.F. *et al.* (2018) reported that *Malva* plants reached 163 cm in height, with yields of 40.3 t/ha green mass, 8.49 t/ha dry matter, 730 kg/ha digestible protein and 82.90 GJ/ha of metabolizable energy (ME). For comparison, maize plants reached 158 cm, with yields of 25.3 t/ha green mass, 6.37 t/ha dry matter, 440 kg/ha digestible protein and 80.53 GJ/ha ME. In a previous study, Ţîţei V&Teleuță A. (2018), found that the green mass yield of *Malva crispa* reached 3.98 kg/ m ^{2} and *Malva meluca* – 2.83 kg/ m ^{2}. Kintl A. *et al.* (2022) remarked that the fodder mallow (*Malva verticillata* var. *crispa*), achieved 37.1 t/ha fresh mass and 8.1 kg/ha dry matter.

The performance, welfare and health of livestock are significantly influenced by feed quality indices. Based on the results presented in Table 1, which show the quality indices of the harvested whole plants, we noted that the nutrient content of the dry matter varied within the following ranges: 159–182 g/kg CP, 9.6–10.4 g/kg ash, 308–363 g/kg ADF, 453–540 g/kg NDF, 50–51 g/kg ADL, 257–313 g/kg Cel and 145–167 g/kg HC. Compared to maize forage, the studied *Malvaceae* species had 1.9–2.2 times higher crude protein content. The highest level of crude protein was found in the fodder from *Malva crispa* plants. *Alcea rosea* plants contained lower amounts of ash and structural carbohydrates compared to *Malva crispa*, but higher levels than those found in *Zea mays* green mass. The concentration of structural carbohydrates directly influences forage digestibility, feed value and energy supply. Accordingly, the green fodder from *Malva crispa* contained 606 g/kg DDM, RFV = 104, 9.84 MJ/kg ME, and 5.85 MJ/kg NEl. In contrast, *Alcea rosea* plants had 649 g/kg DDM, RFV = 133, 10.47 MJ/kg ME and 6.49 MJ/kg NEl, while the control – maize forage – had 678g/kg DDM, RFV = 133, 10.90 MJ/kg ME and 6.91 MJ/kg NEl.

Some authors mentioned various findings about the nutrient quality of the green mass of the studied grasses. Morosan A.E. (1971) determined that under the conditions of the Northern zone of Moldova, depending on the level and type of soil fertilization, the productivity of *Malva crispa* increased and the chemical composition of the fodder changed: 17.94-22.90% CP, 2.43- 3.48% EE, 22.44-28.32% NFE and 9.23-13.84% ash. Bonnemaire J. *et al*. (1975) reported that *Malva verticillata* forage depending on the harvest period had 189-277 g/kg dry matter with 13.03-19.56% CP, 10.47-13.92% ash, 19.21-27.77% CF, 65.7-72.7% DMD and 0.62-073 nutritive units/kg DM. According to Medvedev P.F.& Smetannikova A.I. (1981), that the green fodder of *Malva meluca* had 128-212 g/kg DM, 16.8-26.8% CP, 2.3- 4.5 % EE, 21.1-26.7% CF, 8.1-16.9% minerals, 31.7- 41.2% NFE, 26-68 mg/kg carotene and 297 mg/kg ascorbic acid. Gutiérrez D.M *et al.* (2008) remarked the quality of *Malva parviflora* was 26.33% NDF, 21.41*%* ADF, 29.86*%* CP. Avetisyan A.T. (2011) reported that the forage value of *Malva meluca* green mass included 152 g/kg DM, 26.1% CP, 16.6% CF, 8.20% sugars, 11.6 MJ/kg ME, and 1.1 nutritive units/kg DM. In comparison, maize green mass contained 166 g/kg DM, 17.2% CP, 30.1% CF, 4.1% sugars, 9.1 MJ/kg ME, and 0.7 nutritive units/kg DM. Rakhmetov D.B. and Rakhmetova S.N. (2011) stated that *Malva* plants mown during the budding stage contained 140-160 g/kg DM, 25-26% CP, 14-16% ash, 25-30 mg/kg carotene and 280-300 mg/kg ascorbic acid. The green biomass at this stage can be used to produce high-quality, vitamin-enriched flour. When harvested at the early fruiting stage, the plants contained 200-210 g/kg DM and 17-19% CP, making them suitable for silage production. Iskanderova A.I. and Ibadullayeva S.J. (2013) observed that at the flowering stage, the green mass of *Malva erecta* contained 175.9 g/kg DM, 22.07% CP, 3.46% EE, 18.33 % CF, 43.18% NFS, and 12.99% ash; *Malva parviflora* forage had 167.2 g/kg DM, 19.37% CP, 3.09% EE, 20.08% CF, 44.89% NFS, 12.58% ash, while *Malva pusilla* 181.2g/kg DM, 19.96 % CP, 3.56% EE, 18.38% CF, 45.52% NFS, 12.59% ash; *Malva sylvestiris* 181.8g/kg DM, 19.00 % CP, 3.64% EE, 18.60% CF, 46.54 % NFS, 12.02% ash; *Malva nicaeensis* 189.4 g/kg DM, 19.81% CP, 2.81% EE, 20.86% CF, 43.96% NFS, 12.56% ash. Khismatov M.M. and Trots V.B. (2013) reported that the forage value of pure *Malva* green mass included 14.15% CP, 9.20% minerals, 10.7 MJ/kg ME, and 153 g DP / nutritive unit. In comparison, green mass maize forage contained 6.5% CP, 7.00% minerals, 9.5 MJ/kg ME, and 75 g DP / nutritive unit. Barros M. et al. (2017) noted that the quality of green fodder from *Malva parviflora* was characterized by 160.6 g/kg DM, 866 g/kg ODM, 22.8% CP, 7.46% CF, 18.8% NDF, 9.57% ADF, and 13.4% ash. Ţîţei V. and Teleuță A. (2018a) reported that the forage quality indices for *Malva crispa* included 186.0 g/kg DM, 19.11% CP, 2.15% EE, 32.00% CF, 12.01% minerals, 2.22% Ca, 0.69% P, 34.74% NFE, 191.00 g DP / nutritive unit; *Malva meluca* forage contained 200.8 g/kg DM, 15.67% CP, 2.07% EE, 30.07% CF, 11.53% minerals, 3.18% Ca, 0.49% P, 40.66% NFE, 154.20 g DP / nutritive unit. For comparison, *Medicago sativa* contained 263.7 g/kg DM, 17.03% CP, 2.30% EE, 33.31% CF, 8.01% minerals, 1.69% Ca, 0.44% P, 39.41% NFE, 164.29 g DP per nutritive unit and *Sida hermaphrodita* 179.7 g/kg DM, 21.67% CP, 4.46% EE, 29.10% CF, 36.42% NFE, 8.35% minerals. Zielewicz W. and Wróbel B. (2018) found that the nutrient content in fodder mallow varied depending on nitrogen fertilization levels: CP ranged from 16.75 to 18.95%, sugars from 3.42 to 5.81%, ADF from 36.61-40.69%, NDF from 47.67-53.55%, lignin from 3.51-3.98%, Cel from 36.61-40.69%, and HC from 10.06-12.86%. Burykina S.I. (2019) stated that *Malva crispa* forage harvested during the budding-flowering period contained 3.26-3.73% N, 24.40-25.71% CF, 10.00-12.10% Cel, 3.63-6.98% HC, 10.19-10.85% lignin, 4.26-5.29% sugars and 0.33% starch. Cerempei V. *et al*. (2023) mentioned that *Malva crispa* forage had 929 g/kg organic matter, 119 g/kg CP, 360 g/kg ADF, 531 g/kg NDF, 57 g/kg ADL, 303 g/kg Cel, 171 g/kg HC, with 68.6% DMD, 60.9% DOM, RFV=107, 12.03 MJ/kg DE, 9.88 MJ/kg ME and 5.89 MJ/kg.

Silage is an important feed source for ruminant animals, especially during the autumn-spring period, but also throughout the year, as it provides a substantial amount of nutrients, vitamins and minerals. During the sensory evaluation of the ensiled mass from the studied Malvaceae species, it was observed that *Alcea rosea* silage exhibited olive-green leaves and yellow stems, while the silage from *Malva crispa* had a uniform olive coloration. Both silages emitted a specific, pleasant aroma reminiscent of pickled vegetables. The texture of the silage remained consistent and very sticky, with no signs of mold or mucus formation.

The results concerning the biochemical composition and the feed value of the silage prepared from the studied *Malvaceae* species are presented in Table 2. The prepared silages contained 19.5-22.9 % dry matter and were characterized by: pH=4.33-4.44, 35.5 g/kg lactic acid, 8.1-11.5 g/kg acetic acid and 0-0.3 g/kg butyric acid. The dry matter of the silages contained 76-178 g/kg CP, 132-141g/kg ash, 269-357 g/kg ADF, 440-540 g/kg NDF, 24-50 g/kg ADL, with 61.1-67.9 % DMD, RFV=105-144, 9.91-10.91 MJ/kg ME, 5.93-6.93 MJ/kg NEl.

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Table 1.
The biochemical composition and the feed value of the green mass

Indices	*Alcea rosea*	*Malva crispa*	*Zea mays (control)*
Crude protein, g/kg DM	159	182	84
Crude fiber, g/kg DM	299	361	248
Ash, g/kg DM	96	104	52
Acid detergent fiber, g/kg DM	308	363	271
Neutral detergent fiber, g/kg DM	453	540	474
Acid detergent lignin, g/kg DM	51	50	48
Cellulose, g/kg DM	257	313	223
Hemicellulose, g/kg DM	145	177	203
Dry matter digestibility, g/kg DM	649	606	678
Digestible energy, MJ/kg DM	12.75	11.98	13.28
Metabolizable energy, MJ/kg DM	10.47	9.84	10.90
Net energy for lactation, MJ/kg DM	6.49	5.85	6.91
Relative feed value	133	104	133

Table 2.
The fermentation profile, the biochemical composition and the nutritive value of the ensiled mass from the studied species

Indices	*Alcea rosea*	*Malva crispa*	*Zea mays* (control)
pH index	4.33	4.44	3.77
Organic acids, g/kg DM	43.9	47.0	48.6
Total acetic acid, g/kg DM	8.1	11.5	10.3
Total butyric acid, g/kg DM	0.3	0	0.2
Total lactic acid, g/kg DM	35.5	35.5	38.1
Acetic acid, % of organic acids	18.00	24.00	21.19
Butyric acid, % of organic acids	1.14	0	0.41
Lactic acid, % of organic acids	80.86	76.00	78.40
Crude protein, g/kg DM	176	178	80
Crude fiber, g/kg DM	240	341	245
Ash, g/kg DM	141	132	59
Acid detergent fiber, g/kg DM	269	357	258
Neutral detergent fiber, g/kg DM	440	541	469
Acid detergent lignin, g/kg DM	24	41	37
Cellulose, g/kg DM	245	316	221
Hemicellulose, g/kg DM	171	184	211
Dry matter digestibility, g/kg DM	679	611	689
Digestible energy, MJ/kg DM	13.29	12.07	13.45
Metabolizable energy, MJ/kg DM	10.91	9.91	11.04
Net energy for lactation, MJ/kg DM	6.93	5.93	7.06
Relative feed value	144	105	136

Table 3.
The biochemical composition and biomethane production potential of the substrates from the studied species

Indices	*Alcea rosea*		*Malva crispa*		*Zea mays* (control)	
	fresh mass	ensiled mass	fresh mass	ensiled mass	fresh mass	ensiled mass
Crude protein, g/kg DM	159.00	176.00	182.00	178.00	84.0	80.0
Ash, g/kg DM	96.00	141.00	104.00	132.00	52.0	59.0
Nitrogen, g/kg DM	25.40	28.20	29.40	28.40	13.4	12.8
Carbon, g/kg DM	502.20	477.70	497.80	482.22	526.7	522.8
Ratio carbon/nitrogen	19.77	16.91	16.93	16.97	39.3	40.8
Acid detergent lignin, g/kg DM	51.00	24.00	50.00	41.00	48.0	37.0
Hemicellulose, g/kg DM	145.00	171.00	177.00	184.00	203.0	211.0
Biomethane potential, L/kg DM	257.00	323.00	295.00	299.00	304	318
Biomethane potential, L/kg VS	329.00	376.00	330.00	344.00	321	338

Alcea rosea silage contained lower amounts of fibers and lignin, higher levels of metabolizable energy and net energy for lactation than *Malva crispa* silage. However, as compared to corn silage, both silages had higher crude protein and lower energy concentrations.

According to Cottyn B.G. *et al.* (1970), the silages prepared from fodder mallow (*Malva crispa*) were characterized by the following indices: pH=4.61-6.60, 0.61-1.15% lactic acid, 0.10-0.53% acetic acid, 0.38-1.31% butyric acid, 90.6-143.0 g/kg DM, 16.22-23.02% CP, 22.41-33.15% CF, 12.10-17.22% DP, 23.2-32.0% CF, 36.85-44.70 % NFE+EE, 11.43-13.78 % ash. Kintl A. *et al.* (2022, 2025) reported that the silage prepared from *Malva verticillata* var. *crispa* had pH= 4.15, 126.2 g/kg lactic acid, 39.3 g/kg acetic acid, 0.3 g/kg butyric acid, 207.5 g/kg dry matter, 16.23% CP, 29.01% aNDFom, 24.78% ADFom, 3.59% ADL, 38.38% NFC, 20.56% CF, 2.62% EE and 13.71% ash, with 9.31 MJ/kg ME, 5.75 MJ/kg NEl, but mixed silages prepared from *Malva verticillata* var. *crispa* and *Melilotus albus* were characterized by pH=4.15-4.18, 85.6-104.5 g/kg lactic acid, 29.7-42.0 g/kg acetic acid, 244.7-293.8 g/kg DM, 15.19-16.02% CP, 34.82-38.58% aNDFom, 30.60-34.09% ADFom, 4.34-5.46% ADL, 33.31-34.99% NFC, 25.43-29.52% CF, 2.83-291% EE, 9.08-11.35% ash, 8.98-9.24 MJ/kg ME, 5.52-5.66 MJ/kg NEl.

Plant biomass (phytomass) can be effectively transformed into multiple types of biofuels suitable for transportation, heating, and electricity generation. Through anaerobic digestion in biogas reactors, both fresh and preserved phytomass substrates can be converted into biomethane, offering a viable alternative to natural gas in the energy and transport sectors. Moreover, the digestate produced during this process can be applied as an organic fertilizer in agricultural systems. The results related to the quality indices of the studied Malvaceae substrates and their potential for biomethane production are presented in Table 3. We found that in the investigated substrates, according to the C/N ratio, which constituted 16.91-19.77, the amount of acid detergent lignin (24-51g/kg) and hemicellulose (145-184 g/kg) met the established standards. The biochemical methane potential (BMP) of the *Malvaceae* substrates varied from 329 to 376 L/kg VS, compared to 321-338 L/kg VS for maize substrates. High biochemical methane potential was also observed in the ensiled *Alcea rosea* substrate.

Various research studies have reported differing results regarding the biomethane potential of *Malvaceae* substrates. Dubrovskis V. *et al.* (2012) reported that the average methane yield from *Malva* and maize silage was 412 L/kg VS, with a methane content of 56.13%, while the methane yield from *Malva* and sunflower silage was 389 L/kg VS, with a methane content of 58.18%. Ţîţei V. and Teleuță A. (2018a) found that the biomethane potential of digestible organic compounds from *Malva* substrates was 236-237 L/kg, *Medicago sativa* 248 L/kg and *Sida hermaphrodita* 266L/kg. Kintl A. et al. (2022) observed that the biogas yield from fodder mallow substrate was 600 L/kg VS, with a methane yield of 294 L/kg VS. For a mixed substrate of fodder mallow and white sweet clover, the biogas yield was 574 L/kg VS and methane yield reached 303 L/kg VS. Cerempei V. et al. (2023) reported that the *Malva crispa* substrate had a C/N ratio of 27 and a biochemical methane potential of 312 L/kg VS. In comparison, *Sida hermaphrodita* substrates had a C/N ratio of 23 and a BMP of 309 L/kg VS, while the *Medicago sativa* substrate had a C/N ratio of 18 and a BMP of 321 L/kg VS.

CONCLUSIONS

The studied species of *Malvaceae* – *Malva crispa* and *Alcea rosea* – have optimal nutrient content, and they can be used as an alternative forage source for ruminant animals, or as substrates in biogas reactors for biomethane production.

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SOME ASPECTS REFERING TO VARIABILITY OF MORPHO-PHISIOLOGICAL AND BIOCHEMICAL TRAITS TO COMMON BEAN *(PHASEOLUS VULGARIS*) LOCAL LANDRACES

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Abstract

The common bean (*Phaseolus vulgaris* L.) is a vital legume crop globally, especially in developing regions. This study evaluated 40 local bean populations from Romania and neighboring countries to assess their morphological, physiological, and biochemical variability. Nine key traits—including plant height, flowering time, pod characteristics, resistance to *Xanthomonas campestris* pv. *phaseoli*, protein and amino acid content, and cooking time—were analyzed over two growing seasons (2023–2024) at the Suceava Gene Bank. Significant variability was observed, particularly in flowering time and number of ovules per pod (CV > 20%), and in amino acid content (CV = 32.46%). Disease resistance showed a broad range, with 3 genotypes classified as immune and 8 as moderately susceptible, suggesting a high level of genetic diversity. Correlation analyses revealed significant associations, such as between plant height and pod insertion height, and negative correlations between biochemical and morphological traits. These findings highlight the adaptive potential of local germplasm and its value for breeding programs aimed at improving yield, nutritional quality, and disease resistance.

Key words: bean genotypes, morphological traits, quality traits, foliar diseases

The common bean (*Phaseolus vulgaris* L.) is one of the most important legume crops worldwide, serving as a major source of dietary protein, carbohydrates, vitamins, and minerals, particularly in developing countries (Broughton et al., 2003; Blair et al., 2010). Beyond its nutritional value, the crop holds significant agronomic and socio-economic importance, especially in regions where it is a staple food and contributes to the livelihoods of smallholder farmers (Beebe et al., 2013).

Local landraces of common bean, maintained through traditional agricultural practices, represent a valuable reservoir of genetic diversity (Sonnante et al., 2009). These landraces are often characterized by considerable variability in morphological, physiological, and biochemical traits, shaped by natural selection, human preferences, and specific agroecological conditions (Singh et al., 1991; Gepts & Bliss, 1988). Understanding and documenting this variability is critical for the conservation and effective utilization of genetic resources in breeding programs aimed at improving yield, stress tolerance, and nutritional quality (Sperling, 2001; Blair et al., 2010).

The evaluation of morphological differences is a traditional method for determining evolutionary relationships and pedigree lines. It is particularly useful in common bean, where numerous phenotypic differences—such as seed size, shape, and pattern are evident (Singh et al., 1991; Gaitán-Solís et al., 2002).

This study aims to explore and analyze the extent of variability present in selected common bean landraces, with a focus on key morpho-physiological and biochemical traits. By evaluating these characteristics, the research seeks to provide insights into the adaptive potential and genetic diversity of local germplasm, which are essential for

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the development of sustainable bean improvement strategies (Beebe et al., 2013; Blair et al., 2010).

MATERIAL AND METHOD

The present study was carried out during 2023-2024, in the experimental field and labs of Suceava Gene Bank

Forty beans local populations coming from Romania and neighbors countries (table 1) were sown and evaluated over two consecutive years. Each genotype was sown in one replication on two rows, with a row spacing of 0.60 m. The agronomic practices and plant protection measures were carried out in accordance with good practices.

Nine traits, including plant height (PH); number of days from emergence to flowering (DF); height of first pod insertion (HP); length of mature pod (LP), number of ovules per pod (NP); resistance to *Xanthomonas (RX);* protein content (PC); amino acid content (AC) and cooking time (CT) were accomplished (ECPGR descriptor list, 2010).

The protein content of studied beans local population was accomplished with Kjeldahl method (Nielsen, 2017).The determination of amino acids content was carried out using spectrophotometry after the reaction with ninhydrin (Nielsen, 2017). The cooking time was measured using an electric hot plate with a thermostat.

Statistical analyses for studied traits was estimated by, variation amplitudes, correlations coefficients and variance components, methods based on the analyses over two growing seasons (Burton &Vane, 1953; Shivendra et al., 2024).

Table 1

The origin of the bean samples evaluated in the field and laboratory in the years 2023- 2024.

No.crt.	Accession number	Collecting site	No.crt.	Accession number	Collecting site
1	SVGB-19319	Vaslui, Lipovat	21	SVGB-15488	Vrancea, Carligele
2	SVGB-21456	Viisoara , R. Moldova	22	SVGB-19345	Constanta, Constanta
3	SVGB-8201	Cainari, Republica Moldova	23	SVGB-8123	Bistrita Nasaud, Zagra
4	SVGB-14689	Bistrita Nasaud, Livezile	24	SVGB-5449	Caras-Severin, Lapusnicel
5	SVGB-14245	Alba, Almasu de Mijloc	25	SVGB-19336	Pusta, Ungaria
6	SVGB-2382	Suceava, Frumosu	26	SVGB-18278	Harghita, Mihaileni
7	SVGB-19353	Botosani, Corni	27	SVGB-15311	Salaj, Plesca
8	SVGB-3899	Vrancea, Podu Stoica	28	SVGB-11590	Botosani, Hudesti
9	SVGB-21460	Corpaci, R. Moldova	29	SVGB-18684	Botoșani, Botoșani
10	SVGB-19341	Tapiobicske, Ungaria	30	SVGB-17563	Iasi, Focuri
11	SVGB-2061	Iasi, Iasi	31	SVGB-15222	Hunedoara, Bulzestii de Sus
12	SVGB-18859	Suceava, Lucăcești,	32	SVGB-14713	Bistrita Nasaud, Anies
13	SVGB-2047	Iasi, Iasi	33	SVGB-2270	Suceava, Brodina
14	SVGB-20165	Malo Konare, Ungaria	34	SVGB-5376	Mures, Galaoaia
15	SVGB-19340	Botosani, Corni	35	SVGB-2909	Gorj, Sohodol
16	SVGB-18293	Harghita, Voslobeni	36	SVGB-19303	Vaslui, Pietrosu
17	SVGB-1988	Suceava, Bosanci	37	SVGB-21464	Cotu Morii R. Moldova
18	SVGB-4507	Iași Podu Iloaie	38	SVGB-14614	Suceava, Botus
19	SVGB-21458	Balauresti R. Moldova	39	SVGB-14650	Suceava, Costisa
20	SVGB-12255	Suceava, Straja	40	SVGB-18688	Botoșani, Botoșani

RESULTS AND DISCUSSIONS

Morphological Characterization

For the descriptors plant height, number of days from emergence to flowering, height of the first pod insertion, length of the mature pod, and number of ovules per pod, the average (x), variation amplitude, standard deviation (√s), and coefficients of variation (s%) were calculated.

The five morphological descriptors related to plant and fruit architecture are presented in Table 2. The interpretation of the results is based on the determination of the coefficient of variation, as an expression of the diversity of the studied biological material, with a high coefficient of variation observed — over 20% — for the number of days from emergence to flowering and the number of ovules per pod.

Table 2

Estimators calculated from morphological descriptors performed on the analyzed bean samples

Descriptor	Average	Maximum values	Minimum values	Standard deviation	Coefficient of variation (%)
plant height (PH)	35.17	82	18	16.56	11.57
number of days from emergence to flowering (DF)	72.15	78	68	3.90	23.23
height of first pod insertion (HP)	29.7	35	25	4.16	7.03
length of mature pod (LP)	7.43	8	5	1.91	18.60
number of ovules per pod (NP)	0.62	1.2	0	0.16	70.05

Resistance to *Xanthomonas campestris pv.phaseoli* under Field Conditions of the Analyzed Bean Cultivars

Study of the variability regarding the resistance to micromycete *Xanthomonas campestris pv.phaseoli*, of 40 bean genotypes under agro climatic conditions in the experimental field of the Suceava Gene Bank in two years (2023, 2024), were accomplished. The micromycete manifested during the vegetation period, starting from emergence until plant maturation.

During the two years of experiments the micromycete *Xanthomonas campestris pv.phaseoli* presented a moderate variability of the intensity of the attack from immune to moderately susceptible with an amplitude of variation (Xmax, Xmin) ranging between 0-21.07 (Table 3). Also, the value of the variance (28.81) and the coefficient of variation (65.52%) (Table 3) signifies a heterogeneous distribution of the disease within the analysed bean samples

During the testing period, the bean genotypes exhibited different levels of resistance to the fungal pathogen *Xanthomonas campestris* pv. *phaseoli*, according to the FAO scoring system (scale 1–9). Out of the 40 accessions analysed, 3 were immune, 4 resistant, 10 moderately resistant, 15 slightly resistant, and 8 moderately susceptible (table 4)

The histogram of the fungal pathogen *Xanthomonas campestris* pv. *phaseoli* (Fig. 1) displays a platykurtic distribution (Kurtosis > 3 / –0.28), with values varying around the mean and fewer in the tails of the graph. The variation curve shows a positive skew, inclined to the right toward the area of higher disease severity (Skewness < 0 / 0.65), indicating a transitional distribution of the disease infestation pattern — from resistant indicating a transitional distribution of the disease infestation pattern — from resistant genotype reactions toward moderate susceptibility in some genotypes (15 genotypes in the MR–MS transition and 8 moderately susceptible).

Table 3

Statistical parameter values for *Phaseolus spp.* genotypes tested for common blight

Estimators / Common blight	Average (X)	(Xmin)	(Xmax)	Kurtosis	Skewness	Variance (S^2)	Coefficient of variation (S %)
Xanthomonas campestris pv.phaseoli	8.18	0	21.07	-0.28	0.65	28.81	65.52

Table 4

Resistance response of *Phaseolus* spp. genotypes to common blight

Name of pathogen	Tested genotypes (number)	Infested genotypes (number)	Infection percentage (%)	FAO scoring	Resistance level of the analyzed bean genotypes
Xanthomonas campestris pv.phaseoli	40	3	0-0,75	1	Immune
		4	2- 4	3	Resistant
		10	4-7	4	Moderately resistant
		15	7-13	5	Transition from MR to MS
		8	13-21	6	Moderately susceptible

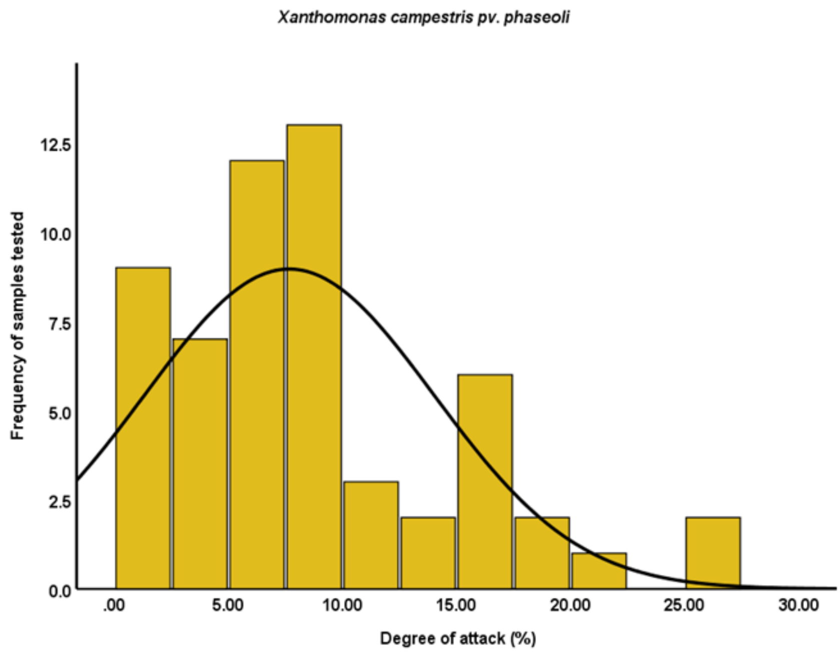

Fig. 1. Histogram Showing the Distribution of *Phaseolus vulgaris* Genotypes Tested for Common Bacterial Blight"

Biochemical Analyses of the Studied Bean Genotypes

For both biochemical descriptors and cooking time, the arithmetic mean (x̄), range of variation, standard deviation (√s), and coefficients of variation (s%) were calculated. The three seed quality descriptors are presented in Table 5, where a high variability is observed in amino acid content (32.46%), while the other two traits show very low variability (below 10%).

Correlation of Morphological and Quality Traits in Local Populațions of *Phaseolus vulgaris*

The table 6 presents the Pearson correlation coefficients for 8 morphological and quality traits measured in 40 bean populations stored in Suceava Gene Bank. The coefficients range from negative to positive values, indicating varying degrees of association between traits.

Negative Correlations: BT shows significant negative correlations with several traits, such as PH, HP and AC. This suggests that BT tend to have lower values for these traits.

Positive Correlations. HP shows positive correlation with two traits, PH and NP**,** indicating that height of first pod insertion might be associated with plant height and number of ovules per pod (NP)

Table 5

Statistical estimators for seed quality descriptors in the bean samples under study

Descriptor	Average	(Xmin)	(Xmax)	Standard deviation	Coefficient of variation (%)
Protein content (% d.m.)	21,23	25,91	12,67	2,24	7,04
Free amino acids content (%)	1,27	1,74	0,72	0,17	32,46
Boiling time (min)	64,48	109	39	19,85	6,90

Table 6

The Pearson correlation coefficients, between analyzed traits at40 common bean local landraces

	PH	DF	HP	LP	NP	PC	AC	BT
Plant height (PH)	1							
number of days from emergence to flowering (DF)	-.079	1						
height of first pod insertion (HP)	**,293***	.155	1					
length of mature pod (LP)	.186	-.007	.168	1				
number of ovules per pod (NP)	.013	.005	**,296***	-.068	1			
Protein content (PC)	-.194	-.219	-.096	-.025	.132	1		
Free amino acids content (AC)	-.060	-.160	.188	-.045	-.007	.179	1	
Boiling time (BT)	**-,274***	.004	**-,274***	.001	-.036	.209	**-,281***	1

CONCLUSIONS

- The evaluated local populations of *Phaseolus vulgaris* exhibited substantial genetic diversity in both morphological and biochemical traits, underlining their potential as valuable resources for breeding and conservation.
- Morphological traits such as days from emergence to flowering and number of ovules per pod showed high coefficients of variation, indicating broad adaptability and selection potential within the germplasm.
- The resistance to *Xanthomonas campestris* pv. *phaseoli* varied significantly among genotypes, with a portion of the populations demonstrating immunity or high resistance. This provides promising material for developing disease-resistant cultivars suited to regional agro-climatic conditions.
- Among the biochemical traits, amino acid content displayed the greatest variability, which could be utilized to enhance the nutritional value of common bean varieties.
- The observed correlations among traits—both positive and negative—offer important insights into the relationships between plant architecture and seed quality, informing selection strategies in breeding programs.

ACKNOWLEGMENTS

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EFFECTS OF A SEAWEED-BASED BIOSTIMULATOR ON TOTAL CHLOROPHYL AND TOTAL SUGAR CONTENT IN BITTER CUCUMBER (*MOMORDICA CHARANTIA*)

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Abstract

The growth of the global population and the pressure on food resources require finding sustainable solutions for agriculture. Biostimulants, organic compounds with a role in stimulating the physiological and biochemical processes of plants, represent an ecological alternative for increasing productivity. In this study, the effect of the biostimulant Algevit, based on seaweed extract, on five genotypes of *Momordica charantia* was analyzed. The experiments were carried out under controlled conditions, applying treatments with Algevit 0.5%. The determinations targeted the total chlorophyll content and the concentration of carbohydrates, essential parameters for the photosynthetic intensity and the nutritional value of the fruits. The results showed a significant increase in photosynthetic pigments in all treated genotypes, with the largest difference observed in Line 1 followed by Line 4. The sugar content also increased between 21% and 31%, with the maximum in Line 1. Statistical analysis revealed a strong positive correlation between photosynthesis and carbohydrate accumulation.

Key words: *Momordica charantia, biostimulator, chlorophyll, sugars*

The continuous growth of the global population places significant pressure on food resources, leading to a real increase in food insecurity, which requires the identification and implementation of sustainable and long-term solutions to ensure adequate food supply (Miladinov G., 2023). According to the United Nations, the population is expected to exceed 9 billion by 2050 and reach a peak of 9.73 billion in 2060 (Daszkiewicz T., 2022). At present, plants represent the main source of food worldwide, which imposes the need for the sustainable use of arable land in order to obtain high yields necessary to meet increasing demands (Tachie C., Nwachukwu I. D. and Aryee A. N. A., 2023). However, natural factors such as high temperatures, drought, UV radiation, salinity, and climate change, along with anthropogenic factors such as pollution from chemical fertilizers and pesticides, contribute significantly to the reduction of agricultural production (Moldavan L. *et al.*, 2024; Mishra H., 2025).

Biostimulants represent a class of organic compounds characterized by the absence of toxic effects on both plants and soil. They contain organic substances or microorganisms that play a role in stimulating and modulating the main physiological and biochemical processes in plants (Drobek M., Frąc M. and Cybulska J., 2019). These compounds can enhance plant growth, development, and resistance by optimizing nutrient uptake, increasing photosynthetic efficiency, and improving the activity of defense mechanisms, thus supporting the health and productivity of agricultural crops in a sustainable manner (Yakhin O. I. *et al.*, 2017).

Photosynthesis is the most important physiological process in plants, whose efficiency is strictly dependent on the optimal concentration of photosynthetic pigments (Tanaka A. and Makino A., 2009; Muhammad *et al.*, 2021). A high amount of photosynthetic pigments is an essential indicator of plant health, reflecting their enhanced capacity to capture light and carry out the photosynthetic process efficiently. Maintaining and protecting adequate pigment levels directly contributes to increased productivity and crop yield (Alisofi S., Einali A. and Sangtarash M. H., 2020; Kumar M. *et al.*, 2021).

Through the Calvin cycle, the photosynthetic process results in organic compounds, primarily carbohydrates (Li W. *et al.*, 2019). A high amount of carbohydrates in leaves is strictly dependent on

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the intensity of photosynthesis. After fruit formation, the carbohydrates accumulated in the leaves are translocated through the vascular system to the storage organs. The mobilization of carbohydrates toward the fruits is essential for increasing their mass and volume, which leads to higher agricultural (Marquardt A., Henry R. J. and Botha F. C., 2021; Ren Y., Liao S. and Xu Y., 2023).

Momordica charantia is a tropical and subtropical climbing plant belonging to the Cucurbitaceae family. Commonly known as bitter melon, this plant is widely cultivated in South America, Asia, and East Africa (Czompa A. *et al.*, 2017). Momordica charantia contains a wide range of biologically active compounds, including proteins, alkaloids, saponins, flavonoids, triterpenes, and amino acids, which confer antiviral, antifungal, antibacterial, antiparasitic, antitumor, and hypoglycemic properties, earning it the name "green insulin" (Abascal K. and Yarnell E., 2005; Joseph B. and Jini D., 2013). Bitter melon is valued in nutrition for its high content of minerals such as copper (Cu), calcium (Ca), iron (Fe), magnesium (Mg), and zinc (Zn). The fruit is rich in several nutrients, including vitamins A and C, tocopherols, thiamine, riboflavin, niacin, and folic acid (Yuwai K. E. *et al.*, 1991).

MATERIAL AND METHOD

2.1 Materials

Momordica charantia leaves, 80% acetone (C_3H_6O), anthrone ($C_{14}H_{10}O_2$), sulfuric acid (H_2SO_4), glucose ($C_6H_{12}O_6$).

2.2 Methods

Algevit is a commercial biostimulant based on seaweed extract (Ascophyllum nodosum, 30%), containing 3.9% potassium oxide, 1.5% alginic acid, and 0.5% mannitol. It stimulates photosynthesis, increases plant resistance to stress, reactivates metabolism, and delays cellular aging. It improves nutrient uptake and availability through the formation of complexes with micronutrients, promotes root system development, and enhances physiological processes. It also induces early flowering, improves fruit set, and increases the uniformity and quality of production. It is applied foliarly (200–300 mL/100 L water) or to the roots (3–5 L/ha), and is compatible with most plant protection products, though compatibility testing is recommended before use [20].

Plant material preparation:

For the experiment, five bitter melon genotypes were used, including two Romanian cultivars (Rodeo and Brâncuși) and three experimental lines (Line 1, Line 3, and Line 4). Seeds of equal size were selected, sterilized for 5 minutes with sodium hypochlorite, and then rinsed with distilled water. The experiment was carried out in the greenhouse of the Research Institute for Agriculture and Environment (ICAM) belonging to the "Ion Ionescu de la Brad" University of Life Sciences Iași. The seeds were sown in trays and kept at a temperature of 26°C during the day and 20°C at night, with 70% relative humidity. After germination, the seedlings were transferred into vegetation pots and divided into control variants and variants treated with 0.5% Algevit biostimulant. Two treatments were applied during the experiment at 5-day intervals. Leaves were harvested at BBCH phenological stage 102, corresponding to the full development of the first true leaves.

Chlorophyll determination:

A 0.5 g sample of plant material was used for the analysis of photosynthetic pigments. The leaf was ground in the presence of acetone, and extraction was performed using a Gooch filter. The obtained extract was brought to a final volume of 50 mL with acetone. Measurements for total chlorophyll determination were taken at 663 and 645 nm. Absorbance values were quantified using the following formula:

Total chlorophyll (mg/g) = (8.2 · A663) + (20.2 · A645)

where A663 and A645 represent the absorbances measured at 663 nm and 645 nm, respectively (Khaleghi *et al.*, 2012; Cojocariu *et al.*, 2024). Each analysis was performed in triplicate.

Carbohydrate determination:

For total carbohydrate determination, 0.1 g of plant material was homogenized and extracted in water, then 1 mL of the extract was mixed with 5 mL of anthrone reagent (0.2% anthrone in concentrated sulfuric acid). The mixture was heated in a water bath at 90–100°C for 15 minutes, cooled to room temperature, and absorbance was measured at 620 nm. Total carbohydrate concentration was calculated by comparison with a standard glucose calibration curve. Each analysis was performed in triplicate.

Statistical analysis:

Data were statistically analyzed using Duncan's post-hoc test, which provides information on significant differences between the values shown in the graphs, and Pearson's correlation matrix, in order to identify the relationship between photosynthetic intensity and carbohydrate content.

RESULTS AND DISCUSSIONS

Photosynthesis is the physiological process through which plants synthesize organic substances from mineral salts, CO_2, and H_2O in the presence of sunlight and photosynthetic pigments, with the release of O_2 (Toma L. D. and Jităreanu C. D., 2007; Marta A. E., Covașă M. and Jităreanu C. D., 2025). The total chlorophyll pigment content indicates photosynthetic capacity, growth, nutritional status, and plant health—factors that ultimately influence crop yield and quality (Buchanan B. B. and Balmer Y., 2005).

Analysis of the total chlorophyll content showed that the control variants recorded a minimum of 15.58 mg/g in genotype Line 4 and a maximum of 18.57 mg/g in genotype Line 3. The significant differences observed in total pigment content may reflect genetic variation among the bitter melon genotypes studied (Fig. 1).

Application of the commercial seaweed-based biostimulant resulted in an increase in photosynthetic pigment content in all analyzed genotypes. According to a study by the European Biostimulants Industry Council (2023), increases in chlorophyll content can be attributed to the presence of phytohormones such as auxins, cytokinins, and gibberellins, which enhance the number and size of chloroplasts, improve granal development, and intensify photosynthetic reactions (EBIC, 2023). The greatest increases compared to the untreated control were observed in genotypes Line 4 (23%) and Line 1 (39%). In contrast, the smallest increase was recorded in Line 3, with a 16% difference relative to the control. Similar responses have been reported in the literature by Himanshu Sati and colleagues (2021), who observed the strongest increase in total pigment content after applying a biostimulant treatment based on the algae Kappaphycus alvarezii (0.4%). The authors attributed these changes to quaternary ammonium compounds such as glycine betaine, which support photo-assimilation rates and thus indirectly contribute to increased photosynthetic pigment content (Sati H. *et al.*, 2021).

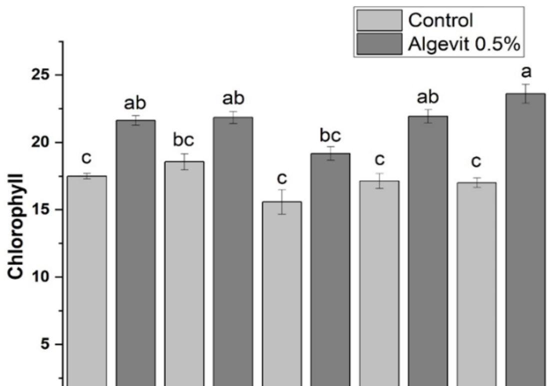

Figure 1. **Influence of Algevit biostimulant treatments on total chlorophyll content in the studied *Momordica charantia* genotypes, expressed in mg/g; B – Brâncuși, L3 – Line 3, L4 – Line 4, R – Rodeo, L1 – Line 1;** followed by treatment: M – Control, A – Algevit 0.5%. Error bars represent the standard deviation of three replicates, and letters indicate significant differences identified through Duncan's post hoc test.

Carbohydrates represent the main energy source for plants, playing a fundamental role in photosynthetic and metabolic processes and in the biosynthesis of structural compounds. These compounds accumulate in fruits, directly influencing both yield and nutritional value (Lal M., 2018; Khornti S., 2023).

Analysis of the obtained results showed different carbohydrate levels among the five bitter melon genotypes. The highest value in the control was recorded in genotype Line 3 (44.07 mg/100g), while the lowest was observed in Line 4 (35.90 mg/100g). Application of the Algevit biostimulant increased carbohydrate concentration in all genotypes, demonstrating a strong positive effect. Mahbobeh Zamani-Babgohari and colleagues (2019) tested the effect of an Ascophyllum nodosum-based biostimulant on tobacco plants and reported increased carbohydrate content due to upregulation of GOLS2 and GOLS3 genes involved in carbohydrate biosynthesis and downregulation of genes related to sucrose degradation (Shukla P. S. *et al.*, 2019). The most pronounced increase was observed in Line 1, where carbohydrate content rose by 31%. The smallest increases compared to the control were found in Line 3 (23%) and Rodeo (21%).

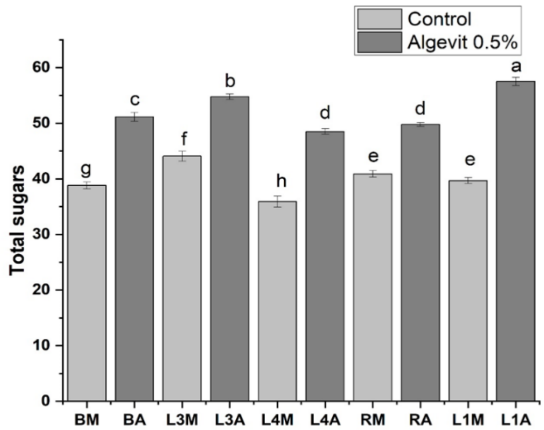

Figure 2. **Influence of Algevit biostimulant treatments on total carbohydrate content in the studied *Momordica charantia* genotypes, expressed in mg/100g; B – Brâncuși, L3 – Line 3, L4 – Line 4, R – Rodeo, L1 – Line 1; followed by treatment: M – Control, A – Algevit 0.5%.** Error bars represent the standard deviation of three replicates, and letters indicate significant differences identified through Duncan's post hoc test (n = 3).

To identify the relationship between photosynthetic intensity and total carbohydrate content following the application of the seaweed-based biostimulant, a Pearson correlation matrix was generated. Specific notations composed of letters and numbers were used for this statistical test.

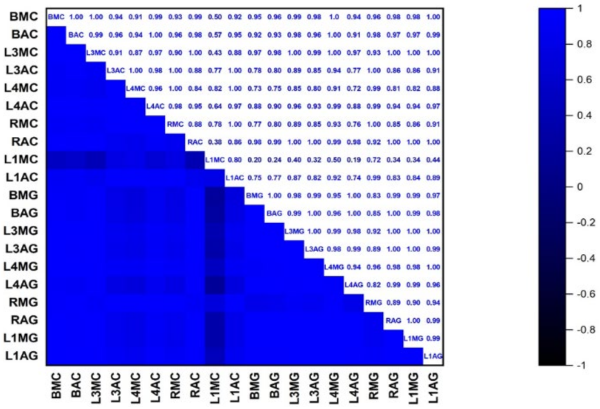

Figure 3. **Pearson correlation matrix constructed between total chlorophyll content and total carbohydrate content. Pearson correlation values were obtained using three replicates for each analysis (n = 3).**

The first letters represent the studied genotypes (B – Brâncuşi, L3 – Line 3, L4 – Line 4, R – Rodeo, L1 – Line 1), the next letters indicate the applied treatment (M – Control, A – Algevit 0.5%), and the final letters represent the analyzed parameter (C – Total chlorophyll content, G – Soluble carbohydrate concentration).

The lower part of the matrix shows color gradients from dark blue (low correlation) to light blue (strong positive correlation). The upper part displays the actual Pearson correlation coefficient values.

According to the statistical results, a positive correlation can be observed between the two analyzed parameters, confirming the direct relationship between increased photosynthetic pigment content and total carbohydrate accumulation. A very strong positive correlation was particularly evident in Line 1—the genotype that exhibited the highest increase in both analyses (r = 0.92). This confirms that this genotype is the most compatible with the *Ascophyllum nodosum*-based biostimulant. Although the correlation is very strong and the percentage increases are similar, they are not identical, as carbohydrate synthesis and accumulation are influenced to some extent by genetic, enzymatic, and hormonal regulatory factors, each acting through specific mechanisms (Seydel C. *et al.*, 2022; Mehdi F. *et al.*, 2024).

CONCLUSIONS

Following the application of Algevit biostimulant treatments, a significant increase was observed in both total chlorophyll content and total carbohydrate levels, highlighting a favorable physiological response of the bitter melon genotypes. This suggests a potential increase in yield and nutritional value.

The application of the biostimulant had the most pronounced beneficial effect in the case of genotype Line 1, indicating a high level of compatibility between this genotype and the applied product. This provides strong support for their combined use in order to maximize production.

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AGRICULTURAL LAND DEGRADATION IN BOTOȘANI COUNTY THROUGH EROSION PROCESSES, LANDSLIDES AND EXCES HUMIDITY

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Abstract

A series of natural phenomena, but especially anthropogenic intervention on some of the ecosystem components have contributed to the manifestation of processes by which soils insidiously lose their properties that make them suitable for agricultural use. Therefore, it was considered necessary to identify areas in Botoșani County with agricultural lands affected by erosion, landslides and excess humidity. Establishing the areas affected by limiting factors of fertility and the physical condition of land improvement works carried out to combat the effects of natural phenomena that negatively influence crops. These studies can provide useful information for reconsidering measures and works that can contribute to the valorization of areas with unproductive soils, increasing the productivity of lands with poorly productive soils and creating conditions for increasing the quality of life in local communities.

Key words: soil erosion, landslide, water excess, land reclamation, Botoșani County

INTRODUCTION

Soil erosion has favorable conditions for manifestation in Botoșani County, given that a large part of the land has undergone a change in its natural state by removing the vegetation cover and transforming it into arable land and secondary pastures.[1] Despite the fact that one of the favoring morphometric factors - slope - has low and medium values on most of the territory, the removal of natural vegetation has disturbed the natural balance on the one hand and deprived the soil of its protective blanket in relation to morphogenetic agents. On the one hand, on arable land, agricultural works affect the structure and cohesion of the upper soil horizon, increasing its vulnerability in relation to pluvio denudation, runoff and torrential rain.[2]

At the same time, by changing the type and properties of the vegetation cover, conditions were created to accelerate suffocation processes (especially in the northwestern compartment of the Jijiea Plain), resulting in the formation of ridges and valleys that change the micromorphology of the relief but also generate the removal of part of the nutrients from the soil, with the loss of fertility and productivity.

On the other hand, overgrazing leads to a decrease in the grass layer, which loses mass and density, and the formation of cattle tracks favors the concentration of runoff in streams and the process of siltation.

The sedimentary substrate in which alternations of sandy and clayey rocks are present induces a certain predisposition to the occurrence of landslides. In addition to the petrographic characteristics, among the favorable factors can also be mentioned: the slope with medium and high inclination, the depreciation of the natural vegetation layer (its role is also manifested by the delay of water infiltration, but also by the root system of the plants that fix the soil, increasing its cohesion).

According to the existing PATJ Botoșani, the landslide situation is different in the geomorphological subunits of the Moldavian Plateau found on the territory of the county. Thus, the plateau area is characterized by landslides of different ages, over the old ones, generally stabilized, often overlapping new landslides, with smaller thicknesses and extents. On the other hand, in the hilly plain, superficial landslides are predominantly found, with a predominantly clayey substrate. Eight types of landslides can be identified at county level (according to PATJ Botoșani, 2012)

- Landslides in the form of mounds: the most widespread in the county, they have a hilly appearance, in the form of mounds;

[1] Boegiu Sandu, Grigoraș Constantin, 2024;- Soils of Romania, University Publishing House, Bucharest.

[2] Târziu Dumitru, 2004- Pedology with elements of geodesy, Silvodel Publishing House, Bucharest.

- Terraced (stepped) landslides: occupy fairly large areas, especially in the area of the cuestas made up of alternating permeable and impermeable rocks;
- Wave-shaped landslides: determined by the alternation of layers of sand and clay-marl;[3]
- Mixed fragmentation landslides: formed by a microrelief in the form of mounds, waves and landslide terraces;
- Semicircular nest-shaped landslides: occur on marls and clays in the event of the appearance of groundwater lenses on the surface;
- Landslides of the hilltop type (slide cirques): have the shape of depressions similar to glacial cirques, they form in torrent reception basins;[4]

Excess moisture and claying affect important surfaces, especially in river meadows and where the slope does not ensure efficient drainage of precipitation water, or due to the water table being located very close to the surface. Compared to the situation of excess moisture, which can be perceived as a physical manifestation of inefficient drainage, claying involves the development of an alternation of chemical oxidation and reduction processes; the latter lead to the appearance of iron and manganese compounds, inhibiting the assimilation of phosphorus and nitrogen by transforming them from assimilable forms into non-assimilable forms (phosphates of Fe, Mn, Al).

The purpose of the research is to identify areas affected by erosion, landslides or excess humidity in Botoșani County and also to establish measures that can be taken to reduce degraded areas.[5]

MATERIAL AND METHOD

The work was developed using data kindly provided by the Botoșani Agriculture Directorate, the Botosani Territorial Branch of Land Improvements and the communal agricultural chambers in the territory, as well as based on detailed studies and observations carried out in the field by the authors.

Topographic maps (scale 1:50,000; 1:100,000) and soil map (scale 1:200,000) of the studied area were also used.

To carry out the scientific approach, specific stages were completed that aimed at documentation, conducting observations and measurements in the field, analyzing and processing data obtained in the laboratory, and preparing the final material.

Bibliographic documentation consisted of consulting various books and scientific articles on the process of soil erosion and prevention and control measures. Titles developed by specialists from the country but also from other areas with similar physical-geographic and climatic conditions were consulted.

RESULTS AND DISCUSSIONS

Regarding soil erosion control works (CES), they are present on the territory of 66 UATs, totaling 126510.5 ha (Figure 1), the average area/UAT being 1916.7 ha. These aim to reduce superficial or linear erosion processes (runoff, ravinement), given that the lands taken up for agricultural cultivation are particularly susceptible to being affected by such phenomena, especially given the torrential nature of precipitation (especially in summer). The CES arrangements on the territory of Botoșani County are represented in the table below.

Table 1.

CES developments in Botoșani County

Number	Designation name	Surface
1	CES Balabani Dimăcheni	625
2	CES Bucecea-Corni	3.150
3	CES Burla	11.500
4	CES Coasta Burlești	232
5	CES Cozancea	3.535
6	CES Cucorăni	5.147
7	CES Curtești Prășeni	1.388
8	CES Dorohoi – Davidoaia	4.905
9	CES Hănești Dângeni	544
10	CES Horia-Liveni-Manoleasa	6.758
11	CES Ibăneasa	5.317
12	CES Jijia Dorohoi-Ungureni	4.679
13	CES Jijia Superioară	13.269
14	CES Miletin	6.339
15	CES Morișca	11.302
16	CES Podriga	9.559
17	CES Poienile Harigii	1.950
18	CES Pomi Avrămeni	292
19	CES Pomi Frumușica	670
20	CES Pomi Răchiți	324

[3] Jesús Rodrigo-Comino, Artemi Cerdà, 2018 - Improving stock unearthing method to measure soil erosion rates in vineyards, Ecological Indicators, vol. 85, p. 509-517.

[4] Jiang C., Haiyan Zhang, Zhidong Zhang, Dewang Wang, 2019 - Model-based assessment soil loss by wind and water erosion in China's Loess Plateau: Dynamic change, conservation effectiveness, and strategies for sustainable restoration, Global and Planetary Change, vol. 172, p. 396-413.

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21	CES Pomi Vorona	253
22	CES Sitna	5.087
23	CES Stăuceni-Siliștea	408
24	CES Terase Albești	731
25	CES Valea Viilor	163
26	CES Vii Bălușeni	306

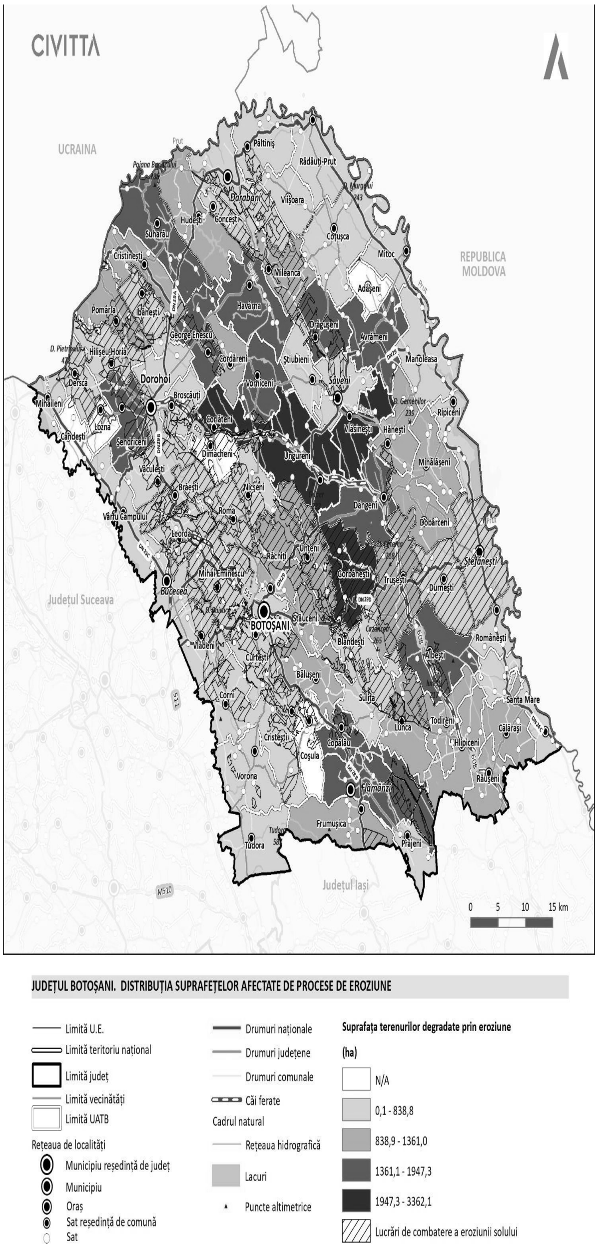

Figure 1 Distribution of areas affected by soil erosion

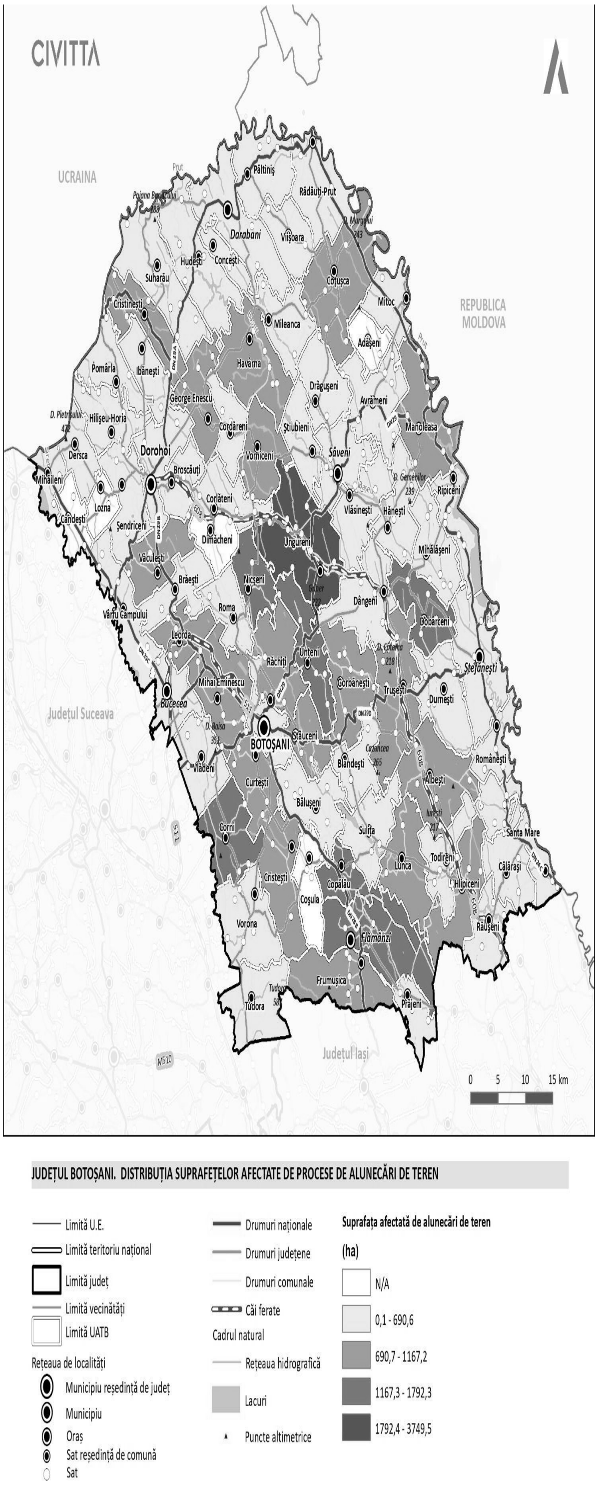

Figure 2 Distribution of areas affected by landslides

In the territory of Botoșani County, the total area affected by landslides is 48,012 ha (figure 2). At the level of UATs, the largest areas are present in the commune of Ungureni (over 3,700 ha), to which are added the UATs of Nicșeni, Dobârceni, Unțeni, Copălău, Corni, Flămânzi, Răchiți, Vorniceni, Hlipiceni, Manoleasa, Lunca, Frumușica, where areas of over 1,000 ha are affected.

As for the areas affected by excess humidity, they are found on an area of 30684 ha (*figure 3*), the largest being present in the Vârfu Câmpului (2055.8 ha) and Mihălășeni (1411 ha) ATUs. The drainage works were carried out on an area of 6314 ha and are present on the territory of 14 ATUs comprising a total of 6 drainage arrangements (*table 2*). The largest areas with such works were carried out in the Flămânzi (1218 ha) and Vârfu Câmpului (1009 ha) ATUs.

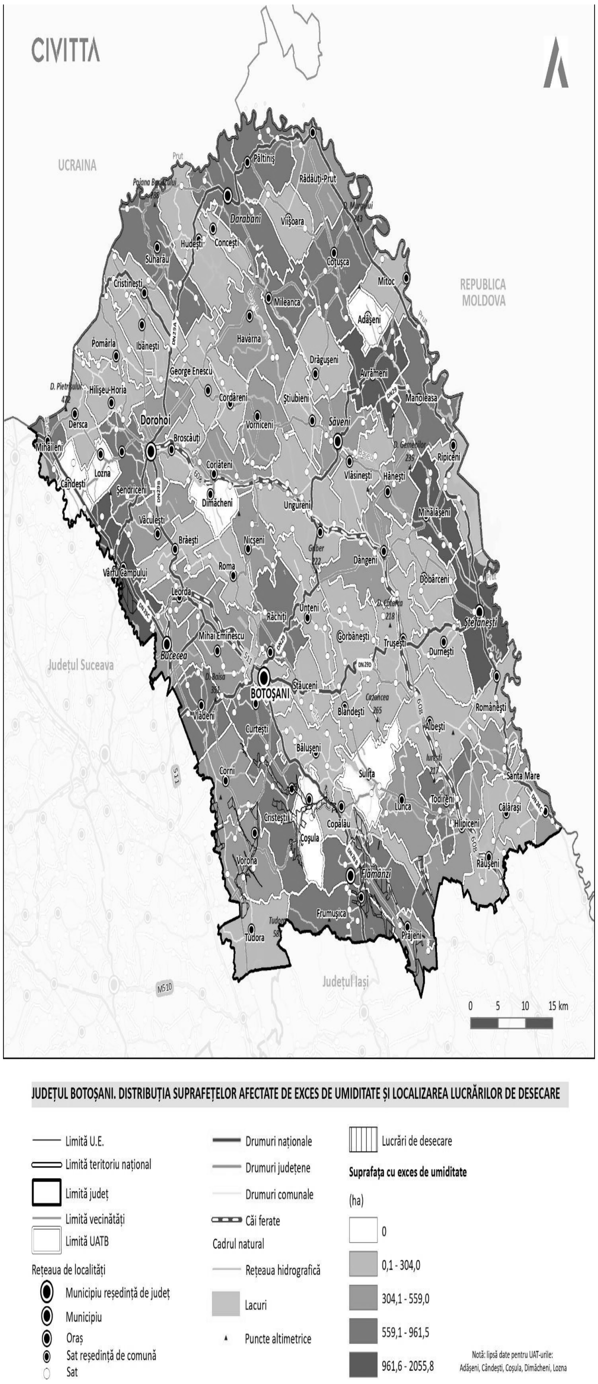

Figure 3 Distribution of surfaces affected by excess moisture

Table 2

Drainage facilities

Number	Designation name	Surface(hectare)
1	Draining Curtești-Prăjeni	2500
2	Drainig Miletin	203
3	Draining Bucecea-Corni	5226
4	Draining Tudora-Corni	1314
5	Draining Poienile-Harigii	550
	Draining Coșula-Oneaga	1741

CONCLUSIONS

In conclusion, the issue of soil degradation in the territory of Botoşani County has a complex causality (meteo-climatic, hydrological and edaphic causes) so that it is necessary to carry out works in certain areas to protect the soil as best as possible in relation to the processes that can generate a reduction in fertility or even removal from the agricultural production circuit.[6] Regarding the fight against soil erosion, the specific works that must be carried out on the affected areas are: the creation of grassed outlets, the construction of terraces and horizontal channels and last but not least, the planting of strips of trees as protective curtains. Also, excess humidity can be reduced through drainage works. These works consist of the creation of drainage channels and underground drainage systems with the role of collecting water in areas where gravitational evacuation can be achieved, and where this is not allowed, the construction of pumping stations.[7]

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STRUCTURE OF AGRICULTURAL LAND USE CATEGORIES IN DIMĂCHENI COMMUNE

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Abstract

The area of agricultural land located on land with a slope greater than 5% in Botoșani County represents 285.11 thousand ha, i.e. 70% of their total. The analysis of the changes in the structure of the use categories in recent decades shows that the arable area increased by 2.8% reaching 219.6 thousand ha. Meadows have reduced their area by more than 5000 ha, while vineyards and tree plantations have registered insignificant changes but the trend is decreasing. These changes reflect the intensification of land use for field crops, simultaneously with the reduction of livestock and the decrease in interest in measures and works to prevent and combat soil erosion. The consequence of this state of affairs is the intensification of erosion processes and the decrease in agricultural production and the decrease in long-term soil protection. The results obtained show that appropriate agricultural policies are needed to reconsider anti-erosion concerns not only due to the unfavorable evolution of agricultural exploitation but also to improve and enhance significant areas of sloping agricultural land in an advanced state of degradation.

Keywords: use categories, soil erosion,land improvements, Botoșani county.

Soil refers to that external part of the earth's crust, made up of a mixture of mineral materials, water, atmosphere and organic matter, characterized by fertility and by being the basis of agricultural yield. It changes over time through physical, chemical or biological processes, which can have beneficial or harmful effects on it.

The land fund encompasses the total area of the territory, as well as its use, and the natural properties of the land fund constitute the basis of any agricultural business.

Of the total area of the country of 23.839 million hectares, the agricultural area occupies almost 15 million hectares (approximately 62%). The diversity of physical-geographical conditions and the temporal change of climatic, hydrological and hydrogeological parameters from time to time favor, on approximately 70% of the cultivated area, the reduction or annual losses of agricultural production due to the individual or collective influences of moisture deficit, excessive humidity, soil erosion, etc.

It will be found that most of those portions of agriculture that fall within the limiting factors require two types of recovery works. Therefore, river meadows, before exploiting their potential, require protection against floods, drainage, irrigation and, sometimes, desalination and/or adjustment of the soil reaction. The elimination of the negative effects of drought, excessive humidity and soil erosion is achieved by arranging the affected agricultural areas through land improvement works (irrigation, drainage, dams, erosion control, river regulation, etc.) which lead, as the case may be, to achieving a favorable hydrological, aerothermal and nutritional state of the soil for plant growth and development, as well as to protecting the territory from destruction by floods, erosion, clogging, pollution, etc.

MATERIAL AND METHOD

The agricultural potential of Botoșani County is remarkable if we consider its vast agricultural areas. Although today not all the agricultural area is fully exploited, the analysis predicts that, in the coming years, it will represent one of the greatest opportunities for economic cooperation from Botoșani County to entrepreneurs.

Information was taken according to the most recent data provided by the Botoșani county branch of the National Institute of Statistics, the situation of the agricultural land fund at the level of communes in Botoșani county.

At the same time, there are inaccuracies between the data provided by the National Institute of Statistics and the reality on the ground.

The analysis method was carried out through measurements using the QGIS application, but also through the platform of the Agricultural Payments and Intervention Agency (AGI), studying topographic maps (scale 1:50,000 and 1:100,000) and soils (scale 1:200,000) and querying the database provided by OCPI.

RESULTS AND DISCUSSIONS

According to figure 1, we observe the trend of transformations of use categories. Land with the use categories of orchards, vineyards, meadows and pastures is losing land areas in favor of arable land.

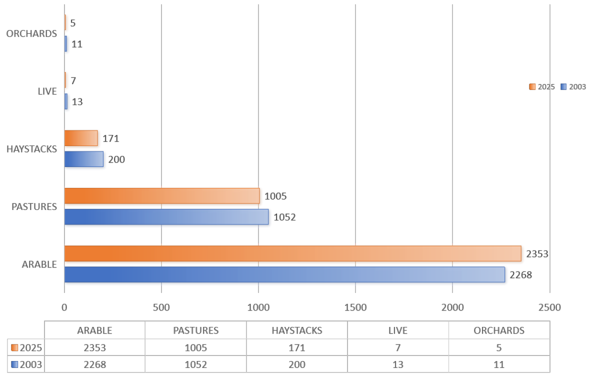

Figure 1 **Evolution of agricultural land in Botoșani County**

As for vineyards and orchards, following the restitution of land to the population - the recovery of previous pre-collectivization holdings - a systematic destruction of these plantations and deforestation followed. This created an alternation of narrow strips of arable land, oriented in the hill-valley direction. Such land arrangements generate negative areas from the following points of view: firstly, the complication of mechanization and the use of machines in the production process; secondly, the low productivity for certain crops incompatible with adjacent uses; and thirdly, the creation of areas with very high susceptibility to erosion.

Today, the commune of Dimăcheni is undergoing serious changes in the categories of use. Data from the National Institute of Statistics does not clearly reflect the situation on the ground. The modernization of agriculture brings with it changes in this sphere because farmers have begun to have pastures and hayfields where they are allowed to carry out agrotechnical soil processing works. "Slope" combines have a self-leveling system (the axes and the cutting table can tilt independently), so that the combine remains horizontal even if the land is sloping. This bonus brought to agricultural machinery encourages farmers to transform as much as possible the land that was once used only for grazing or mowing, into arable land, acceptable for growing field crops, namely wheat, barley, corn, rapeseed, sunflower, soybeans, etc.).

At the same time, the animals that were used for household use, but also as a source of income for certain farmers, are becoming fewer and fewer due to the fact that for most, they no longer consider it a source of income. The price of a liter of milk is 1.8 ron, which often does not cover the cost of production, according to cattle, sheep and goat breeders in this region.

Of the total area of 3544 Ha, 874 Ha are owned by SC ŞOIMII FERME SRL, a company with foreign capital that uses the land only for cereal production. SC COMCEREAL SA also owns an area of 230 Ha, Cojocariu Ștefan owns 107 Ha, SC GAVRIL SRL owns 217 Ha, MORUZ ELENA INTRPRINDERE INDIVIDUALA 260 Ha. Almost half of the total agricultural land is owned by 5 companies, and 123 APIA requests are registered annually at the City Hall.

The year 2024 stands out as a year with a negative impact on livestock farmers in Dimăcheni because through the afforestation program through the PNRR, approvals are being sought and have already been issued for the afforestation of 80 hectares of pasture land. This land was leased by the farmers from SC ȘOIMII FERME SRL. Since 2025, they have lost this area of land because they were forbidden to graze due to the fact that preparatory works for afforestation are beginning. Most farmers give up livestock farming over the years.

Table 1

Structure of use categories in Dimăcheni commune, Botoșani county

Category	2003 (ha)	2025 (ha)	Difference (ha)	Difference (%)	Intension
•Arable	2 268	2 353	+85	+4%	mild to moderate
•GRASSLAND	1052	1008	-44	-4%	mild to moderate
•Rough	200	171	-29	-14%	strong
•Live	13	7	-6	-53%	very strong
•Orchards	11	5	-6	-45%	very strong

In Dimăcheni commune, according to INSSE (National Institute of Statistics), compared to 2003, in 2025 the land structure is as follows:

- Strong–very strong trends (>5–15%) signal real structural processes: conversion, abandonment, replanting or change of destination.
- Strong–very strong trends (>40%) → signal major structural processes, namely the decline of perennial plantations and the conversion of land to simpler uses, dependent on annual crops.
- Mild–moderate trends (<5%) indicate stability and natural or administrative adjustments.

According to the AGI application, areas are noted where land use categories were no longer respected. From pastures and hayfields, in areas where they were allowed, farmers carried out soil cultivation work.

This has a negative effect on the soil and the environment by destroying the stable vegetation cover that protects the soil from erosion and drought. Microorganisms and biodiversity in the grass layer are lost. The risk of compaction and erosion increases if the land is on a slope.

The reason why farmers have started to have pastures is that the struggle for farm expansion is increasing, livestock numbers are decreasing from one year to the next, and the mechanization of agriculture allows them to work even on sloping land.

Ploughing of permanent pastures is generally prohibited under European and national legislation.

INTERPRETING TRENDS

1. INCREASE IN ARABLE LAND AND GRASSLANDS (PASTURES + HAYFIELDS)

➤ IT IS POSSIBLE THROUGH:

O Conversion of abandoned vineyards and orchards into arable land or meadows (very frequent phenomenon after 2000, especially in hilly and mountainous areas).
O Reclassification of land in agricultural statistics (e.g. land previously considered "unproductive" or "other uses" was integrated into the agricultural category after redevelopment or temporary use).
O Cessation of maintenance of perennial plantations, followed by plowing and sowing, hence the transition to "arable".

2. DECLINE OF VINEYARDS AND ORCHARDS

➤ GENERAL PHENOMENON IN ROMANIA BETWEEN 1990–2020:

O Aging of plantations and lack of their renewal.
O Fragmentation of property: smallholders can no longer maintain perennial plantations.
O Loss of economic interest in these crops, especially in the absence of processing centers.
O Converting the respective lands to annual crops or grasslands, for subsidies easier to obtain through APIA.

3. INCREASE IN AGRICULTURAL TOTAL.

➤ IT MAY HAVE ADMINISTRATIVE AND PHYSICAL CAUSES:

O Uncultivated / unused land (e.g. "other land" or "non-agricultural") has been recategorized as agricultural.
O Rehabilitation of degraded lands.
O Cadastral/statistical rectifications: some areas previously classified as "non-agricultural" (roads, unproductive areas, yards) may now be considered "agricultural" following INS or APIA updates.
Currently, procedures are underway for the afforestation of 80 hectares of land with the use category of pastures and hayfields.
This afforestation program through the PNRR (National Recovery and Resilience Plan), is to increase Romania's forested area and improve environmental quality, contributing to combating climate change and the sustainable development of rural areas by planting new forests, forest curtains on degraded, unproductive or erosion-risk lands. The program offers non-refundable grants (100% financing), and beneficiaries receive, in addition to financing for planting, annual compensatory payments for plantation maintenance and loss of agricultural income.

CONCLUSIONS

1. Significant transformations of agricultural land use

In recent decades, there has been an increase in arable land at the expense of pastures, hayfields, orchards and vineyards. These changes reflect a sharp focus on field crops and a decrease in interest in animal husbandry and the maintenance of perennial plantations.

2. Effects on the environment and soil

The conversion of pastures and hayfields into arable land, especially on sloping surfaces, has led to the degradation of the protective vegetation cover, increased risk of erosion, compaction and loss of soil biodiversity.

3. Administrative and economic cases

The changes are determined both by economic factors (decreased profitability of perennial crops, mechanization of agriculture, easier access to APIA subsidies), and by statistical and cadastral updates that have reclassified some land as agricultural.

4. Trend towards ecological rebalancing

The initiation of afforestation programs through the PNRR, such as the 80 ha in Dimăcheni commune, represents an important step towards restoring the ecological balance, combating erosion and increasing the forested area.

5. Perspectives

For sustainable management of agricultural land, it is necessary to implement integrated soil protection measures, stimulate the maintenance of permanent grasslands and support sustainable agricultural practices.

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INTEGRATED DRONE MULTISPECTRAL AND LIDAR ANALYSIS FOR ASSESSING WHEAT DEVELOPMENT DURING THE BOOTING STAGE

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Abstract

The use of multispectral imaging and LiDAR technology for monitoring wheat development during the booting stage was studied in a 2 hectare field located in Neamț County, northeastern Romania. A DJI Matrice 400 UAV equipped with multispectral and LiDAR sensors was deployed to collect high resolution spectral and structural data. Multispectral images were processed to generate a normalized difference vegetation index (NDVI) map, while LiDAR data were used to derive a realistic canopy height model (CHM), reflecting booting-stage wheat heights of 23–48 cm. The NDVI map revealed substantial spatial variability in crop vigor, and the CHM indicated corresponding differences in structural development. A strong positive relationship between NDVI and canopy height ($R^2 \approx 0.82$) demonstrated the complementary value of integrating spectral and structural indicators for crop assessment. The combined analysis effectively identified areas of reduced performance, suggesting potential nutrient or moisture limitations. Overall, the study confirms that UAV-based multispectral and LiDAR sensing provides reliable, early-season diagnostics that support precision agriculture and informed decision-making in wheat production.

Key words: multispectral imaging, LiDAR canopy height, precision agriculture

Agriculture has undergone a profound transformation in the last decades, driven by the integration of advanced technologies that aim to increase production efficiency, reduce environmental impacts, and improve the overall understanding of crop dynamics. Among these technologies, remote sensing has become one of the most valuable tools available to researchers and practitioners seeking to support precision agriculture. The capacity to monitor large areas quickly, objectively, and repeatedly represents an essential advantage when compared to conventional ground-based measurement techniques, which are often time-consuming, labour-intensive, and limited in spatial coverage. With the emergence of unmanned aerial vehicles (UAVs), commonly known as drones, the accessibility and applicability of remote sensing tools have expanded significantly, allowing for detailed, high-resolution analyses of crop conditions throughout the growing season (Ballester C. *et al*, 2017).

Multispectral imaging and Light Detection and Ranging (LiDAR) technologies have become indispensable components of agricultural remote sensing. Multispectral sensors capture reflectance values across several specific wavelengths, typically located in the visible and near-infrared regions of the electromagnetic spectrum. These spectral bands allow the computation of vegetation indices such as the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Red Edge Index (NDRE), which are widely used to evaluate plant health, chlorophyll content, biomass accumulation, and stress levels. Multispectral imagery provides a high-resolution, two-dimensional overview of crop condition, highlighting spatial variation that is not always visible to the human eye (Holman F.H. *et al*, 2016).

LiDAR technology, on the other hand, contributes unique three-dimensional structural information by measuring distances through laser pulses. While multispectral data offer insight into the physiological state of the crop, LiDAR data describe its physical structure, allowing for assessments of plant height, density, and volume.

The integration of multispectral and LiDAR data has received growing attention in scientific research, especially in cereal crops such as wheat, which represent a substantial portion of global food production. Wheat is particularly responsive to environmental conditions and management practices, making it a suitable crop for studies involving remote sensing. Throughout its development, wheat undergoes several

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physiological phases, each associated with particular morphological and biochemical changes. Among these stages, the booting phase stands out as an optimal moment for remote sensing assessments. During this phase, the wheat canopy is fully developed, the flag leaf is visible and actively photosynthesizing, and the ear remains enclosed within the stem sheath. These characteristics ensure stable spectral reflectance values across vegetation indices and provide a well-formed canopy structure suitable for LiDAR scanning (Madec S. *et al*, 2017).

The booting stage also precedes the emergence of the wheat spike, which can influence reflectance properties by introducing additional texture and shadow effects.

The study area for this research consists of a 2 hectare wheat field located in Neamț County, in the northeastern region of Romania. This area is representative of the agricultural landscapes of the Moldavian Plateau, characterized by gently undulating terrain and fertile soils such as chernozems and grey forest soils.

The study includes a structured workflow encompassing field data acquisition, sensor calibration, photogrammetric processing, LiDAR point cloud classification, vegetation index calculation, canopy height modelling, and statistical comparison of results.

By integrating multispectral and LiDAR data acquired via a DJI Matrice 400 UAV over a 2 hectare wheat field in the booting stage, the research seeks to demonstrate the advantages of combining spectral and structural remote sensing techniques for precision agriculture. The results aim to contribute both theoretically and practically by improving understanding of vegetation indices, canopy height modelling, and their joint interpretation.

MATERIAL AND METHOD

Data collection was performed using a DJI Matrice 400, a professional unmanned aerial vehicle frequently employed in high-precision environmental monitoring, surveying, and agricultural analysis. The Matrice 400 (*figure 1*) features a robust quadcopter design, long service endurance, and compatibility with advanced sensor payloads.

A high resolution multispectral imaging sensor was mounted on the UAV to capture reflectance data across several narrow spectral bands. The multispectral camera was equipped with a downwelling light sensor and radiometric calibration panels, allowing reflectance correction to eliminate illumination differences caused by changes in solar angle and atmospheric conditions.

For structural canopy analysis, the UAV carried an airborne LiDAR (Light Detection and Ranging) sensor capable of generating a high-density point cloud across the surveyed area. The sensor operates by emitting laser pulses at high frequency and measuring the return time of signals reflected from objects on the surface (Primicerio J. *et al*, 2012). Wheat was surveyed during the booting stage, when the developing spike is enclosed within the sheath of the flag leaf.

The canopy is fully developed, providing stable reflectance values and minimizing soil interference. Flag leaf activity is maximal, making vegetation indices highly sensitive to nitrogen and water status. The canopy structure is dense and uniform, allowing LiDAR to characterize plant height accurately.

Figure 1 **DJI Matrice 400 drone**

The booting stage typically occurs in late April to early May in northeastern Romania, though exact timing depends on sowing date and local climatic conditions. Data were collected on April 17 2025, with stable weather conditions, low wind speed, and minimal cloud cover to ensure optimal image quality.

Data acquisition was conducted between 10:30 and 13:30 local time, a period that ensures high solar elevation and reduces shadow effects in both multispectral imagery and LiDAR returns. Wind speeds were below 5 m/s, allowing the UAV to maintain stable flight. The sky was mostly clear, and no precipitation occurred, ensuring optimal radiometric consistency.

To ensure uniform data collection and consistent spatial resolution across the field, the flight was configured with 50 - 70 m flight altitude above ground level, 3 - 8 cm ground sampling distance (GSD) for multispectral imaging, 75 - 80%

forward overlap, 70 - 75% side overlap, 3 - 5 m/s flight speed and LiDAR scan frequency was set to maximize point density for low lying crop canopies.

The flight path orientation was aligned approximately perpendicular to row orientation to minimize directional bias in canopy representation.

Raw images were synchronized with UAV telemetry records. Radiometric calibration allowed the conversion of pixel intensities into surface reflectance values. Vignetting, distortion, and illumination inconsistencies were corrected automatically based on the sensor's calibration files (Zhang C., Kovacs J.M., 2012).

Using the calibrated imaging, a georeferenced multispectral orthomosaic was constructed. From the orthomosaic, vegetation indices were computed at pixel level.

The field was partitioned into a uniform grid to facilitate spatially explicit analysis. LiDAR raw data were georeferenced using RTK - GPS and IMU trajectory information.

RESULTS AND DISCUSSIONS

The conducted research on the 2 hectares wheat field in Neamţ County produced a series of multispectral and LiDAR derived datasets that enabled a detailed analysis of crop condition during the booting stage. The processed outputs included a multispectral NDVI map, a Canopy Height Model (CHM) obtained from LiDAR data, and a statistical regression describing the relationship between vegetation vigor and structural canopy development.

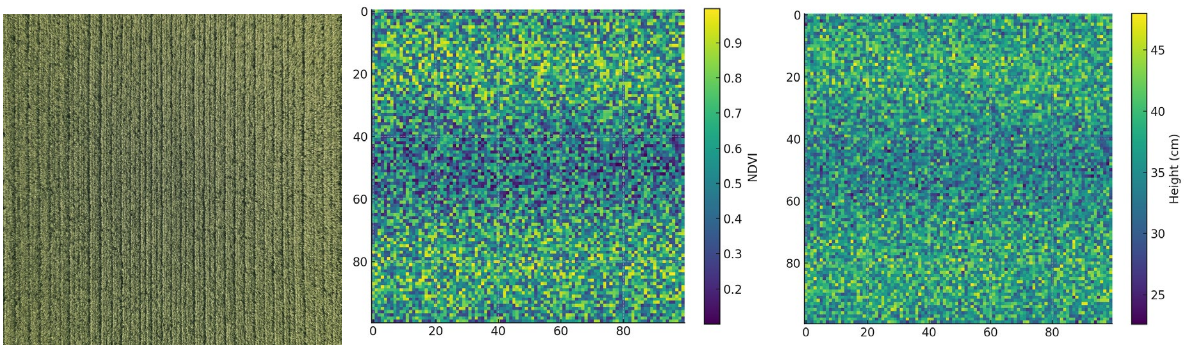
Figure 2a shows an aerial view of the wheat field, revealing the row structure and the canopy appearance during the booting stage. The NDVI map (*figure 2b*) revealed marked spatial heterogeneity in the physiological condition of the wheat canopy. NDVI values ranged from approximately 0.10 in the weakest areas to values approaching 1.00 in the most vigorous regions, with an overall mean of 0.57. Such variability indicates significant differences in photosynthetic capacity, leaf area, and chlorophyll concentration across the field.

Higher NDVI values were generally associated with dense, healthy stands that likely benefited from favorable soil moisture, adequate nutrient uptake, and good tillering. In contrast, lower NDVI areas appeared in patches that may correspond to zones of nutrient deficiency, soil compaction, or micro-relief patterns that influence water retention.

The structural analysis conducted using LiDAR data produced a Canopy Height Model consistent with expected wheat development during the booting stage. Canopy heights varied between 22.6 cm and 48.0 cm, with an average height of 36.4 cm (*figure 2c*).

These values fall well within the biological norms for winter wheat in this phenological phase and confirm that the LiDAR sensor accurately captured the crop's physical structure.

Taller canopy regions tended to coincide with the high NDVI zones, suggesting that plants in these areas were developing rapidly both physiologically and structurally.



a. b. c.

Figure 2 **UAV multispectral and LiDAR observations of wheat in the booting stage**
a. field view; **b.** NDVI map; **c.** LiDAR canopy height model (CHM)..

Despite the overall agreement between spectral and structural patterns, canopy height variability was slightly lower than NDVI variability. The coefficient of variation for NDVI exceeded 37%, while canopy height variability was approximately 13%. This difference reflects the fact that physiological metrics respond more quickly to environmental stressors than structural traits, which require time to manifest as observable differences in plant height.

To further explore the connection between these two datasets, a regression analysis was performed comparing NDVI values with corresponding canopy heights (*figure 3*). The analysis revealed a strong positive relationship, with a correlation coefficient of 0.90 and an R^2 value of approximately 0.82. This indicates that more than four-fifths of the observed variation in canopy height can be explained by differences in NDVI. The regression model suggests that for each full unit increase in NDVI, canopy height increases by roughly 19.9 cm, beginning from a baseline elevation of around 25 cm. While such large NDVI changes would not occur at this scale, the slope nevertheless illustrates the strength of the physiological structural link at this stage of development.

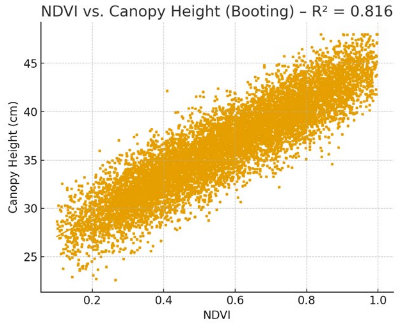


Figure 3 **Linear association between NDVI and canopy height**

Although the relationship between NDVI and canopy height was strong, some scatter was observed around the regression line, reflecting the influence of micro-environmental variation, soil heterogeneity, and measurement noise. Areas with low NDVI and high height or vice versa were rare but present, suggesting localized anomalies such as nutrient depletion occurring after initial structural development or canopy shading effects influencing reflectance values.

When the NDVI and CHM maps are interpreted together rather than separately, a clearer understanding of field performance emerges. Zones where NDVI and canopy height are both high can be considered areas of optimal crop development, where growing conditions are favorable and management practices are effective. Regions where both NDVI and canopy height are low represent consistent stress zones that require further investigation, potentially through soil sampling or field scouting. Areas where NDVI is high but canopy height remains low may reflect dense but short canopies, suggesting early growth delay or structural development lagging behind physiological activity.

The strong correlation between spectral and structural indicators reinforces the reliability of remote sensing for early-season monitoring and suggests that UAV-based data acquisition during critical growth stages such as booting can greatly enhance a farmer's ability to diagnose problems, allocate inputs efficiently, and anticipate yield potential.

CONCLUSIONS

This study demonstrates the effectiveness of integrating multispectral imaging and LiDAR data for assessing wheat development during the booting stage. This combined interpretation underscores the advantages of using multispectral and LiDAR data simultaneously.

The NDVI and canopy height models revealed clear spatial variability across the 2 hectare field, reflecting differences in vigor, biomass, and local growing conditions.

The strong correlation between NDVI and plant height ($R^2 \approx 0.82$) confirms the complementary value of combining spectral and structural indicators. UAV-based sensing proved capable of identifying early stress zones and supporting site-specific management.

Overall, the results highlight the potential of drone technologies to enhance monitoring, decision-making, and precision agriculture practices.

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AUTONOMOUS XAG R150 SPRAYING ROBOT EFFICIENCY FOR PHYTOSANITARY TREATMENTS IN VINEYARDS

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Abstract

This study evaluates the performance of the autonomous XAG R150 spraying robot in vineyard conditions and compares its effectiveness with that of a conventional sprayer. Field experiments were conducted using a randomized block design with two treatments and three replications. A copper based fungicide was applied at a medium field rate, and spray deposition was assessed using water-sensitive papers placed in multiple canopy zones. The robotic system achieved consistently higher spray coverage across outer, inner, upper, and lower foliage layers, demonstrating improved penetration and more uniform droplet distribution. Operational measurements showed that the XAG R150 delivered the target spray volume with stable working speed and required significantly fewer operator interventions. Resource consumption analysis revealed a dramatic reduction in energy use, with the robot requiring only 1.32 kWh/ha compared to the 93 kWh/ha equivalent consumed by the diesel-powered sprayer. The results indicate that autonomous robotic spraying can enhance application precision, reduce energy demand, and support more sustainable viticultural practices. The XAG R150 represents a promising technological alternative for improving crop protection efficiency in modern vineyards.

Key words: agricultural robot, autonomous spraying, energy efficiency.

The agricultural and horticultural sectors have suffered a rapid transformation driven by the increasing demand for higher productivity, improved sustainability, and reduced dependency on manual labor. Viticulture, in particular, faces significant challenges related to labor shortages, rising production costs, environmental constraints, and the growing need for precise and efficient crop protection strategies. Conventional spraying methods in vineyards, whether tractor-mounted sprayers or manual backpack sprayers, are often associated with several limitations, including uneven distribution of phytosanitary products, excessive chemical drift, high fuel consumption, soil compaction, and considerable labor requirements. As vineyards become more intensively managed and environmental regulations surrounding pesticide use tighten, innovative technological solutions are required to improve treatment quality while minimizing ecological impact (Balsari P. *et al*, 2019).

Autonomous ground robots represent one of the most promising technological advancements in modern precision agriculture. These systems combine electric propulsion, advanced navigation, sensor integration, and automated spraying functions to perform tasks with high accuracy and repeatability. Among these, the XAG R150 autonomous robot has emerged as a versatile platform capable of performing multiple field operations, including spraying, crop monitoring, material transport, and precision application of inputs. The integration of an atomizer-based spraying system on the XAG R150 further enhances its potential for phytosanitary applications (Escolà A. *et al*, 2013). Atomization technology produces fine, uniform droplets that improve leaf surface coverage and reduce chemical waste compared to traditional hydraulic sprayers. This is especially advantageous in vineyards, where dense canopies and irregular leaf arrangements make uniform penetration difficult. By adjusting spray parameters, such as droplet size, airflow velocity, and spray direction, the robot can deliver targeted treatments that optimize plant protection while reducing environmental contamination. Compared to conventional tractor-mounted sprayers, the electric and lightweight design of the R150 minimizes soil compaction and allows operation even under wet soil conditions, expanding the treatment window for growers (Guilpart N. *et al*, 2014).

Furthermore, the adoption of autonomous spraying robots aligns with broader trends in

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sustainable agriculture. Their electrically powered systems contribute to lower greenhouse gas emissions, reduced noise pollution, and improved energy efficiency. The robot's precise application capabilities lower pesticide consumption, reducing chemical exposure risks to workers and decreasing residual accumulation in soil and surrounding ecosystems. In addition, replacing labor-intensive manual spraying with automated systems increases worker safety by limiting contact with hazardous substances. These factors collectively support the transition toward more environmentally responsible and economically viable viticultural practices (Oberti R. *et al*, 2020). Despite these potential benefits, the practical performance of autonomous robots such as the XAG R150 in real vineyard conditions remains an important subject of investigation. Differences in canopy structure, terrain variability, climatic conditions, and vineyard management practices can influence the effectiveness of robotic spraying (Rosell J.R., Sanz R., 2012).

This study aims to evaluate the efficiency of phytosanitary treatments applied with the autonomous XAG R150 spraying robot in vineyards and to compare its performance with standard spraying techniques currently used in commercial viticulture. By analyzing parameters such as spray coverage, product consumption, operational efficiency, and environmental impact, the research seeks to determine whether robotic spraying can serve as a reliable and advantageous alternative to traditional methods.

MATERIAL AND METHOD

The experiment was conducted during the 2025 growing season in a vineyard planted with *Vitis Vinifera*, situated in Neamt county, in the North East of Romania, established on a uniform layout with 2.0 m spacing between rows. The objective of the study was to evaluate the efficiency of phytosanitary treatments applied using the autonomous XAG R150 spraying robot (*figure 1a*) and to compare its performance with a conventional vineyard spraying method (*figure 1b*). A randomized block design was used, consisting of two treatments and three replications. Each experimental plot measured 30 m in row length and included three consecutive vine rows. The central row of each plot was used for all measurements, while the flanking rows served as buffer zones to reduce interference between treatments. The total experimental area covered approximately 0.12 ha.

A copper-based fungicide was selected for the trial because it provides visible deposition on leaf surfaces and is commonly used in vineyard disease management.

The application rate corresponded to approximately 6 kg of commercial product per hectare, representing a mid-range dose within the approved label recommendations.

The fungicide was mixed with water to obtain a spray volume of 174 L/ha, which reflected the operational spray volume derived from the selected working parameters of the robotic system. Prior to spraying, all plots were inspected to confirm uniform canopy development and comparable disease pressure.

a.

b.

Figure 1 **Autonomous and conventional spraying systems**

a. XAG R150 autonomous spraying robot; **b.** Conventional mounted vineyard sprayer.

For the robotic treatment, the XAG R150 was configured to operate at a forward speed of 1.2 m/s, with the pump calibrated to deliver a flow rate of 2.5 L/min. These settings were chosen to ensure a realistic working scenario for vineyard operations and to achieve an appropriate balance between coverage and efficiency. The robot navigated autonomously along the vine rows using RTK-GPS guidance to maintain precise alignment. The conventional treatment was applied using a tractor-mounted sprayer operated according to standard vineyard practice. The operator adjusted pressure and nozzle configuration to deliver a spray volume similar to that used in the robotic application, ensuring a fair comparison between systems.

Spray deposition was assessed using water-sensitive papers placed at several canopy positions within the central measurement row of each plot. Papers were positioned on the exterior and interior of the foliage wall, as well as in upper and lower foliage zones, to capture both horizontal and vertical variability in deposition. Immediately after spraying, the papers were collected, dried, and stored in sealed envelopes. In the laboratory, they were scanned and analyzed to determine spray coverage and droplet density, which served as indicators of application quality and penetration into the canopy.

Operational parameters were recorded throughout the applications. Treatment time for each plot was measured to calculate field capacity and working efficiency. Battery charge levels of the XAG R150 were recorded before and after application to estimate energy consumption per hectare. For the conventional sprayer, fuel consumption was determined by refilling the tractor's tank to a reference level after each plot. Meteorological conditions, including temperature, humidity, and wind speed, were measured during each application to ensure that treatments were carried out under acceptable and comparable environmental conditions.

This methodological approach provided a consistent and controlled framework for evaluating the performance of the autonomous XAG R150 robot in comparison with conventional spraying practices, enabling quantitative assessment of spray deposition quality, operational efficiency, and resource use under real vineyard conditions.

RESULTS AND DISCUSSIONS

The results obtained from the field experiment highlight clear differences between the autonomous XAG R150 spraying robot and the conventional vineyard sprayer, both in terms of spray deposition patterns and resource consumption. *Figure 2* shows the distribution of spray coverage across the main canopy zones, while

Spray coverage results demonstrate that the XAG R150 robot achieved consistently higher deposition levels across all canopy zones compared to the conventional sprayer. In the outer canopy region, the robot produced an average coverage of 78.4%, compared with 73.6% for the conventional method. This difference, although moderate, indicates that the air-assisted atomization system used by the robot is highly effective at depositing droplets on exposed foliage surfaces. The advantage of the robotic system became more evident in the inner canopy, where achieving adequate deposition is typically more challenging due to the denser leaf structure. Here, the robot reached a mean coverage of 61.8%, substantially higher than the 46.7% recorded for the conventional sprayer.

This suggests that the robot's airflow characteristics and droplet formation parameters contribute to better penetration into the foliage wall, overcoming the shielding effect commonly observed in vineyards with vertical shoot positioning.

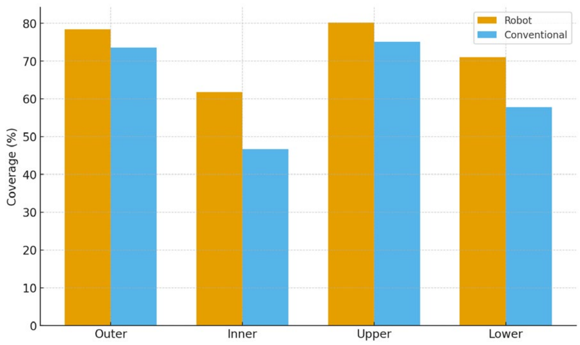

Figure 2 **Spray Coverage by Canopy Zone**

A similar pattern was observed for the upper and lower portions of the canopy. The upper foliage zone exhibited the highest levels of deposition overall, with the robot reaching 80.2% coverage and the conventional system achieving 75.1%. In the lower foliage zone, the robot again performed better, reaching 71.0%, compared with 57.8% for the conventional sprayer. These results collectively indicate that the robotic spraying system is more uniform in delivering spray solution across vertical canopy strata, improving the homogeneity of coverage, which is a critical factor for effective disease control.

The improved deposition patterns of the robot were mirrored by the droplet density measurements. The robot consistently produced higher droplet densities across all canopy zones, with a particularly notable advantage in the inner and lower zones. Although droplet density is not discussed in detail in this section, these findings complement the coverage data and reinforce the conclusion that the robotic system provides superior canopy penetration.

Table 1 summarizes the main indicators of resource use for the two application systems. Together, these datasets provide a comprehensive view of the performance of the robotic sprayer under real vineyard conditions. The spray solution volumes applied per hectare were comparable between the robot (174.2 L/ha) and the conventional sprayer (183.6 L/ha). However, the energy profiles of the two systems differed dramatically. The XAG R150 required an average of 1320 Wh/ha of electrical energy to complete the application, whereas the conventional sprayer consumed 9.5 L of diesel fuel per hectare. When converted to an energy equivalent, the diesel use corresponds to approximately 93 kWh/ha, revealing that the conventional system required roughly 70 times more energy input than the electric robotic sprayer. This big contrast emphasizes the potential of autonomous electric sprayers to reduce the energy footprint of crop protection operations in vineyards.

Table 1

Resource consumption of the two spraying systems

Parameter	Robot (XAG)	Conventional sprayer	Unit
Spray solution volume	174.2	183.6	L/ha
Battery energy consumption	1320	-	Wh/ha
Fuel consumption	-	9.5	L diesel/ha
Energy equivalent	1.32	93.1	kWh/ha (9.8 kWh/L)

The reduced energy use of the robot also translates into substantial environmental benefits. Lower energy consumption is directly associated with reduced greenhouse gas emissions, especially when the robotic system is powered by electricity sourced from renewable energy. Additionally, the absence of diesel combustion eliminates local emissions of nitrogen oxides and particulate matter, contributing to a cleaner working environment for vineyard operators.

Another relevant aspect is the difference in operational dependency. Although not quantified in energy units, the lack of fuel refilling, engine noise, and vibration further differentiates the robotic sprayer from conventional systems. The robot's energy consumption pattern aligns with a more sustainable approach to vineyard management, especially in regions where environmental regulations and consumer expectations are increasingly focused on reducing the ecological impact of agricultural operations.

The results clearly indicate that the autonomous XAG R150 robot outperforms the conventional sprayer in terms of spray coverage uniformity and energy efficiency. The superior penetration into the inner canopy suggests a potential for improved disease control, while the drastic reduction in energy use confirms the sustainability advantage of autonomous, electrically powered spraying technology.

CONCLUSIONS

The results of this study demonstrate that the autonomous XAG R150 spraying robot provides clear advantages over conventional spraying methods in vineyard conditions. The robot achieved higher and more uniform spray coverage across all canopy zones, especially within the inner foliage, where deposition is typically challenging. Resource consumption analysis confirmed a major reduction in energy use, with the robotic system requiring only a fraction of the energy demanded by diesel based equipment. These findings highlight the robot's potential to improve application efficiency, reduce environmental impact, and support more sustainable vineyard management. Overall, the XAG R150 represents a promising alternative for modern precision viticulture.

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THE QUALITY OF SOME ASSORTMENTS OF RIPENED SOFT CHEESES WITH WHITE MOLD SOLD IN ROMANIA

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Abstract

The purpose of this paper was the comparative assessment of the quality of some assortments of ripened soft cheeses sold in Romania. Two batches of four varieties of ripened soft cheeses with white mold (Brie cheese) were taken in the study: Ile de France, Alpenhain, President and Paysan breton, coded from A to D. Sensory (five-point scale method) and physico-chemical properties were analyzed. Were determined the treatable acidity (by Thörner metod), the pH (with Hanna cheese pH tester), the lipids (by the acid-butyrometric method), and salt content (by titration with silver nitrate) of the products. The results showed high differences between products in terms of fat content: the highest values were obtained for product C (29.00% determined and 31.00% on the label) and the smallest values were found for product A (23.50% determined and 25.00 on the label), with differences of 5.5 percentage points for the values determined in the laboratory and 6.0 percentage points for the values declared on the product label. The highest salt values were obtained for product A (2.89%) and the smallest values were found for product C (1.44%), with differences of 1.35 percentage points. The results of the sensory analysis revealed a minimum score for product C (14.17 points- "satisfactory product" according to quality standards), compared to product A which obtained the best score among all the analyzed assortments (18.77 points- "very good product"). Following statistical processing, predominantly significant differences ($p < 0.05$) were observed for the most of the quality parameters analyzed.

Key words: soft cheese, lipids, salt, acidity, sensory proprieties

Cheese is a food product made from fermented milk that is consumed globally (Khattaba A.R. *et al*, 2019). Cheeses have evolved uniquely depending on climate and region, resulting in the development of over 1,000 cheese varieties, which can be grouped based on moisture content into categories such as hard, semi-hard, and soft cheeses (Almeida A.M. *et al*, 2019, Pana G-F. *et al*, 2024).

Mold cheeses belong to a specific group of ripened rennet cheeses which, when ripened in suitable conditions, develop exquisite flavors, aroma, and texture resulting from the presence of selected microbiological bacteria and production methods (McSweeney P.L.H. and Sousa M.J., 2000, Caldaza J. *et al*, 2014, Galli B.D. *et al*, 2016, Diezhandino I. *et al*, 2016, Paszczyk B., 2022). They fall into the category of rennet cheeses made from milk and rennet. Depending on the method of production adopted, they are divided into white-mold cheeses, such as Camembert and Brie, and blue-green-veined cheeses, such as Roquefort. The first are produced with white mold cultures of *Penicillium camemberti* or *Penicillium candidum* and feature a soft texture, creamy color, no holes, melting in the mouth, and a mild aroma, as well as a mushroom, slightly spicy, bitter-sour taste. In turn, strains of the species *Penicillium roqueforti*, *Penicillium gorgonzola*, or *Penicillium glaucum* are used to make the blue-veined cheeses characterized by mold growth throughout the bulk of the cheese, which has a semi-soft consistency. After a few weeks of ripening, these cheeses acquire a mild, slightly sour mushroom aftertaste. As they ripen, their taste and aroma become sharper, and their consistency turns more crumbly.

The characteristics of brie cheese, a ripened soft cheese, are a buttery, savory taste, and if fermentation is carried out longer, the aroma will be more pungent, and the texture inside will be more melted; this is the reason why Brie Cheese is often referred to as the "King of Cheese" because of its luxurious characteristics (Pratiwi L.F.L. *et al*, 2025).

Consumers of brie cheese are usually consumers who have often consumed fermented cheese as an appetizer, snack or part of a dessert (Ouyang, H. *et al*, 2021). Brie cheese, which has a unique taste and aroma, makes this cheese more widely enjoyed with the pairing method or paired

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when consuming other foods or drinks such as fruits, nuts, bread, meat, jam, honey or white wine (Pratiwi L.F.L. *et al*, 2025). Brie cheese is also more expensive than other types of natural cheese because the manufacturing technique requires special treatment, the fermentation process requires a special room, and the fermentation time is around 2-4 weeks (Abbas A. & Dobson A. D. W., 2011).

Brie may be produced from whole or semi-skimmed milk. The curd is obtained by adding rennet to raw milk and warming it to a maximum temperature of 37 °C. The cheese is then cast into moulds, sometimes with a traditional perforated ladle called a pelle à brie. The 20 cm mould is filled with several thin layers of cheese and drained for approximately 18 hours. The cheese is then taken out of the moulds, salted, inoculated with cheese culture (*Penicillium camemberti* and/or *Brevibacterium linens*), and aged in a controlled environment for at least four or five weeks (Chambers D.H. et al, 2005; McGee H., 2004). Overripe brie contains an unpleasantly excessive amount of ammonia, produced by the same microorganisms required for ripening.

The purpose of this paper was the comparative assessment of the quality of some assortments of ripened soft cheeses (Brie assortment) sold in Romania.

MATERIAL AND METHOD

Sensory analysis was performed by five-point scale method according SR 6345/1995 (*Milk and dairy products. Sensory analysis*) national standard. The sensory analysis was carried out by a group of 31 trained tasters (fourth year students of the Food Products Control and Expertise specialization). From physico-chemical point of view the fallowing properties were analyzed: the treatable acidity (by Thörner metod), the pH (with Hanna cheese pH tester), the lipids (by the acid-butyrometric method using the Van Gulik butyrometer), and salt content (by titration with silver nitrate) of the products.

The results of the analyses were statistically processed using the Paired t-test, direct test between two conditions.

RESULTS AND DISCUSSIONS

The results obtained from the sensory analysis (*figure 1*), carried out according to the five-point scale method (SR 6345/1995), showed that A and D cheeses were distinguished by high scores for most attributes, especially taste (4.71 and 4.79) and appearance (4.64 and 4.79).

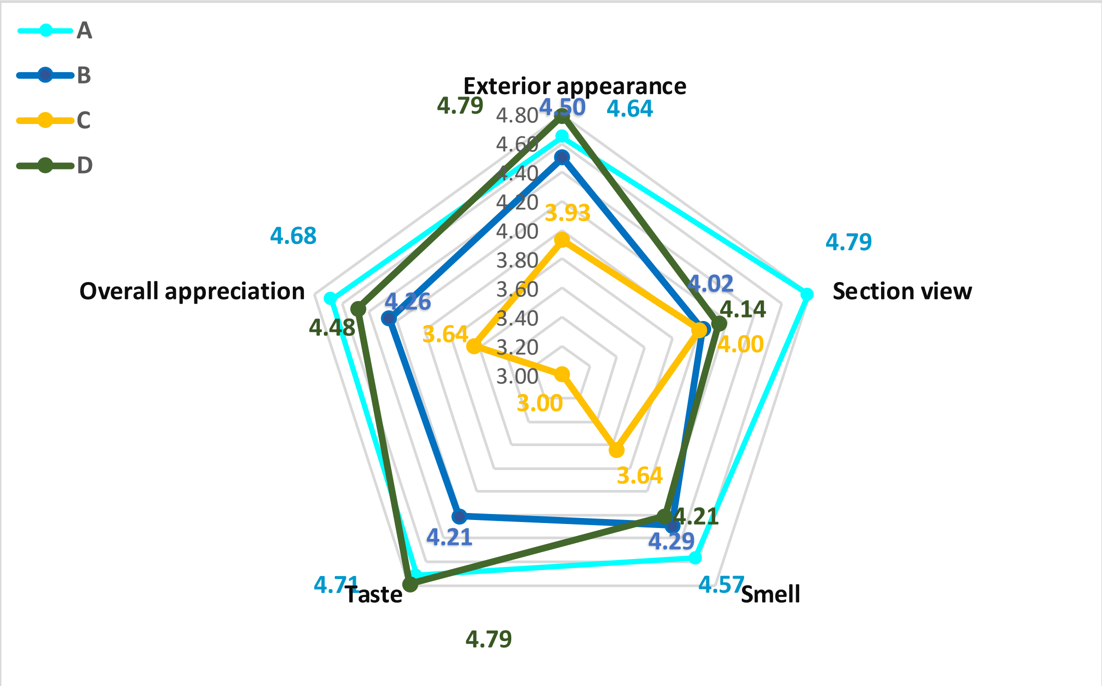

Figure 1. **The score obtained for the sensory analysis of Brie cheese**

The overall assessment was also superior for these two varieties. B product had good, but lower results, while C variety obtained the lowest values, especially for taste (3.00), an aspect considered to be negatively influenced by the appearance of sauerkraut and ammonia aromas and the possible exceeding of the optimal stage of consumption.

The results of the sensory analysis revealed a minimum score for C product (14.17 points, falling into the "satisfactory" product quality class, according to quality standards) compared to A product, which obtained the best score (18.77 - "very good" product), followed by a difference of 0.37 percentage points by D product (18.40 points), belonging to the same quality class. The product B obtained 17.06 points, a ”good product” quality class (*figure 2*).

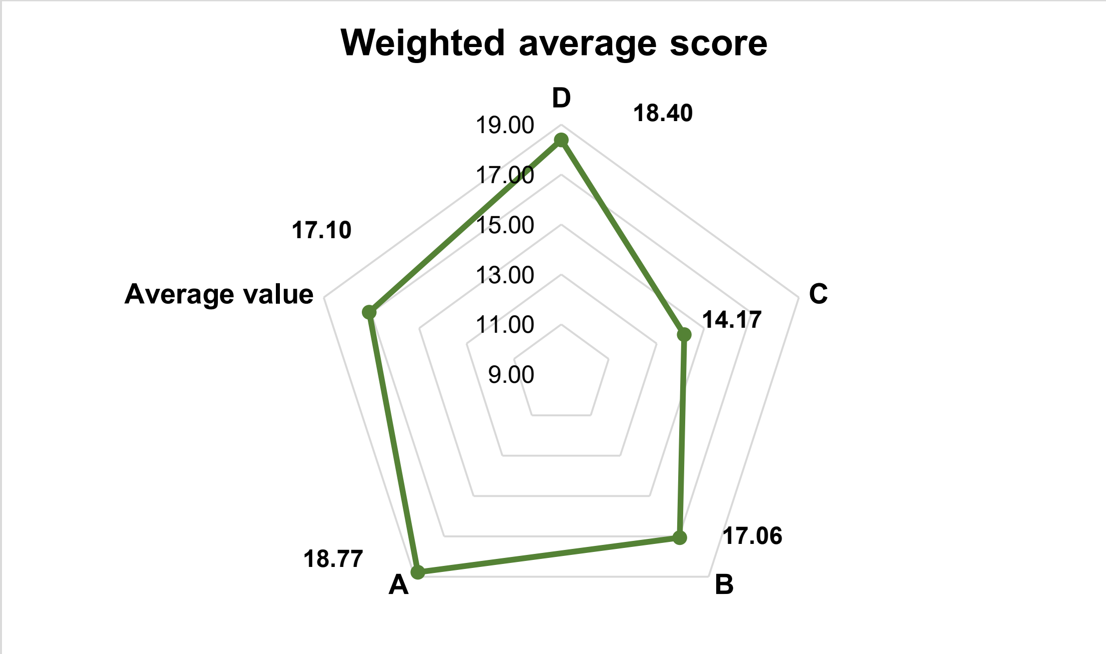

Figure 2. **Weighted average score of Brie cheese**

The lipids content determined on laboratory was higher for all product compared with the value declared on the label by manufacturers (*figure 3*).

Are observed differences between the four producers for the amount of lipids determined, but also for the values declared on the labels. The highest values were obtained for C product (29.00% determined and 31.00% on the label) and the smallest values were found for A product (23.50% determined and 25.00 on the label), with differences of 5.5 percentage points for the values determined in the laboratory and 6.0 percentage points for the values declared on the product label. The products B and D have the same values determined (24.25%) and also had close value declared on the label (25.20 vs. 25.00).

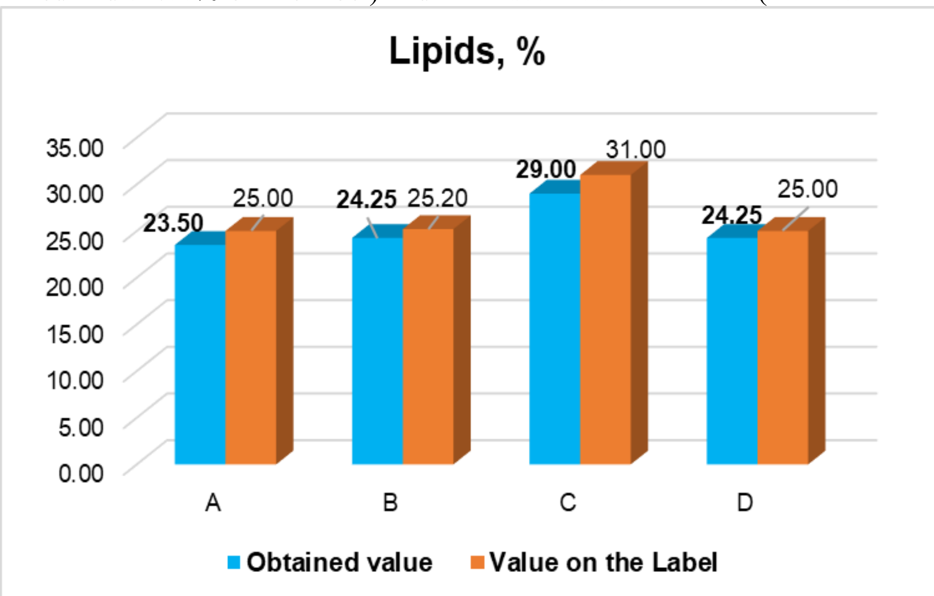

Figure 3. **The lipids content of Brie cheese**

The salt content determined on laboratory (*figure 4*) was higher for all product compared with the value declared on the label by manufacturers, as well as for lipid content.

Are observed differences between the four producers for the amount of salt determined, but also for the values declared on the labels. The highest salt values were obtained for A product (2.89% determined and 2% on the label) and the smallest values were found for C product (1.44% determined and 1.20 on the label), with differences of 1.35 percentage points for the values determined in the laboratory and 0.8 percentage points for the values declared on the product label. The products

B and D had close values determined (2.24% vs 1.94%) and also declared on the label (1.4 vs. 1.6).

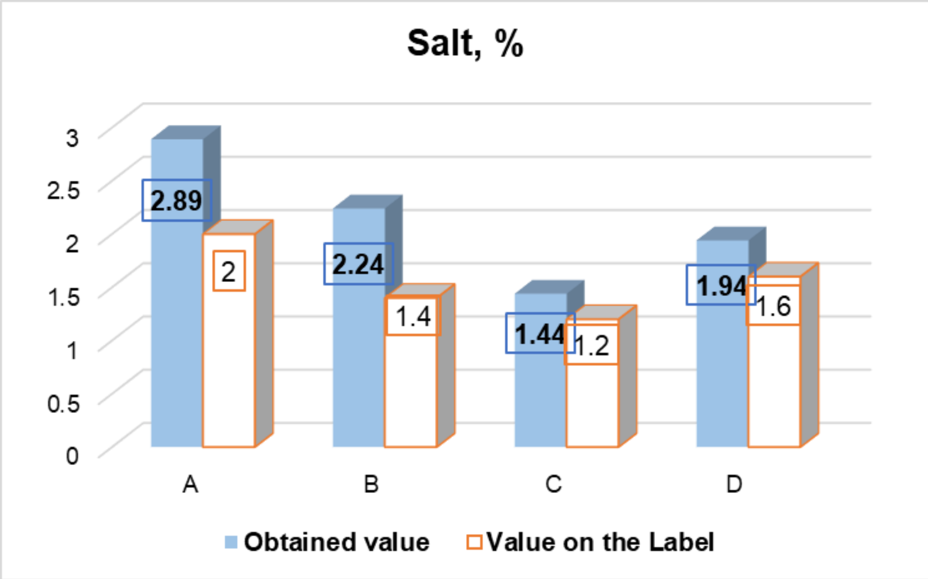

Figure 4. **The salt content of Brie cheese**

By comparatively analyzing the average results (*figure 5*), it is observed that cheese B has a significantly higher titratable acidity than the other varieties (121.50 °T), indicating an intense lactic activity, a more advanced stage of maturation at the time of analysis or maintenance of curd at higher temperatures within the technological process of obtaining it.

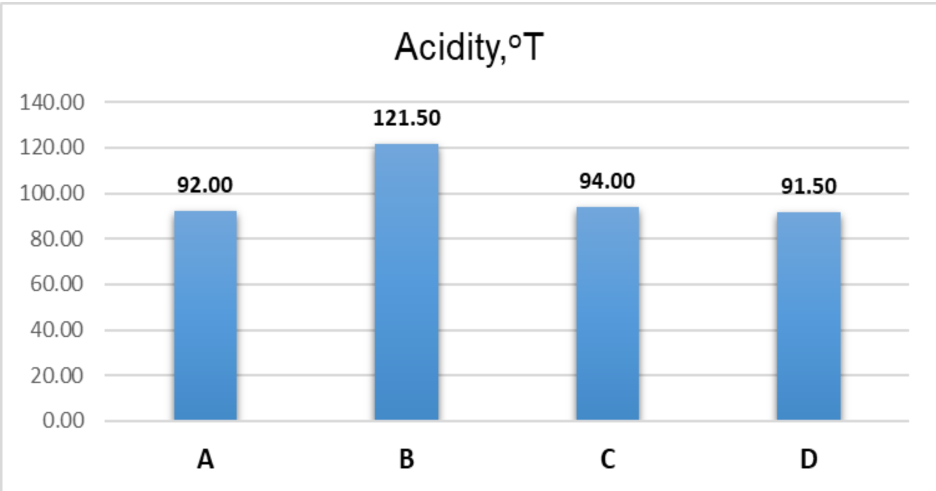

Figure 5. **The titratable acidity of Brie cheese**

In contrast, the other three cheese varieties analyzed have values closer to each other, located between 91.5 and 94 °T, which suggests a moderate acidity, specific to a mature stage sufficient to confer a characteristic taste, but without pronounced microbial and enzymatic intensity.

The pH values analyzed (*figure 6*) varied significantly, cheeses C (7.17) and D (7.14) recorded an increased pH possibly associated with intense proteolytic activity or advanced ripening; in contrast, B product presented a lower value (5.04), indicating a state of biochemical equilibrium alongside cheese A (with an average pH value of 5.61).

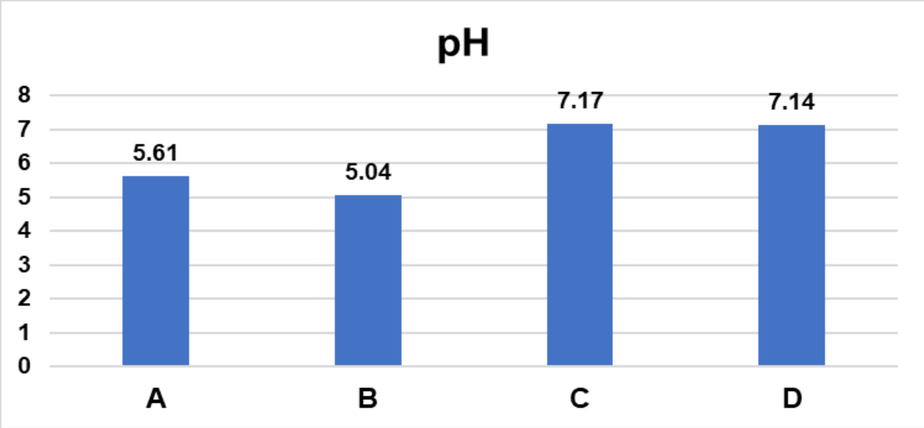

Figure 6. **The pH value of Brie cheese**

The economic evaluation of the products highlighted relevant differences between the price per kilogram and the perceived quality (*figure 7*).

Product D was the most affordable assortment (93.83 lei/kg), and the price-quality ratio was favorable. The products A, B and C had higher prices (approx. 120-140 lei/kg), without a direct correlation between price and the sensory scores obtained. This discrepancy suggests that economic value is not always a true indicator of the quality perceived by consumers.

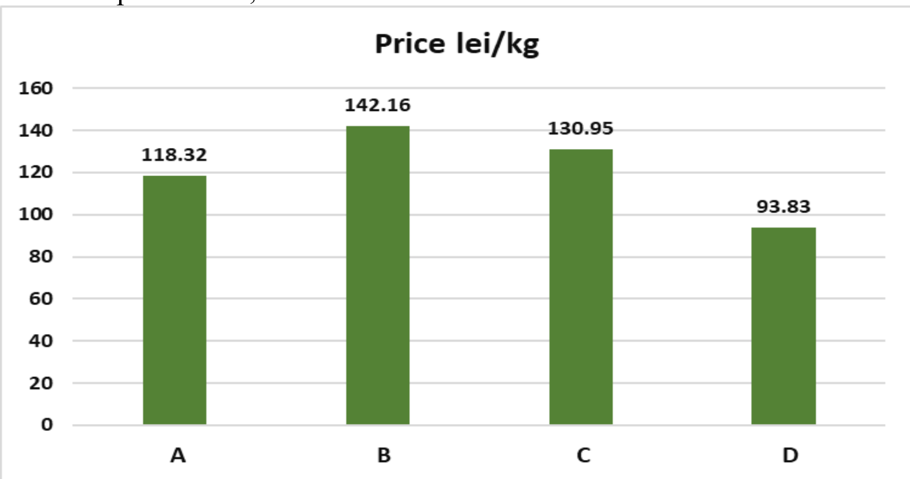

Figure 7. **The average price of Brie cheese**

Following statistical processing, predominantly significant differences were observed for the most of the quality parameters analyzed (*table 1*).

Table 1

The statistical differences of quality parameters for Brie cheese analyzed

Products	A vs B	A vs C	A vs D	B vs C	B vs D	C vs D
pH	p=0.0003, ***	p<0.0001, ***	p<0.0001, ***	p<0.0001, ***	p<0.0001, ***	p=0.77, ns
Acidity °T	p=0.004,**	p=0.67, ns	p=0.83, ns	p=0.006, **	p=0.002, **	p=0.53, ns
Lipids	p=0.32, ns	p<0.0001, ***	p=0.32, ns	p<0.0001, ***	p=1.00, ns	p<0.0001, ***
Salt	p=0.0004, ***	p<0.0001, ***	p<0.0001, ***	p=0.001, ***	p=0.04, *	p=0.01, **
Price	p<0.0001, ***	p=0.005, **	p=0.001, ***	p=0.02, *	p<0.0001, ***	p=0.0003, ***
Weighted average score	p=0.02, *	p<0.0001, ***	p=0.57, ns	p=0.005, **	p=0.26, ns	p<0.0001,***
Exterior appearance	p=0.33, ns	p = 0.003, **	p = 0.42, ns	p = 0.001, ***	p = 0.13, ns	p < 0.001, ***
Section view	p=0.004, **	p=0.002, **	p=0.02, *	p=0.90, ns	p=0.49, ns	p=0.89, ns
Smell	p=0.28, ns	p=0.002, **	p=0.08, ns	p=0.006 ,**	p=0.94, ns	p=0.05,*
Taste	p=0.04, *	p<0.001, ***	p=0.94, ns	p=0.001, ***	p=0.04, *	p<0.001, ***
Overall ppreciation	p=0.02, *	p<0.001, ***	p=0.26, ns	p=0.002, **	p=0.09, ns	p<0.001, ***

$p < 0.05$ → significant (*)
$p < 0.01$ → distinctly significant (**)
$p < 0.001$ → highly significant (***)
$p \geq 0.05$ → not significant (ns)

CONCLUSIONS

The analyzed Brie cheese varieties present relevant differences from a sensory, physico-chemical and economic point of view ($p < 0.05$), even though they are part of the same product category. Products A and D stood out for their superior overall quality, being well balanced in all the analyzed criteria. The presence of a high pH in two of the samples, corroborated with less favorable sensory perceptions, underlines the importance of controlling ripening and storage conditions throughout the entire technological flow and commercial circuit of the product. Authorities that carry out quality controls of marketed products should be notified in the event of a deviation related to the sensory quality of food products, especially when we are talking about products that are considered “luxury products” and have a high price.

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QUALITY ANALYSIS OF SOME ASSORTMENTS OF DARK CHOCOLATE

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Abstract

The aim of this study was the comparative assessment of the quality of some varieties of dark chocolate sold in Romania, evaluating their sensory, physical-chemical, aesthetic and economic characteristics. In the study were taken, two batches of five varieties of dark chocolate with 85% cocoa content: "Delicata", "Noir", "Heidi", "Lindt", "Kaufland Favourites" (coded from A to E) purchased from supermarkets from Iasi. Sensory characteristics were analyzed by tasting using the five-point scale method, moisture and dry matter by oven drying (at 105 °C), fat content was determined by the Soxhlet method and ash content by calcination (at 550 °C). Following the results obtained in the sensory analysis, all five products fell into the "good product" quality class according to the standards, determining a higher score for product C (17.94 points) and a lower one for product E (16.84 points), differences of 1.1 points. Assortment C scored the highest in sensory analysis for appearance, color and taste and assortment A scored the highest for smell and consistency. Assortment E scored the lowest for appearance, consistency, color and taste, ranking in last place as a brand. The results of the physical-chemical determinations carried out showed higher differences in fat content (which varied between 43.46% and 50.54%), and lower differences for ash (between 2.60% and 3.40 %), dry matter (between 98.20% and 98.86%) and water (between 1.14% and 1.80%).

Key words: soft cheese, lipids, salt, acidity, sensory proprieties

Cocoa derived from *Theobroma cacao* L., the botanical name for the cocao (cacao) tree, has been known for thousands of years and played important roles during sacred ceremonies (“the food of the gods”), but also in human nutrition and traditional medicine (Sitarek P. *et al,* 2024). Particularly the beans of cocoa have been shown to be rich in a multitude of bioactive compounds, such as polyphenols including flavonoids (e.g., catechins, epicatechins) and proanthocyanins, as well as methylxanthines (e.g., theobromine, caffeine) that are responsible for health-promoting including anti-inflammatory effects (Fraga C.G. *et al*, 2019, Samanta *et al*, 2022, Muth H. *et al*, 2025). Cocoa beans for chocolate production are obtained from three major varieties: Forastero, Criollo, and Trinitario (Herreros-Chavez, L. *et al*, 2019), which grow in different tropical regions and produce cocoa beans with varying taste characteristics. Varieties grown in Central and South America (Trinitario and Criollo) produce the “fine” cocoas, which are distinguished by preferred aroma and colour, and are usually used for the production of dark chocolate (Kongor J.E. *et al,* 2016). Chocolate can be classified into dark, milk, and white, depending on manufacturing. In commercial dark chocolate, the solid cocoa content ranges from 47% (sweet dark) to 70%, 75%, or even above 90% for highly dark chocolate (Jaćimović S., *et al*, 2022). Nowadays, the trends in the chocolate industry are changing, influenced by increasing consumer concern with the nutritional status. The primary nutrients of chocolate are fat, carbohydrates, and proteins. In addition, chocolate contains various biologically active compounds such as polyphenols, lipo- and hydrosoluble vitamins, phospholipids, dietary fibers, and essential elements. Due to the high level of polyphenols, as its main bioactive components, it has been documented that dark chocolate has possible positive effects on human health, e.g., regulating cholesterol levels, reducing stress and depression, even protecting against many types of cancer, etc. The most important polyphenol feature is attributed to the antioxidant activity (Yanus R.L. *et al,* 2014, Katz D.L. *et al*, 2011, Patel, N. *et al*, 2019, Jaćimović S., *et al*, 2022).

The aim of this study was the comparative assessment of the quality of some varieties of dark chocolate sold in Romania, evaluating their sensory and physical-chemical characteristics.

MATERIAL AND METHOD

Sensory characteristics were analyzed by tasting, using the five-point scale method, where

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participated 53 tasters from the specialization of Control and expertise of food products. Moisture and dry matter were analyzed by oven drying (at 105 °C), fat content was determined by the Soxhlet method and ash content by calcination (at 550 °C).

Table 1

Five-point rating scale for dark chocolate

Characteristics	Characteristics description	Score
Appearance	Regular shape, glossy, smooth surface, without stains and scratches; well-contoured drawings	4
	The surface is smooth, has small scratches and irregularities in design and shape	3
	The surface is matte, with small irregularities in shape and design	2
	The surface is slightly matte, showing obvious scratches, irregularities in shape and design	1
	The surface is totally uneven, showing traces of melting	0
Color	Uniform and appropriate on the entire surface of the product	4
	Uneven on a certain region of the product	3
	Uneven on the entire surface of the product	2
	Stains of different shades that are not specific to the product	1
	Inappropriate product, with foreign shades, color unsuitable for the assortment	0
Smell	Well defined, pleasant, characteristic of the assortment	4
	Specific, poorly defined characteristic of the assortment	3
	Poorly pronounced, without foreign taste and smell	2
	Indefinite or too vague	1
	Unpleasant, foreign or odour is missing	0
Consistency	Strong, fine, creamy	4
	Strong, slightly creamy	3
	Soft, slightly creamy	2
	Soft, semi-rough	1
	Soft, rough	0
Taste	Well defined, fragrant, pleasant	4
	Typical of the assortment, slightly aromatic, pleasant	3
	Poorly defined, characteristic of the aroma used	2
	Indefinite or too vague	1
	Uncharacteristic, astringent, rancid, unpleasant	0

Table 2

Five-point rating scale for dark chocolate (SP 3196-87)

Score	Positive and negative characteristics
4	Very good = specific positive characteristic, very well defined. It does not present any kind of lacks or perceptible defects.
3	Good = specific positive characteristic, quite defined, but also very small, insignificant shortcomings or defects.
2	Satisfactory = specific positive characteristic, poorly outlined and small deficiencies or defects; the ***quality is at the minimum level allowed by the standard.***
1	Unsatisfactory = lacks or defects in the appropriation, does not meet the minimum condition in the standard, but can be used under certain conditions.
0	Bad/ Altered = defects in the property such that it can no longer be used for consumption/ altered product

Table 3

Weighting factors of dark chocolate

Characteristics	Weighting factors
Appearance	1
Consistency	1
Color	0.5
Smell	0.5
Taste	2.0

Table 4

Classification of the products in the appropriate quality class according to standards

Total average score	Provided qualifying
18.1 ÷20	Very good
15.1÷18	Good
11.1÷15	Satisfactorily
7.1÷11.0	Unsatisfactory
0÷7	Altered

RESULTS AND DISCUSSIONS

The results obtained from the sensory analysis (*figure 1*), carried out according to the five-point scale method showed that C product was distinguished by high scores for most attributes, especially color (3.86) and appearance (3.74).

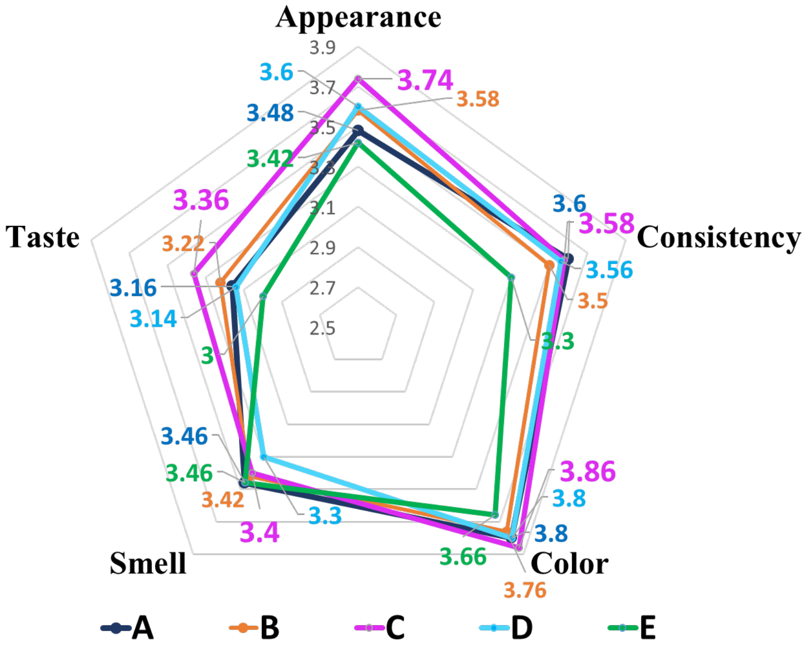

Figure 1. **The score obtained for the sensory analysis of dark chocolate**

The results of the sensory analysis and weighted average score of dark chocolate revealed that all products fell into the ”good” product quality class according to the standards in force. Thus, were obtained a minimum score for E product (16.84 points) compared to C product, which obtained the best score (17.94 points- "good" product), followed by a difference of 0.44 percentage points by A product (17.50 points), belonging to the same quality class (*figure 2*).

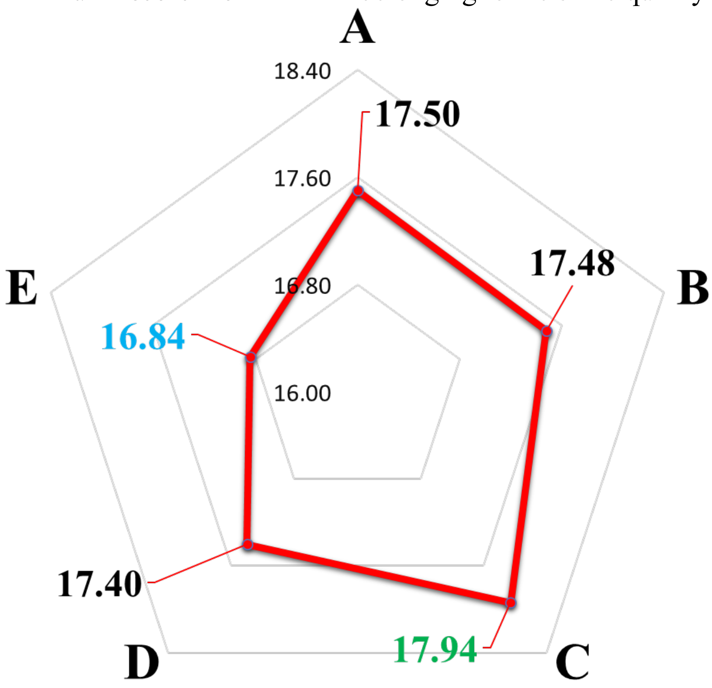

Figure 2. **Weighted average score of dark chocolate**

The dry matter content determined on laboratory was higher for product C (98.84%) compared with the value obtained for E product that revealed the smallest value (98.29%). Overall, no major differences were found for all five products analyzed (*figure 3*).

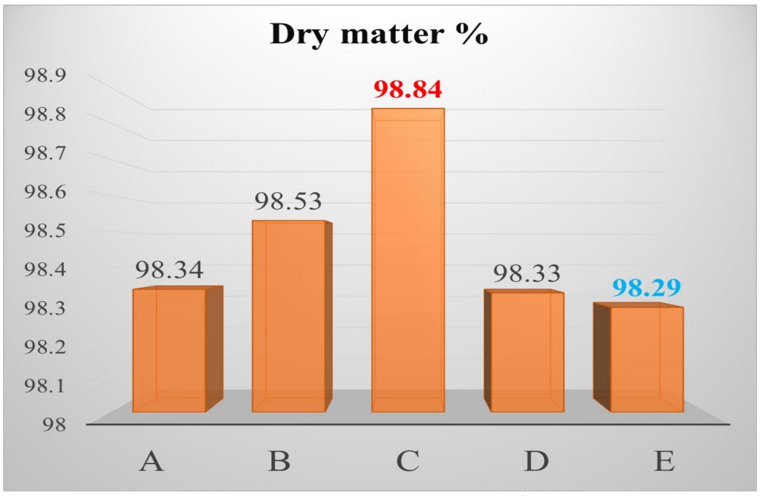

Figure 3. **The dry matter content of dark chocolate**

By comparatively analyzing the average results (*figure 4*), it is observed that product B has a higher lipids content (50.28%) than the other varieties, the smallest values being found for E product (43.64%), with differences of 6.64 percentage points.

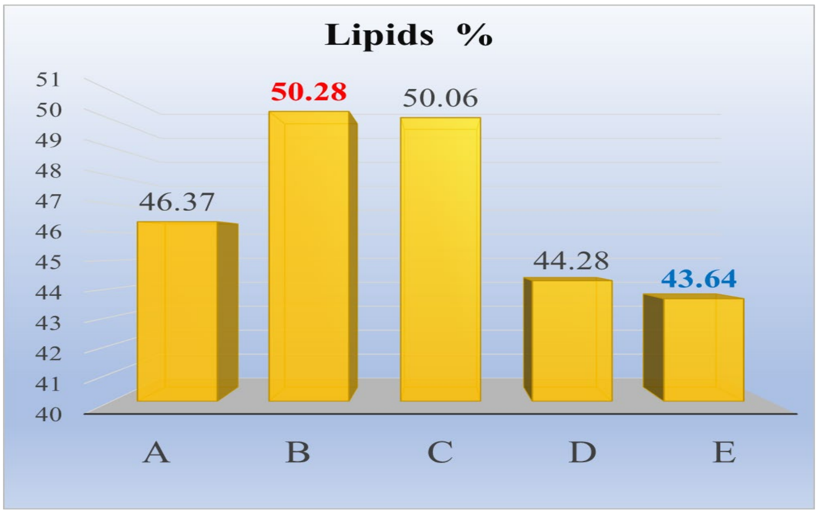

Figure 4. **The lipids content of dark chocolate**

The ash values determined revealed higher values for product C (3.35%) compared with product B (2.59%), with differences of 0.76 percentage points (*figure 5*)

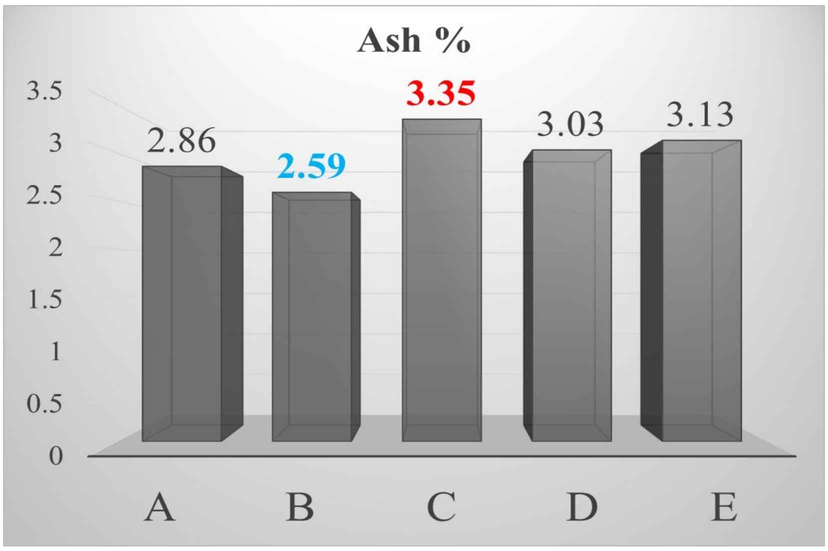

Figure 5. **The ash content of dark chocolate**

The water content was higher for product E (1.71%) and smallest for product C (1.16%), with differences of 0.55 percentage points (*figure 6*). However, the differences were not that great between the five products analyzed for moisture content.

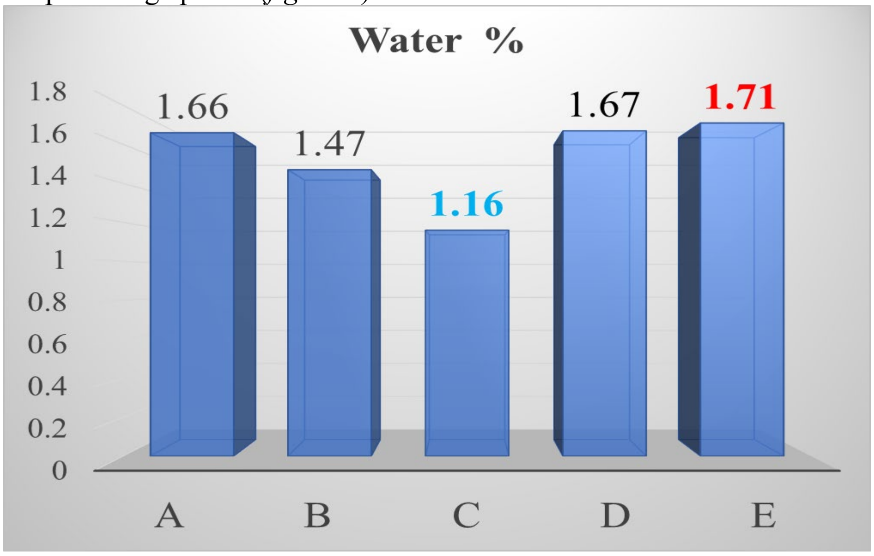

Figure 6. **The water content of dark chocolate**

The ingredients and the information from the label of dark chocolate are presented in next table (*table 5*). It was observed that 85% of dry matter is from cocoa, for all producers. Only product E present the percentage of cocoa butter. Three producer from five had use emulsifier (lecithin).

Table 5

The ingredients and the information from the label of dark chocolate

Ingredients %	Dark chocolate				
	A	**B**	**C**	**D**	**E**
Cacao	min 85% dry matter from cocoa	min 85% dry matter from cocoa	min 85% dry matter from cocoa	min 85% dry matter from cocoa	min 85% dry matter from cocoa
Cocoa Butter	-	-	-	-	minimum 4%
Additives	emulsifier: soybean lecithin	-	emulsifier: soybean lecithin	-	emulsifier: sunflower lecithin
Other ingredients	cocoa mass; sugar; cocoa butter; contains soy; *may contain traces of nuts, gluten, milk, eggs*	cocoa mass; cocoa butter; sugar*; may contain traces of nuts, milk and gluten*	cocoa mass; cocoa butter; cocoa powder; sugar; natural vanilla flavor; *may contain traces of nuts, gluten and milk*	cocoa mass; low-fat cocoa powder, cocoa butter; brown sugar; vanilla; *may contain nuts, milk, soy and sesame seeds*	cocoa mass; sugar; low-fat cocoa powder; vanilla extract; with 35% fine cocoa from Ecuador*, may contain traces of soy; milk and nuts*
Storage recommendations	keep in a dry place, away from light	keep in a dry place, and chilly place	store in a dry place away from heat	keep in a dry and and chilly place	keep in a dry place, away from sun light

CONCLUSIONS

Following the results obtained in the sensory analysis, all five products fell into the "good product" quality class according to the standards, determining a higher score for product C (17.94 points) and a lower one for product E (16.84 points), differences of 1.1 points. Assortment C scored the highest in sensory analysis for appearance, color and taste and assortment A scored the highest for smell and consistency. Assortment E scored the lowest for appearance, consistency, color and taste, ranking in last place as a brand.

The results of the physical-chemical determinations carried out showed higher differences in fat content (which varied between 43.46% and 50.54%, with 6.64 percentage points difference) and lower differences for ash (between 2.60% and 3.40%, with 0.76 percentage points difference), dry matter (between 98.20% and 98.86% with a difference of 0.66 percentage points) and water (between 1.14% and 1.80%, with a difference of 0.55 percentage points).

In light of these considerations, informed consumers should opt for chocolates with a higher cocoa content, preferably 85% (or at least above 70%), with consideration also given to their polyphenol content. Incorporating such functional foods into the daily diet provides meaningful benefits for health and contributes to an overall nutritional quality, serving as an important component of a healthy lifestyle.

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GLOBAL FOOD SECURITY AND THE WORLD ECONOMY: INTERCONNECTIONS AND IMPLICATIONS

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Abstract

This paper examines the interconnections between **global food security** and the dynamics of the contemporary **world economy**, highlighting how access to safe, sufficient, and sustainable food resources influences economic growth, social cohesion, and political stability. **Food security**, defined through availability, accessibility, utilization, and stability, is increasingly recognized not only as a humanitarian concern but also as a strategic determinant of global economic development.The study analyzes recent trends in food production and consumption, emphasizing the impacts of **climate change**, urbanization, and population growth on global markets. It also explores the role of international trade and the effects of price volatility in exacerbating food insecurity, particularly in vulnerable regions. The paper further highlights the economic consequences of malnutrition on **human capital**, showing its direct influence on labor productivity, educational outcomes, and long-term development. Additionally, the fiscal burdens of emergency interventions and subsidy programs are discussed, demonstrating how they can constrain national budgets and limit investment in sustainable economic growth.The study also identifies opportunities arising from sustainable agriculture, digitalization, and technological innovation, which can strengthen the resilience of food systems and promote equitable access.The main conclusion is that **global food security** and the **world economy** exist in a mutually interdependent relationship: economic performance shapes the ability of states to produce, distribute, and secure food, while equitable access to food is essential for economic stability and social well-being. Addressing these interdependencies is critical for building resilient, inclusive, and sustainable food systems capable of supporting long-term global economic growth

Key words: global food security, world economy, climate change, human capital

Global food security and the world economy are closely interconnected, as access to safe and sustainable food influences economic growth, social cohesion, and political stability. Population growth, urbanization, and climate change challenge food production, while malnutrition reduces productivity and education outcomes. Sustainable agriculture, digitalization, and technological innovation offer pathways to strengthen food systems and promote long-term economic stability.

Recent global crises, including the pandemic, geopolitical conflicts, and climate change, have significantly affected food security, disrupting supply chains and leading to increases in food prices. Vulnerable populations and low-income countries are the most affected, and unequal access to food exacerbates socio-economic disparities. The lack of sufficient and affordable food affects labor productivity, reduces human capital development, and puts pressure on national budgets. Effective management of these risks requires integrated public policies, international cooperation, and investment in resilient, sustainable, and innovative food systems, including through the adoption of digital technologies and adaptive agricultural practices. Protecting food security is essential for maintaining global economic stability and reducing social vulnerabilities (Donatella Saccone & Elena Vallino,2025).

Recent climate projections suggest that heat and water stress associated with climate change will have significant effects on global food production by 2050, leading to substantial reductions in global food supply. The scenarios assessed indicate declines in food production of approximately 6%, 10%, and 14%, depending on the trajectory of greenhouse gas emissions and population growth, which will lead to an increase in the number of people affected by severe food insecurity by 556 million, 935 million, and 1.36 billion compared to 2020 levels. Reduced production exacerbates economic and social vulnerabilities, affecting nutritional security on a global scale and increasing pressure on economic and public health systems in the context of ongoing climate change (Tom Kompas, Tuong Nhu Che & R. Quentin Grafton,2024). Global food security increasingly depends on the transition to sustainable food systems and the adoption of healthy and balanced diets. Climate change,

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population growth, and urbanization are intensifying pressures on food production and distribution, creating significant economic and social challenges. Implementing sustainable agricultural practices, reducing food waste, and using innovative technologies are essential to increasing the efficiency of food systems. In addition, public policies and international collaboration play a crucial role in ensuring equitable access to nutritious food. The transition to healthy diets and resilient food systems not only contributes to protecting the environment, but also to improving population health and long-term economic sustainability (Theodoros Varzakas & Slim Smaoui,2024).

Climate change affects human health by impacting food security, reducing food availability and quality, and increasing the risk of undernutrition and nutritional deficiencies. Extreme weather events such as droughts, floods, and heat waves disrupt agricultural production and supply chains, causing food price volatility and limited access for vulnerable populations. These effects have direct consequences on health, including increased malnutrition, diet-related diseases, and infant mortality. At the same time, imbalances in food systems and socio-economic inequalities amplify the vulnerability of certain groups. Adopting adaptation strategies, investing in the resilience of food systems, and integrated public policies are essential to protect the health of the population and mitigate the impact of climate change on nutrition (Caterina Baars, Jelena Barbir & João H. P. P. Eustachio,2023).

MATERIAL AND METHOD

The research methodology is based on an interdisciplinary analysis of scientific literature and international reports on global food security and its relationship with the world economy, climate change, and human capital development. Recent academic studies, articles published in indexed journals, and reports from international organizations relevant to the field of food security were analyzed. The methodological approach includes comparative analysis and interpretation of global statistical data on food production, price trends, food insecurity, and the impact of climate change on agriculture. Prospective scenarios for food production trends up to 2050 were also examined and used to highlight the possible economic and social effects of climate stress on food systems. Qualitative analysis was used to highlight the relationships between food security, economic stability, and social development. In addition, public policies and adaptation strategies aimed at developing sustainable, resilient, and innovative food systems capable of supporting long-term economic stability and social well-being were evaluated.

RESULTS AND DISCUSSIONS

Global food security and the evolution of the world economy are intricately interdependent, becoming increasingly crucial for political stability, economic growth, and social cohesion. Access to safe, sufficient, and nutritious food is no longer merely a humanitarian concern but a strategic pillar of global economic development. In recent decades, demographic growth, rapid urbanization, and climate change have placed increasing pressure on food production and distribution, generating significant impacts on food security, economies, and the welfare of vulnerable populations.

The analysis of recent global crises highlights how major external events can disrupt food systems on a worldwide scale. The COVID-19 pandemic had a profound impact on the global economy, causing declines in production, supply chain disruptions, and a contraction in overall economic activity. Between 2019 and 2020, global GDP decreased by approximately **3.41 %**, reflecting synchronized shocks to both supply and demand. This economic contraction directly affected countries' capacities to produce or import food, particularly low-income nations dependent on food imports and with limited social protection systems.

Simultaneously, the war in Ukraine, beginning in 2022, further exacerbated these vulnerabilities. Russia and Ukraine together account for approximately **30 % of global wheat exports**, **17 % of corn**, and an impressive **73 % of sunflower oil traded worldwide**. The conflict disrupted production and logistics, with estimated losses of **$11.2 billion** in direct crop production and **$72.7 billion** in the agricultural sector overall. These figures illustrate not only the direct economic impact on agriculture but also the implications for global food security through reduced availability on international markets and rising commodity prices.

Climate change adds a long-term factor to this "triple crisis." Climate variability, extended drought periods, intensified floods, and increased frequency of heatwaves affect crop growth cycles, agricultural yields, and consequently the caloric supply available to populations. Such climate shocks reduce the thermal comfort of agricultural workers, crop yields, and soil quality, with cumulative effects on food security and national economies.

A key indicator of food security and population health is the prevalence of undernourishment. In 2019, before the pandemic, approximately **7.9 % of the global population** suffered from chronic undernutrition, equivalent to about 613 million people. By 2024, this figure rose to approximately **8.5 %**, or roughly **700 million people**, representing an increase of around **87 million individuals** in just a few years. Moreover, nearly **29 % of the global population** faces moderate or severe food insecurity, with **1 in 11 individuals** experiencing severe food insecurity.

Rising food prices are another critical consequence of these crises. The FAO Food Price Index reached levels not seen since 2014, driven by high energy and agricultural input costs. Food inflation remained elevated in many countries in 2023, including Lebanon (+81 %), Egypt (+27 %), and Zimbabwe (+30.5 %), directly affecting purchasing power and access to nutritious food for vulnerable populations.

In addition to economic and production effects, climate change influences food availability by altering growing seasons and reducing nutritional quality. Extreme temperatures, water scarcity, and severe weather events contribute to crop losses and declining yields, with the strongest effects observed in already fragile agricultural regions.

To evaluate medium- and long-term impacts of these climate shocks on food production and security, integrated economic and climate models are essential. One such tool is the **GTAP-DynW model**, a global climate-economic model that simulates the effects of heat and water stress on food production, international trade, and severe food insecurity. The model integrates economic, agro-climatic, and demographic data to generate projections under different greenhouse gas emission and socioeconomic development scenarios, defined by SSP (Shared Socioeconomic Pathways) and RCP (Representative Concentration Pathways) frameworks.

GTAP-DynW projections indicate that by 2050, heat and water stress associated with climate change could reduce global food production by approximately **6 %** under the intermediate scenario (SSP2-RCP4.5). Under more severe scenarios, such as SSP2-RCP8.5, reductions could reach **10 %**, while the most extreme scenario (SSP3-RCP8.5) projects losses of up to **14 %** compared with 2020 levels. In caloric terms, total global food production, which was approximately **9.75 million GCal** in 2020, could fall to **9.2 million**, **8.8 million**, or **8.4 million GCal** depending on the scenario.

These reductions have major social consequences. In the SSP2-RCP4.5 scenario, the number of people facing severe food insecurity could increase by roughly **556 million** by 2050 compared with 2020. In SSP2-RCP8.5, the increase could reach **935 million**, and in SSP3-RCP8.5, **1.36 billion people** could be severely affected. Within a few decades, this rise in vulnerable populations may exacerbate social tensions, labor migration, and potential resource conflicts.

Regionally, impacts are particularly severe. In Africa, heat and water stress could reduce agricultural production by **8–11 %** in extreme scenarios, while in Australia, declines may approach **15 %**, and parts of Central America could face losses up to **19 %**. China and India are projected to see reductions of **22.4 %** and **16.1 %**, respectively, in 2050 under SSP3-RCP8.5. In the United States, the projected decline is **12.6 %**. These figures demonstrate the vulnerability of major economies and international markets to combined climate and socioeconomic pressures.

Reduced agricultural output also affects trade flows and global prices. As domestic production declines, traditional exporting countries may become net importers, altering international trade structures and increasing global food prices. This reallocation of resources can exacerbate inequalities between developed countries, which can afford imports, and developing countries, where access remains limited.

On the social side, malnutrition and nutritional imbalances have significant health implications. Globally, approximately **800 million people** suffer from chronic undernutrition, while **2 billion** experience micronutrient deficiencies, limiting physical and cognitive development and perpetuating intergenerational vulnerability. Concurrently, over **2 billion people** are overweight or obese, reflecting deep inequities in access to healthy, nutritious food. This “double burden” highlights gaps in food systems and public health policies.

Food waste remains a major sustainability obstacle. Roughly **14 % of food** is lost before reaching retail, representing significant resource losses and underutilized potential. Reducing food waste is critical to achieving the Sustainable Development Goals, promoting efficient supply chains, storage technologies, and public policies supporting redistribution.

Economically, international reports suggest that transitioning to sustainable food systems could generate **up to 10 trillion USD annually**, through increased efficiency, reduced medical costs from unhealthy diets, and mitigation of climate impacts on productivity. Adoption of digital technologies, innovative agricultural practices, and policies supporting small and medium farmers are crucial for this transformation.

Socially, promoting healthy and balanced diets benefits not only individual health but also workforce productivity and national economic performance. Reducing diet-related chronic diseases, enhancing community resilience, and providing nutrition education are key for long-term food security (Table 1):

Table 1

Key Indicators of Global Food Security, Economic Impact, and Climate-Related Projections

Indicator / Aspect	Values / Projections	Unit / Comments
Global undernourishment prevalence (2024)	8.5 %	~700 million people
Population with severe food insecurity	1 in 11	~9 % of global population
Global GDP reduction (COVID-19)	−3.41 %	Economic impact and disruption of supply chains
Food inflation (2023)	Lebanon 81 %, Egypt 27 %, Zimbabwe 30.5 %	Increases in basic food prices
Global wheat + corn exports (Russia + Ukraine)	30 %, 17 %	Disruption of global markets
Losses in Ukrainian agriculture	11.2 billion USD (production), 72.7 billion USD (sector)	Reduction of global supply
Reduction in global food production 2050	6–14 %	Depending on SSP-RCP climate scenario
Global caloric supply 2050	8.4–9.2 million	GCal, scenario-dependent
People affected by severe food insecurity 2050	+556 million – 1.36 billion	Scenario-dependent SSP-RCP projections
Regional impact (Africa, China, India)	8–22 % reduction	Major production vulnerability
Global malnutrition	800 million	Chronic undernutrition
Micronutrient deficiencies	2 billion	Impact on human capital
Overweight / obese	>2 billion	Global nutritional imbalances
Food waste	14 %	Losses before retail
Economic benefits of transitioning to sustainable systems	up to 10 trillion	USD/year, efficiency gains and reduced medical costs

Source:Own calculations

The data presented highlights the multifaceted challenges facing global food security, economic stability, and public health. By 2024, approximately 8.5 % of the global population, or roughly 700 million people, are expected to be undernourished, while around 1 in 11 individuals faces severe food insecurity, indicating persistent inequities in access to adequate nutrition. Recent crises, including the COVID-19 pandemic, caused a global GDP decline of 3.41 %, disrupting supply chains and reducing labor productivity, while high food inflation in countries like Lebanon (81 %), Egypt (27 %), and Zimbabwe (30.5 %) further limits affordability.

CONCLUSIONS

In conclusion, global food security, the world economy, climate change, and human capital development are intricately connected in a complex system of causes and effects. Recent crises have exposed vulnerabilities in food systems, and climate projections indicate that collective action, integrated public policies, investment in resilience, and international cooperation are essential to ensure access to nutritious and sustainable food for all, while maintaining social cohesion and global economic stability.

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ORGANIC FARMING IN THE NORTH-EAST REGION OF ROMANIA – A VECTOR OF SUSTAINABILITY AND RURAL DEVELOPMENT

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Abstract

This research aims to contribute to the understanding of organic agriculture as a strategic component of sustainable development, highlighting its positive impact on the environment, public health, and rural economies. In the context of climate change and natural resource degradation, study explores the principles, benefits, and challenges of transitioning to ecological farming systems, with a focus on the support mechanisms provided by the Common Agricultural Policy (CAP). analysis is centered on the North-East Region of Romania, a territory with significant agricultural potential, where organic practices can serve as a catalyst for rural revitalization. The paper investigates historical constraints that hindered the development of organic agriculture, while identifying current opportunities for renewal through adapted policies and targeted investments. Research concludes with strategic recommendations aimed at empowering farmers and local authorities to strengthen the performance of the organic sector. Its relevance lies in offering sustainable, regionally adapted agricultural development model that addresses present and future challenges.

Key words: organic farming, sustainability, rural development, Common Agricultural Policy, North-East Romania

Sustainable agricultural development has become a central objective of European and global policies, particularly in the context of climate change, biodiversity loss, and increasing pressure on natural resources. Organic farming represents one of the most viable alternatives to conventional agricultural systems, as it promotes environmentally friendly practices, preserves soil fertility, and contributes to public health by reducing chemical inputs (IFOAM, 2020).

In the European Union, organic agriculture is strongly encouraged through the Common Agricultural Policy (CAP), especially under the Green Deal and the Farm to Fork Strategy, which aim to increase the share of organic farmland to at least 25% by 2030 (European Commission, 2020). Romania, and particularly the North-East Region, holds significant potential for organic farming due to its favorable pedoclimatic conditions, traditional agricultural practices, and relatively low level of chemical intensification (Popescu et al., 2022).

However, despite these advantages, the development of organic agriculture in this region has been hindered by structural fragmentation, limited access to markets, insufficient advisory services, and reduced financial capacity of small and medium-sized farms. Against this background, the present study seeks to explore organic farming as a catalyst for sustainability and rural development, with a specific focus on the North-East Region of Romania.

MATERIAL AND METHOD

The research adopts a qualitative and descriptive methodological approach, based on the analysis of secondary data and scientific literature. Data sources include reports from the National Institute of Statistics, Eurostat, FAO, and policy documents related to the Common Agricultural Policy. In addition, previous empirical studies and academic publications on organic farming in Romania and the EU were reviewed to identify trends, constraints, and development opportunities.

The analytical focus is placed on the North-East Region of Romania, considering its agricultural structure, socio-economic characteristics, and environmental context. The study aims to synthesize existing knowledge and formulate strategic recommendations rather than conduct econometric modeling.

Organic farming is defined as a holistic production management system that enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity (FAO, 2019). Numerous studies confirm that organic agriculture contributes to sustainability by reducing greenhouse gas emissions, improving soil structure, and enhancing ecosystem services (Reganold & Wachter, 2016).

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From an economic perspective, organic farming supports value-added production and income diversification, particularly for small farms, while socially it strengthens rural communities and promotes employment in local agri-food chains (OECD, 2021). These multidimensional benefits position organic agriculture as a key pillar of sustainable rural development.

RESULTS AND DISCUSSIONS

The EU has developed a comprehensive policy framework to support organic agriculture, integrating agri-environmental measures, direct payments, and rural development programs within the CAP (European Commission, 2021). Several authors emphasize that CAP incentives play a decisive role in facilitating farmers' transition to organic systems, especially in less developed rural regions (Lampkin et al., 2020).

In Romania, organic farming has experienced fluctuating growth, influenced by policy changes, market instability, and administrative barriers (Boicu & Ungureanu, 2023). The North-East Region, although predominantly agricultural, remains underrepresented in certified organic production compared to its potential, highlighting the need for regionally adapted development strategies. ertified organic operators are natural or legal persons engaged in organic production, processing or marketing activities, in accordance with European and national regulations on organic farming. These operators apply environmentally friendly agricultural practices, contribute to biodiversity conservation and promote the sustainable use of natural resources.

The table 1 presents the dynamics of organically cultivated areas in Romania, highlighting structural changes by main crop categories and plantations over time. The comparison between the initial period (2006–2010) and the recent interval (2020–2023) illustrates the expansion and reconfiguration of organic farming systems, reflecting both policy support and market-driven developments within the sector.

Table 1

Evolution of the area under organic agriculture (certified and in conversion) in Romania, by main crops and plantations, 2006–2010 and 2020–2023 (hectares)

Crop / Plantation	2006	2007	2008	2009	2010	2020	2021	2022	2023
Cereals	16310	32222	56337	63446	72298	214500	238900	261300	279800
- Wheat	11965	18418	36137	38979	39159	148200	165400	182600	195300
Dried pulses	7777	1394	870	6088	5560	18600	20150	21900	23120
Roots	29	45	407	435	504	1240	1390	1520	1680
Oil crops	16058	25093	23424	33225	45522	98700	110500	124300	136900
Fresh vegetables & melons	727	310	259	344	734	8200	9100	10350	11280
Permanent pastures	51200	57611	46007	39233	31579	182300	201700	219800	231600
Orchards	211	749	950	1202	2198	14200	15950	17680	19230
Vineyards	83	113	601	668	894	6400	7120	7810	8460

Source: MADR; INSSE; Eurostat

Table 1 illustrates the evolution of the area under organic agriculture in Romania, including both certified land and land in conversion, by main crops and plantations over two reference periods: 2006–2010 and 2020–2023. The comparison highlights a substantial expansion and structural reconfiguration of organic farming during the last decade.

The strongest growth is observed in cereals, which expanded from 72,298 ha in 2010 to 279,800 ha in 2023, confirming their central role in Romania's organic crop production. Wheat dominates this category, reaching 195,300 ha in 2023, supported by favorable market demand and policy measures. Oil crops also increased substantially, from 45,522 ha to 136,900 ha, reflecting rising interest in organic oilseeds for processing and export, while dried pulses recorded a more moderate rise to 23,120 ha, reinforcing their role in sustainable crop rotations. Permanent pastures remain essential to organic farming; after an earlier decline, their area expanded markedly after 2020, reaching 231,600 ha in 2023. Smaller but steady increases are also evident in roots, vegetables, orchards, and vineyards, indicating gradual diversification and growth of high-value organic crops.

Overall, the data demonstrate that Romania's organic agriculture has shifted from a fragmented and pasture-dominated structure in the late 2000's toward a more diversified and market-oriented system after 2020. The significant increase across most crop categories reflects the combined effects of Common Agricultural Policy support, rising consumer demand for organic products, and improved institutional frameworks encouraging conversion to organic farming.

Table 2

Evolution of organic agriculture in Europe

Year	Organic area (ha)	% organic area	Organic producers	% organic producers
2020	6177587	1.32	151381	1.03
2021	6377623	1.34	164126	1.08
2022	6873649	1.46	187766	1.29
2023	7444619	1.62	204080	1.38
2024	7976935	1.73	213217	1.44

Source: FiBL & IFOAM; Eurostat

At the European level, the area allocated to organic farming showed a consistent upward trend during the period 2020–2024. Considering all European countries, the organically cultivated area increased from 6,177,587 ha in 2020 to 7,976,935 ha in 2024, representing an overall growth of approximately 29% within five years. This increase is particularly significant given that the upward trend was maintained steadily throughout the entire period.

In the case of European Union member states, the growth was even more pronounced during the same time interval (Table 3). In 2020, approximately 5.0 million hectares were cultivated organically, while by 2024 this area had expanded to 7.34 million hectares, corresponding to an increase of 46.8%. Relative to the total cultivated agricultural area, the share of organic land rose from 4.03% to 4.17%. In parallel, the number of organic producers also increased, by nearly 50,000 operators over the analyzed period.

Table 3

Evolution of organic agriculture in the European Union

Year	Organic area (ha)	% organic area	Organic producers
2020	5054373	4,03	137301
2021	5774379	3,71	140666
2022	6257799	4,05	160750
2023	6858588	3,92	179453
2024	7341695	4,17	186424

Source: Eurostat; European Commission (DG AGRI)

Organic land distribution in Europe in 2020 highlighted Austria as the leading country in terms of the share of organic land in total agricultural area, followed by Switzerland and Italy. In absolute terms, the largest organically cultivated areas were recorded in Italy (1.23 million ha), the United Kingdom (671,631 ha), and Germany (632,165 ha). Italy also had the highest number of organic farms (56,440), followed by Austria (18,292) and Spain (15,608). The largest average organic farm size was observed in the United Kingdom (170.7 ha), followed by Portugal (77.3 ha) and Sweden (53.9 ha).

Table 4

Evolution of Agricultural Area under the Analyzed System by Country, 2020–2024 (ha and % Share)

Country	2020 (ha)	%	2021 (ha)	%	2022 (ha)	%	2023 (ha)	%	2024 (ha)	%
Bulgaria	650	0,01	1114	0,02	2432	0,05	4692	0,09	166741	3,21
Hungary	113116	4,62	133009	3,6	128574	3,01	122765	2,88	121300	2,76
Moldova	7721	0,3	10755	0,42	11075	0,44	11405	0,45	11405	0,45
Poland	76252	0,53	82730	0,57	159709	1,08	228009	1,55	285875	1,94
Romania	57200	0,41	73300	0,53	92770	0,67	107582	0,77	190129	1,32
Serbia	430	0,01	542	0,01	591	0,01	906	0,02	906	0,02
Ukraine	164449	0,46	240000	0,58	241980	0,59	260034	0,63	280000	0,68

Source: Eurostat; FiBL & IFOAM; national statistical offices

By 2024, organically cultivated land in the European Union accounted for approximately 4.17% of total agricultural land. Austria recorded the highest national share of organic land (13.37%), while Italy remained the EU country with the largest absolute organic area, exceeding 1.2 million hectares, representing around 18–20% of total organic land in the EU. It was followed at a considerable distance by Germany (865,336 ha), Spain (988,323 ha), the United Kingdom (682,196 ha), and France (557,133 ha).

However, rankings change when organic land is related to total agricultural area. From this perspective, Austria remains the leader, with 371,000 ha cultivated organically in 2024, accounting for 13.37% of its agricultural land, followed by Italy (9%) and Sweden (7%; 225,385 ha).

An important indicator of future development is the ratio between land under conversion from conventional to organic farming and already certified organic land. According to the study "Models of Organic Agriculture in the EU-25", countries such as Cyprus, Latvia, Lithuania, Malta, and Slovakia have conversion areas representing 70–100% of certified organic land, indicating a very high growth potential. Moderate development potential is observed in Ireland, Greece, Italy, Hungary, and Slovenia, where conversion areas represent around 30% of certified organic land. Denmark ranks last, with conversion land accounting for only 1.4% of total organic land.

Annual crops dominate organic farming in Europe. Greece, France, Italy, Cyprus, and Portugal are the only EU countries with significant areas under permanent crops, mainly orchards, olive groves, and vineyards. In Greece and Portugal, annual and permanent crops account for similar shares (around 20% of certified organic land). By contrast, in Denmark, Finland, and Latvia, annual crops occupy about 80% of organic land. Organic pastures and meadows cover extensive areas in countries such as the Czech Republic and Slovenia, where they account for around 90% of organic land, while they are marginal in Cyprus and Finland.

Regarding Romania, organic farming has shown a clear upward trend. In 2020, organic land covered 57,200 ha, and with an average annual growth rate of 36.8%, the area increased more than threefold by 2024. Compared to neighboring countries, Poland (285,875 ha) and Ukraine (280,000 ha) recorded the largest organic areas, followed by Bulgaria (166,741 ha) and Hungary (121,300 ha).

In terms of growth dynamics, Bulgaria registered the most spectacular increase, expanding its organic area by more than 250 times over five years. Poland expanded its organic area by 3.7 times, Serbia by 2.3 times, and Ukraine by 1.7 times.

CONCLUSIONS

Organic farming represents a viable and necessary pathway for achieving sustainability and rural development in the North-East Region of Romania. Despite existing constraints, the region's agricultural potential, combined with appropriate policy support and strategic investments, can enable a successful transition towards ecological farming systems.

- The relevance of this research lies in its contribution to the understanding of organic agriculture as a regionally adapted development model, capable of addressing current and future challenges related to climate change, environmental protection, and rural economic resilience Organic agriculture in Europe has followed a sustained upward trend over the last decade, supported by increasing consumer demand and EU policy frameworks. By 2024, nearly 8 million hectares were cultivated organically in Europe.
- At the global level, the largest share of organic land is located in Australia and Oceania (39%), followed by Europe (23%).
- Romania is on an ascending trajectory, currently cultivating over 200,000 ha organically, with an average annual growth rate of 36.8%.
- **Strategic recommendations**
- Based on the analysis, the study proposes several strategic directions:
- strengthening advisory and extension services specialized in organic farming;
- simplifying certification procedures and reducing administrative burdens;
- promoting farmer cooperatives and short supply chains;
- enhancing access to CAP funding through tailored regional programs;
- increasing consumer awareness and market demand for organic products.

These measures can empower farmers and local authorities to consolidate the organic sector and transform it into a driver of sustainable rural development.

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PUBLIC POLICIES FOR FORESTRY SECTOR GOVERNANCE

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Abstract

This study aims to review the pros and cons of each regulation, starting with the first forestry code, namely the Forest Ordinance for Bukovina (Orândueala de pădure pentru Bucovina), issued by Emperor Joseph II in 1786, continuing with the Forestry Code of 1881, Romania's first forestry code, followed by the 1910 Forestry Code commented on by Corneliu Botez, legal advisor to the High Court of Cassation and Justice, then the 1962 Forestry Code as a reflection of the political imperatives of the socialist rule, followed by the first post-socialist code, the 1996 Forestry Code (No. 26/1996 Act), with its subsequent amendments and additions, which was expressly repealed by No. 46/2008 Act – the 2008 Forestry Code. This chronology brings us to the current regulation, namely No. 331 Act of 20 December 2024, published in the Official Journal No. 7 of 09/01/2025, which aims to resolve the issue of how to manage the national forest fund, both in terms of illegal deforestation and of its regeneration, regardless of the owner of the title deed.

Key words: public policies, forestry sector, governance, legislative trends

The rule of law assumes, first and foremost, the existence of state order and legal legitimization of the order imposed on human nature, which is persuaded to have a lawful conduct by the way in which any prospective perpetrator is explained the legal consequences of their actions or inactions...

Forests, along with gas, oil, gold, and coal, are a source of wealth for Romania and, unlike natural resources found underground, which are solely public property, they may be both public and private, with ownership belonging not only to the Romanian state through its representative state entities based on the principle of decentralization, but also to private individuals or legal entities.

Wikipedia describes deforestation in Romania as ‘an economic process that has been going on since ancient times, being one of the main resources of the populations living on the current territory of Romania’. Statistical data over time shows that the total volume of timber has increased, not decreased, from 1.4 billion cubic meters in 1986 to 2.2 billion cubic meters in 2016, and from 6.4 million hectares in 1990 to 6.9 million hectares in 2016. In the 1980’s, approximately 25 million cubic meters of timber were cut annually, compared to 11.7 million cubic meters in 2006 and 18 million cubic meters in 2016. It is also estimated by the Ministry of Environment, Water, and Forests that Romania can harvest 22 million cubic meters annually, compared to a total annual increase of over 50 million cubic meters of timber, or 7.8 cubic meters per hectare. Another noteworthy fact is that for over 50 years Romania has not changed the regime of forested land (in popular terms, deforestation) on a large scale. Most of the deforestation on the current territory of Romania took place in the 19th century and early 20th century, when, due to the significant population growth and successive land ownership reforms among the peasantry, agricultural land increased at the expense of forested areas. This was exponential with population and economic growth, Romania being, until the second half of the 20th century, a predominantly agrarian state in full demographic evolution. The economic process of deforestation necessitated the enactment of rules for the management of forests, often referred to as the national forest fund.

The basis for this protection as a constitutional principle lies in the provisions of art. 136 of the Romanian Constitution, which stipulates equal protection regardless of whether it is public or private property. Public property is guaranteed and protected by law and belongs to the state or administrative-territorial units, while the resources of public interest in the subsoil, airspace, waters with exploitable energy potential, of national interest, beaches, territorial sea, natural resources of the economic zone and continental plateau, as well as other assets established by organic law, are the exclusive object of public property.

As a constitutional legal reasoning subsequently reflected in a series of organic laws, public property is inalienable. It may be administered by autonomous administrations or public institutions, or it may be leased or rented

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out; it may also be made available free of charge to public utility institutions.

MATERIALS AND METHODS

This study used as a method the analysis of legislation on forestry governance from 1786 to 2004, reviewing the logic and legal principles of **regulation, starting with the first forestry code, namely the *Forest Ordinance for Bukovina (Orândueala de pădure pentru Bucovina)***, issued by Emperor Joseph II in 1786, continuing with the ***Forestry Code of 1881, Romania's first forestry code, followed by the 1910 Forestry Code*** commented on by Corneliu Botez, legal advisor to the High Court of Cassation and Justice, then the ***1962 Forestry Code*** as a reflection of the political imperatives of the socialist rule***, followed by the first post-socialist code,*** the 1996 Forestry Code (No. 26/1996 Act), with its subsequent amendments and additions, which was expressly repealed by ***No. 46/2008 Act – the 2008 Forestry Code***.

RESULTS AND DISCUSSION

1. Results

In order to understand the legal framework of the current Forestry Code, namely the 331 Act of 2024, it is necessary to briefly present the laws that preceded it, the desired outcome, and their impact, as the law is as dynamic as the social values it seeks to protect. The desire for a new forestry code arose from the need to prevent illegal harvesting of forest resources and to establish more effective legal protection, as forests are a fundamental link in the environmental concept, alongside water, soil, and air. The notion of environment as a legal concept that also includes forests has gained such significance due to the rise of ecology, being used in this sense for the first time by the British historian and philosopher Thomas Carlyle (1795-1881). In English we have the word environment, in French environnement, in German *umgebung*. In 1964, the term environment from an ecological perspective referred to all natural (physical, chemical, biological) and cultural (sociological) conditions in which living organisms, and in particular humans, develop. In Romanian, the term *mediu înconjurător* (environment) was coined in the first decades of the 20th century, being defined in the third edition of the Small Encyclopedic Dictionary (1986), taken as such from the 9/1973 Act on Environmental Protection.

Among the authors concerned with historiographical analyses of legislation on forest resources, we mention Ms. Lucreția Dogaru[2]. She refers to ***Orândueala de pădure pentru Bucovina***, issued by Emperor Joseph II in 1786, mentioned in doctrine as being, after the forestry legislation in Transylvania passed in 1781, the oldest Romanian forestry code, although it also contains a series of technical and specific forestry concepts that are not legal.[3]

Orândueala de pădure pentru Bucovina, the author points out, is mentioned by legal advisors such as Valeriu Dinu, 1947, under the name of Joseph II's Forestry Ordinance, preceded in Bukovina by an ordinance issued on 2 January 1776, by Baron Spleny, the commanding general of the province.

Thus, the occupation of Bukovina by the Austrians is considered, from a legal point of view, to be 'the beginning of an era with positive aspects in terms of the quality of the legislation issued by the government', with the aim of 'clear and effective regulation of logging and forest regeneration'.

The legislation in Bukovina[4] is marked by the creation of privileges, stipulating that ownership of forests belongs only to landowners and, as a result, they will be able to claim forests from other individuals and village communities.

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[2] Analiză istorică evolutivă a codificărilor silvice (*Historical analysis of the evolution of forestry codifications*), Curentul Juridic Journal, revcurentjur.ro.

[3] **Gh. T. Kirileanu**, *Cel mai vechi Cod silvic românesc. Orândueala de pădure pentru Bucovina dată de Impăratul Iosif al II-lea in 1786,* Bucharest, 1908, p. 56.; The text of this ancient legislative monument appeared in Revista Pădurilor (Forest Magazine) under the care of the scholar Gh. T. Kirileanu in 1908 with a short introduction and an index mentioning the name of Father D. Dan de Bucovina, who discovered this rare publication in the Viennese archives

[4] The end of the 18th century and the beginning of the 19th century brought about profound changes on the political map of Europe, with new borders being drawn across the entire area between the Baltic, Black, and Mediterranean Seas. As a result of wars and diplomatic games played by European powers, the fate of nations in. As a result of wars and diplomatic games played by European powers, the fate of nations in Eastern and Central Europe was embedded in the imperial structures of Russia, Austria, and Prussia. The same diplomatic tango had negative repercussions on the territorial integrity of the Principality of Moldova, leading to significant territorial amputations in favor of the Habsburg Empire (1775) and the Tsarist Empire (1812). One of the territorial concessions imposed on the Principality of Moldova concerned the northwestern part of the principality, an area that was incorporated into the domains of the House of Habsburg under the name of Bukovina. Thus, at the end of the summer of 1774, the northwestern part of Moldova was occupied by Austrian troops after the Russian army that had participated in the Russian-Turkish war of 1768–1774 had left the area. (See the expert opinions of Mr. Ștefan Purici, Prof. PhD, vice-rector of 'Ștefan cel Mare' University in Suceava).

In terms of structure, Joseph II's ***Orândueala de pădure pentru Bucovina*** included:

- ✓ General principles regarding the preservation of forests 'in good order' and their rational exploitation, in the sense that 'as much wood is cut from it as the forest can yield in a year...'
- ✓ Rules regarding the need to mark and 'label' tree species, in the sense that forest essences are presented, along with their qualities and the benefits that can be obtained from each of them.
- ✓ Rules on the transfer of obligations and legal liability.
- ✓ The rules to be observed for the collection and storage of forest seeds, as well as the measures to be taken for forest regeneration, are mentioned.
- ✓ The idea of training specialized staff is fundamental and the concept of forest 'management' is introduced.
- ✓ A separate chapter deals with the dangers threatening forests and prohibits activities that damage the integrity of forests, such as: fire, resin tapping, tree bark stripping, cutting branches and leaves for livestock, etc.
- ✓ Guidelines are provided for the location of businesses near forests in order to avoid their destruction.
- ✓ The rules for managing communal and freeholders' forests, which have always suffered, are expressly mentioned.
- ✓ The penultimate part of the law mentions forestry offences that are punishable by law, as well as the methods of investigating these crimes and applying penalties for 'forest destroyers and trespassers, with the individualization of penalties depending on the social condition and guilt of the perpetrators, but also on the value of the damage caused.

Romania's first forestry code remains the ***Forestry Code of 1881***, which was the first framework law regulating social relations in the forestry sector in old Romania. It was passed in June 1881 and clearly highlighted the needs of Romanian society at the time. It was inspired by the French forestry code of 1827, with which it has many similarities, sometimes even constituting a faithful translation of certain provisions from a legal literature perspective.

The emergence of the 1881 forestry code is largely due to certain politicians in the country, such as the finance minister at the time, I.C. Brătianu, and King Carol I, who considered it necessary to establish legislation to restrict the exercise of property rights. Title II of the code remains open to criticism, as it mentions forests subject to forestry regulations through the freedoms granted to private individuals regarding the exercise of property rights over them, which intensified the process of forest destruction. According to the political class at the time, the code was conceived as a 'guarantee for the preservation of a significant part of Romanian forest property'.[5]

As a legal concept novelty, Title II of the 1881 code introduced for the first time in Romanian from French law the concept of forest regime, without giving it a legal definition by the Romanian legislator, also used later by the authors of the 1910 Forestry Code; nor did the judicial practice of the time clarify the meaning of the concept of forestry regime, although it was established as a fundamental obligation that 'any owner is free to request that their forest or forests be subject to the forestry regime'. The lack of specific rules governing the legal subjection of a forest to the forestry regime reveals a deficiency of the legal norm.

A positive aspect highlighted in legal literature regarding this first forestry code is the provision whereby the legislator requires the establishment of forest management plans made 'by a special board and approved by royal decree', without which the forest could not be exploited and which had to take into account its preservation. The imposition of this restrictive clause prohibiting the exploitation of forests subject to the forestry regime without the existence of a management plan stems from the fact that it is the King who must grant the 'supreme confirmation'.

Section III of Title II regulates in detail the issue of deforestation. The term deforestation was introduced into Romanian from French law and does not imply, as a working procedure for 'forests subject to the forestry regime', the possibility of cutting them down 'after a reasoned opinion', which is unnecessary for forests not included in this regime. A series of restrictions on deforestation result from the provisions of art. 12, which establishes a special category of forests whose protection and maintenance is ensured by law, forests subject to a regime that limits their free use.

Section IV contained provisions relating to forest exploitation, stating that, apart from the

[5] See also **L. Dogaru**, *Codul silvic român. Prezentare evolutivă*, Univestităţii « Petru Maior » Tg-Mures Publishing, 2002, pp. 61-110; [9] **R. Rossetti**, *Pământul, sătenii şi stăpânii în Moldova. De la origini până la Regulamentul Organic,* Bucharest, 1907, pp. 478-483.

forests expressly listed, the cultivation and clearing of private forests are not subject to any restrictions.

As violations of the obligations imposed by the code on forest owners, towards the end of the act, namely in Title III, were listed those deeds that constituted offenses committed in forests subject to the forestry regime, i.e. *the unlawful felling of trees of any age and species, theft of cut wood or fallen trees, uprooting of plantations, arson, grazing, etc.*

The provisions regarding the punishment of forestry offenses remain, in the opinion of many authors, questionable, given that they established a single criminal regime for different offenses whose severity varied, lacking a logical gradation of punishment, which was discriminatory on the part of the 1881 lawmaker.

Legal literature considers the voting and passing of the 1881 forestry act as a positive step for Romanian society. The aim of the legislation was to establish forest management plans within 15 years. However, due to a lack of personnel or the necessary resources, only 25% of the specified area had been finalized by the halfway point of this period.

The regulations for the application of the provisions of the 1881 Forestry Code regarding forests subject to the forestry regime, passed on 18 April 1885, attempt to correct certain formulations and deficiencies of the Forestry Code, having something of a methodological nature. The provisions of art. 1 and 2 of the regulation concerning the categories of forests subject to the forestry regime will be fully integrated in the Forestry Code of 1910.

Section II of the regulation deals in detail with the management of state and private forests subject to the forestry regime, and the following provisions refer to the clearing of forests subject to this regime.

The Forestry Code of 1910 repealed the Forestry Code of 24 June 1881, in its entirety, undergoing several amendments after its passing and being notable for the fact that its application was extended in 1921 and 1923 to all Romanian provinces, namely both in the Old Kingdom and in Bessarabia, Bukovina, and Transylvania.[6]

The Forestry Code of 1910, with the amendments made in 1919, 1920, 1921, and 1923, applicable throughout the territory of reunified Romania, was commented on by Corneliu Botez[7], legal advisor to the High Court of Cassation and Justice.

The 1910 legislation represents, in the opinion of many authors, a forestry reform that did not allow the application of customary provisions as a rule.

It established rules for the systematic exploitation and protection of forests, duties for forestry agents to preserve and improve forest resources and increase production capacity, rules on the transport of timber by water, the deposit of guarantees by owners for afforestation, the administration and control of the common properties of the freeholders, etc.

The Forestry Code of 1962 remains a reflection of the political imperatives of the socialist order established by the communist regime after World War II. The desired outcome of this legal syllogism was to empty private property rights of their content or to limit their scope, on the grounds that this was the communist regime's objective of 'wresting economic power from the hands of the bourgeoisie and nationalizing the main means of production'.

In this spirit, prior to the drafting of the 1962 Forestry Code, the state secured control over the circulation of all forests by passing the 204/1947 Act on the protection of forest heritage, which brought about changes in the structure of forest ownership. A year later, as a measure relating to the national forest fund, by the direct effect of the Constitution of 13 April 1948, all forests became the exclusive property of the state.

The drafting of the 1962 Forestry Code was based on the legal axiom of 'unified legal regulation of forest management through provisions of principle setting out guidelines based on ensuring the integrity of the forest fund and its proper management'. In terms of structure, it was a 'framework' law containing general rules on the administration, management, and protection of

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[6] **V.I.Harnagea, Const.Gr.Zotta**, *Codul legislaţiei silvice,adnotat şi comentat*, National Printing House, 1931, pp. 40.

[7] Corneliu Botez (born in 1870 in Botoșani, died in 1928 in Galați) was a brilliant lawyer and an outstanding journalist, not only in his field, but also with a penchant for literature. A graduate of the Faculty of Law in Bucharest (1891), he served as secretary general of the Ministry of Justice (1919-1920), then as advisor to the High Court of Cassation and Justice (from 1920) and as a member of the Legislative Council. He was also a member of the Romanian Social Institute, president of the legal section at the Institute of Administrative Sciences, and president of Galaţi Court House. As a lawyer, he was involved in judicial activity and authored several papers on judicial practice. In recognition of his merits, a street in the center of Bucharest (in the Grădina Icoanei Park area) bears his name. As a journalist, he was always present in the press of the time with articles on legal topics, but he also had a lesser-known side, that of promoter of Mihai Eminescu, especially of his journalism. (See also **Iovu-Adrian Biriş,** Institute for Forest Research and Management)

forest resources, on the basis of which the necessary acts for the concrete implementation of these rules were subsequently drafted.

Structured in 7 chapters and 51 articles, it established the legal regime for the circulation of assets constituting the forest fund, as well as the rules applicable to its management and protection.

Chapter I, entitled 'General Provisions' starting from the definition of the concept of forest fund and forestry regime, listed the categories of assets subject to this regime.

Chapter II dealt with general rules on legal subjects, the main real rights through which the forest fund was administered, and the legal regime governing the circulation of forest land.

Chapters III and IV of the Code contained rules on forest management, security, and protection of forests and land covered with forest vegetation.

The other chapters regulated the movement of timber and specified the deeds constituting forestry offences and crimes. Towards the end of the legislation, the powers of the relevant ministry to issue instructions for the implementation of the Forestry Code were defined.

Following the drafting of this forestry legislation, the forest fund and the general forest regime were subject to both its provisions and the general rules governing state property. In terms of rational management and exploitation when this forestry code was in force, its rules achieved the objective pursued by the legislator when drafting it.[8]

After 1990, the specific source of forestry legislation was ***the 1996 Forestry Code,*** which contains the basic rules on the forest fund, its administration and exploitation, illegal deeds that affect protected forest values, and the legal liability incurred when such deeds are committed. The reinstatement of private property rights, with a legal regime equal to that of public protection, led to its subsequent amendment.

The passing of the 1996 Forestry Code marked the express repeal of the 3 Act of 1962 - the Forestry Code, as well as of other legislation passed prior to 1990.

This forestry regulation was correlated with numerous legal provisions on the reconstitution of private property rights in general, and on forests in particular, rules contained in legislation such as the Land Fund Act No. 18 of 1991.

The Forestry Code passed by the 26 Act of 4 April 1996 underwent some subsequent amendments, mainly through the: Government Ordinance No. 96/1998 on the regulation of forestry regime and administration of the national forest fund, 75/2002 Act amending and supplementing the Government Ordinance No. 96/1998, 66/2002 Act approving the Government Emergency Ordinance No. 226/2000 on the legal circulation of forest land, Government Ordinance No. 82/2004 on measures to improve access to the forest fund; Government Emergency Ordinance No. 139/2005 on forest management in Romania, etc.

Article 1 of the Forestry Code introduced the concept of 'national forest fund', specifying the categories of land that make up this fund 'regardless of the nature of the property right', thus establishing from the outset the legal framework necessary to maintain the integrity of the national forest fund by obliging all forest owners, regardless of the form of public or private ownership, to comply with the forestry regime and the provisions of forest management plans, which form the basis of the forest cadastre and title deeds.

The 1996 Forestry Code classifies forests according to their functions and economic importance, thus establishing the regime applicable to each group to which a particular forest belongs, the delimitation of forests as part of the public or private domain, the determination of protected areas subject to restrictions, but also the aggravation of penalties applicable for committing forestry offences in relation to them, the establishment of a differentiated legal regime with regard to forest management and administration actions.[9]After only 12 years of being in force, the 1996 Forestry Code (26/1996 Act), with its subsequent amendments and additions, was expressly repealed by the ***46/2008 Act – the 2008 Forestry Code***.

The 2008 Forestry Code[10] tackles the concept of national forest resources in the same way as the 1996 code, with forests remaining the basic element, which may be public or private property, establishing in this regard the types of forest ownership (art. 7, par. 1).

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[8] **Const. C. Giurescu**, *Pădurea în viaţa şi istoria poporului român,* Bucharest, RSR Publishing, 1981.

[9] **I. Machedon,** *Le Code sylvicole de 1996, commenté et annoté*, Tridona Publishing, Bucharest, 1999, pp. 3-5.

[10] See in this respect **D. Marinescu,** *Tratat de dreptul mediului*, III-e edition, Universul Juridic Publishing, Bucharest, 2008, pp195-197**; D. Marinescu,** *Dreptul mediului***,** IV-e edition, C. H. Beck Publishing, 2010, pp.197-199 ; For further details on forest protection, see **E.M. Minea,** *Protecţia mediului,* Accent Publishing, Cluj-Napoca, 2008, pp.139-144; **St. Ţarcă,** *Dreptul mediului,* Lumina Lex Publishing, Bucharest, 2005, pp.203.

The national forest fund included for the first time protective forest belts (art. 1, par. 1, let. i), juniper groves (art. 1, par. 2, let. j), as well as wooded pastures with a consistency greater than or equal to 0.4, calculated only for the area actually occupied by forest vegetation (art. 1, par. 1, let. k). In the 26/1996 Act, these lands were included in forest vegetation located on lands outside the national forest fund. (**E. M. Minea,** *Protecţia mediului,* Accent Publishing, Cluj- Napoca, 2008, pp.139-144)

Art. 5 of the act specified the principles underlying sustainable forest management, the management of publicly and privately owned forest land through forest management plans, which formed the basis of both the forest cadastre and title deeds. (**St. Ţarcă,** *Dreptul mediului,* .Lumina Lex Publishing, Bucharest, 2005, pp.203.)

The forestry regime established by previous forestry legislation as a separate legal regime with which the national forest fund must comply was maintained by the 2008 Forestry Code, establishing clear rules on the area for which control structures were set up as subunits of the central public authority in charge of the forestry sector. (**D.Marinescu,** *Tratat de dreptul mediului*, III-e edition, Universul Juridic Publishing, Bucharest, 2008, pp195-197)

Art. 10 establishes the obligation to manage forests, regardless of their form of ownership, through state forest ranger's stations subordinated to Romsilva or private forest ranger's stations, forest ranger's stations of public interest. The regulation of forest ranger's stations as administrative structures specialized in the application of the forestry regime represented an effective guarantee of forest protection regardless of ownership. (*Dreptul mediului***,** IV-e edition, C.H.Beck Publishing, 2010)

Title III regulates the concept of sustainable forest management, establishing principles and concrete measures for forest management, biodiversity preservation, ecological reconstruction, forest regeneration and care, ensuring the integrity of the national forest fund, fire prevention and extinguishing, as well as the security and protection of Romanian forests.

The novelties brought about by the 2008 regulation on forest management concerned the establishment of a payment system for management works.

Thus, the cost of management works was borne by the administrator of the publicly owned forest fund (Romsilva) and by the forest owner if the area exceeds 100 ha. For forests owned by natural persons and legal entities smaller than 100 ha, regardless of whether or not they are included in forest ownership associations, the management costs were borne by the state budget.

The 2008 Forestry Code also established the obligation for forest owners, other than the administrator of state-owned forests, to set up a forest conservation and regeneration fund, whereas in the 1996 regulation, this obligation fell exclusively to Romsilva (the National Forest Administration Body) as the administrator of state-owned forests.

In order to ensure the integrity of the national forest fund, a prohibition was established on state-owned forest land being subject to the establishment of property rights, and it was also stipulated that forest property could not be divided below the limit of 1 ha (art. 34, par. 1 and par. 2). This obligation was also established in the case of succession, with the establishment of ownership in favor of one or more heirs, with the payment of compensation by those in whose favor the inheritance was established.

The 2008 Forestry Code was intended to be the general legal framework for the protection and development of Romanian forests, establishing a series of complex rules aimed at both the quantitative and qualitative protection of these categories of assets. For example, the provisions of art. 7 (par. 1) prohibited the transfer of forest land from the public domain of administrative-territorial units to their private domain by resolutions of local councils, county councils, and the Bucharest Municipal Council. It also established a prohibition on including forests in built-up areas as a measure to protect the forest area (art. 7, par. 4), an aspect not found in the 1996 regulation.

A forestry provision that differs from the 1996 regulation was aimed at monitoring the quantitative protection of forests and, implicitly, preventing ecological imbalances with irreversible effects, namely the implementation of a measure limiting clear-cutting to 3 ha compared to the 5 ha allowed by the previous legislation, as well as the effective ban on clear-cutting in national parks.

The 2008 Forestry Code established rules on ecological reconstruction, regeneration, and care of forests (Chapter 3), ensuring the integrity of the national forest fund (Chapter 4), fire prevention and extinguishing (Chapter 5), and forest security and protection (Chapter 6). Some of the assumed objectives were: Chapter 11 – Forest awareness raising and Making forests accessible - Chapter 12, as prerequisites for sustainable forest management.

Title VI of the 2008 Forestry Code deals with the issue of legal liability in forestry matters, establishing the forms of legal liability for situations arising from violations of forest protection regulations. Thus, it stipulated that disciplinary and material liability also applies to deeds committed by forestry workers in the context of their employment relationships.

According to art. 105 of the Code, damage caused to forests, regardless of the legal nature of the property and the area of forest owned, shall be assessed in accordance with the law and shall give rise to civil liability.

However, art. 125 of the 2008 Forestry Code specified that the establishment and punishment of forestry offenses are regulated by special law, and Title VI listed the specific penalties for deeds constituting forestry offenses.[11]

2. Discussion

Despite the desired goal of sustainable management of the forest fund, the 2008 Forest Code republished under art. IV of Law no. 133/2015 amending and supplementing Law no. 46/2008 - Forest Code, published in the Official Gazette of Romania, Part I, no. 411 of June 10, 2015, giving the texts a new numbering, has undergone a large number of amendments:

- ✓ Government Emergency Ordinance no. 193/2008 on the amendment and completion of art. 37 and 39 of Law no. 46/2008 - Forestry Code, published in the Official Gazette of Romania, Part I, no. 825 of December 8, 2008, approved with amendments and completions by Law no. 193/2009, published in the Official Gazette of Romania, Part I, no. 365 of June 1, 2009;
- ✓ Government Emergency Ordinance no. 16/2010 on some measures to streamline the maintenance of the border corridor, the protection strip and border signs, published in the Official Gazette of Romania, Part I, no. 147 of March 5, 2010, approved by Law no. 116/2010, published in the Official Gazette of Romania, Part I, no. 429 of June 25, 2010;
- ✓ Law no. 54/2010 repealing paragraphs (2) and (3) of art. 34 of Law no. 46/2008 - Forestry Code, published in the Official Gazette of Romania, Part I, no. 186 of March 24, 2010;
- ✓ Law no. 95/2010 amending paragraph (1) of art. 10 of Law no. 46/2008 - Forestry Code, published in the Official Gazette of Romania, Part I, no. 350 of 27 May 2010;
- ✓ Law no. 156/2010 supplementing art. 62 of Law no. 46/2008 - Forestry Code, published in the Official Gazette of Romania, Part I, no. 496 of 19 July 2010;– Law no. 60/2012 approving Government Emergency Ordinance no. 79/2011 regulating certain measures necessary for the entry into force of Law no. 287/2009 on the Civil Code, published in the Official Gazette of Romania, Part I, no. 255 of 17 April 2012;
- ✓ Law no. 187/2012 for the implementation of Law no. 286/2009 on the Criminal Code, published in the Official Gazette of Romania, Part I, no. 757 of November 12, 2012;
- ✓ Law no. 255/2013 for the implementation of Law no. 135/2010 on the Code of Criminal Procedure and for the amendment and completion of certain normative acts containing criminal procedural provisions, published in the Official Gazette of Romania, Part I, no. 515 of 14 August 2013.

3. Conclusions

The new forestry code, in particular Law no. 331 of December 20, 2024 published in the Official Gazette no. 7 of 09.01.2025, aims to resolve the management of the national forest fund both from the perspective of illegal deforestation and from the perspective of its regeneration, regardless of the owner of the property right. It has not remained unchallenged in the beginning of its applicability, with NGOs such as WWF-CEE claiming a series of major shortcomings such as:

- ✓ maintaining a control system focused on **"marking" and guarding trees** in the forest and not on controlling volumes of wood when placed on the market. [12]
- ✓ the need to review the Performance indicators for the administration of Romsilva must be through a Ministerial Order
- ✓ regulation of the coordinates of **wood traceability** and the first introduction on the market, provided for in the National Forest Strategy by the Government Decision for the Integrated Forest Information System.
- ✓ the need to regulate through the Regulation on the Valorization of Wood from Publicly Owned Forests through chains of superior wood processing into products with a long lifespan, which embody the highest economic value.

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[11] **L.Dogaru**, *Codul silvic roman.Prezentare evolutiva*, II-e édition, Risoprint Publishing, Cluj-Napoca, 2008.

[12] The NGO WWF-CEE (has had the mission since 2006 of protecting the wild environment in the Carpathian Mountains and along the Danube: protected areas, forests, brown bears, bison, the Danube Delta, sturgeons. It also supported as a legislative proposal: the establishment of payments for contracted and harvested wood based on the quantities of wood declared upon introduction on the market (not for the volume of wood per stem estimated by the valuation act). It is believed that this aspect could be corrected by adopting a Regulation on the Valorization of Wood from Publicly Owned Forests.

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16. Law no. 54/2010 repealing paragraphs (2) and (3) of art. 34 of Law no. 46/2008 - Forestry Code, published in the Official Gazette of Romania, Part I, no. 186 of March 24, 2010
17. Law no. 255/2013 for the implementation of Law no. 135/2010 on the Code of Criminal Procedure and for the amendment and completion of certain normative acts containing criminal procedural provisions, published in the Official Gazette of Romania, Part I, no. 515 of 14 August 2013.
18. Law no. 331 of December 20, 2024 published in the Official Gazette no. 7 of 09.01.2025

ECONOMICS AND ASYMMETRIC WARFARE

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Abstract

In recent decades, the dynamics of armed conflicts have undergone a profound transformation, marking a shift from conventional wars between states to increasingly frequent forms of asymmetric warfare, in which unequal actors – whether state or non-state – confront each other through unconventional tactics. Economy and asymmetric warfare are two concepts that may seem to be from different worlds – one belongs to economic sciences, the other to the military and geopolitical fields – but in reality they are often closely interconnected. This type of conflict is no longer determined exclusively by brute military power, but also by economic, technological and informational factors. The economy thus becomes a central actor in the strategy and conduct of asymmetric warfare. While states invest billions in security, insurgent or terrorist groups operate with reduced budgets but with high efficiency, using informal financial networks and cutting-edge technology. The purpose of this paper is to analyze the complex interaction between the economy and asymmetric warfare, through an interdisciplinary approach, from relevant specialized literature. The paper shows that success or failure in an asymmetric conflict is decisively influenced by economic capacity for support, adaptation, and resilience.

Key words: economics, warfare, asymmetric, resilience

Asymmetric warfare is a form of conflict in which the parties involved have significantly unequal military, economic, technological, and organizational capabilities. In this context, the conventionally weaker side resorts to unconventional strategies to exploit the vulnerabilities of the stronger adversary. This type of warfare does not follow traditional rules, but involves tactics such as: guerrilla warfare, terrorism, information warfare, cyberattacks, mobilization of the civilian population, use of the terrain and local conditions to one's advantage. An essential element of asymmetric warfare is that the goal is not necessarily the military defeat of the adversary, but the erosion of its political and economic will to fight. Increased costs, public pressure, and internal instability become strategic weapons. The economy, in the context of armed conflicts, is no longer just a logistical support for the military effort, but becomes an essential element of the war strategy – both in the state and non-state camp.

There are several dimensions of the involvement of the economy in asymmetric conflicts:

a) The capacity to finance the conflict; states engaged in an asymmetric war must allocate huge budgetary resources for security, reconstruction, logistical support and countering unconventional threats.; non-state groups (e.g. terrorist groups, paramilitary networks) develop autonomous sources of financing: arms trafficking, drugs, people, cryptocurrencies, oil trade, extortion, etc.

b) Informal economy and parallel markets; in conflict theaters, the informal economy becomes the main source of income for both the population and the armed groups. Examples: ISIS and the oil trade in Syria, the cartels in Colombia, the control of black markets in Central Africa.

c) Attacking the adversary's economic resources; economic infrastructure becomes a major target: power plants, gas pipelines, transport and communication networks; the objective is economic destabilization to create internal and international pressure on the target state.

d) Economic exhaustion through prolonged war; insurgent groups, through prolonged and attrition attacks, can increase the state's ongoing spending, weakening its economy. Example: the US interventions in Iraq and Afghanistan have generated costs of trillions of dollars, with a direct impact on the federal budget and public opinion.

These factors demonstrate that the economy is not only a resource in asymmetric conflicts, but also a battlefield in itself. The actors involved use and attack economic structures as part of an overall

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strategy. Groups involved in asymmetric wars – be they insurgents, terrorist organizations or paramilitary militias – depend on alternative sources of financing, often illegal or parallel to the formal economy. Although these entities lack classical state resources, they compensate through economic flexibility, transnational support networks and control of local resources.

MATERIAL AND METHOD

Typical sources of financing are drug trafficking, for example the Taliban financed the fight against NATO forces by controlling opium crops, smuggling and the black market, for example Groups in Syria and Iraq have sold oil or archaeological artifacts on international markets, extortion and taxation of the population, for example organizations such as ISIS and Al-Shabaab have collected “taxes” in controlled areas, external donations, example support from the diaspora, radicalized NGOs, or from sponsoring states, cryptocurrencies and hacking, used for anonymous financing or money laundering (e.g. the use of Bitcoin by terrorist groups).

This diversification makes the fight against these organizations not only a military one, but also a financial one. Asymmetric wars have a disproportionate economic impact on states, especially due to the unpredictable and long-term nature of the conflict. a) Increased budget expenditures is taking into account the costs for internal security, intelligence, Cyber defense, external interventions: troop deployment, support for allies, reconstruction. Speaking about the impact on investments and markets is referring to political uncertainty and prolonged conflict cause investors to withdraw, credit ratings fall and borrowing costs increase. Destruction of infrastructure is referring to preferred asymmetric targets: energy, transport, communications networks, high reconstruction costs and productivity losses. And migration, refugees and humanitarian crisis is about the generation of waves of refugees puts pressure on the budgets of neighboring states, the displacement of the active population leads to long-term economic losses.

In addition to actual armed struggle, the economy can become a strategic weapon in itself. States, but also non-state actors, use economic means to attack or destabilize the enemy. Examples of economic "weapons": economic sanctions used by Western powers to isolate authoritarian actors (e.g. Iran, North Korea, Russia), embargoes: depriving the adversary of essential resources (e.g. oil, weapons, technology), Cyber attacks on financial systems: blocking banks, stealing bank data, paralyzing payments, currency devaluation: currency warfare, as a tool of pressure or response. These measures have a direct impact on military response capacity, public opinion and social stability.

In the contemporary era, technology and globalization have profoundly changed the nature of armed conflicts, especially asymmetric ones. Unconventional actors benefit from modern, accessible and efficient tools, which allow them to compensate for the lack of traditional military resources. At the same time, globalization facilitates the mobility of capital, information and weapons, generating a reconfiguration of economic-military strategies. Technology, as a force multiplier in asymmetric conflicts involves the use of a) Drones and cheap but effective weapons. Thus, non-state groups can acquire or manufacture commercial drones modified for reconnaissance missions or attacks. As an example: the use of drones by the Houthi in Yemen or by Hamas in Gaza. b) Cyberwar is involving attacks on banking, energy and communication networks. As an example: Stuxnet (Iran), ransomware attacks on critical infrastructures in the US and Europe. Or, the costs of Cyber defense for states are huge, while attackers can operate with minimal resources. c) Cryptocurrencies and decentralized financial systems imply the allowing for rapid, anonymous and difficult-to-control financing of non-state actors, avoidance of sanctions and traditional banking controls.

The globalization and transnational networks refers to a) Mobility of capital and goods. Global markets allow for the rapid circulation of economic resources, including for illegal purposes. For example: illegal trade in oil, cultural artifacts, rare metals. b) Diaspora and donation channels. Diaspora networks can contribute to the financing of armed groups through donations or money laundering. NGOs or commercial entities can be used as cover. c) Access to international markets for propaganda and recruitment. Social media and the internet have become key tools of psychological influence and mobilization.

Convergence between state and non-state actors Technology and globalization have led to a dangerous convergence between the tactics of state and non-state actors, through: the use by states of non-state intermediaries (e.g., paramilitary groups supported by Russia or Iran), the "double war": a conventional military front and an economic-cybernetic-asymmetric front.

RESULTS AND DISCUSSIONS

Technology and globalization have not only democratized access to combat tools, but have fundamentally changed the economic logic of asymmetric conflicts. Instead of a traditional military effort based on logistics and weaponry, modern actors rely on:

- cheap but devastating cyberattacks,
- alternative financing systems,
- cross-border informational influence,

• and global underground economic networks.

USA vs Taliban conflict is an emblematic example of asymmetric warfare in which a global superpower, with colossal military and economic resources, faced a local insurgent force, apparently modest, but extremely adaptable and efficient in using limited resources. Relevant economic aspectsare as following: cost of the American intervention was over 2 trillion dollars (including military operations, reconstruction, logistical and medical support). Taliban insurgent economy comprise opium production and trafficking: Afghanistan became the main global supplier, taxation of trade routes and the local population, external financial support from private sources or state-sponsors, economic inefficiency of reconstruction: international investments in infrastructure were often diverted by corruption, lack of coordination and insurgent attacks.

In conclusion: economic superiority did not guarantee victory. The Taliban's attrition tactics and their parallel economic network demonstrated the economic power of a well-organized asymmetric actor.

Economic and hybrid warfare of Ukraine with Russia conflict that began in 2014 and escalated massively in 2022 brought to the fore a complex model of hybrid warfare, in which the economic component plays a central role. The key elements are the followings: western sanctions imposed on Russia: isolation from international financial markets, limiting access to technology, freezing foreign exchange reserves, Russian attacks on Ukrainian energy infrastructure: power plants, pipelines, distribution networks, Western economic support for Ukraine consisted of: Financial packages from the EU, the US and the IMF, Aid for reconstruction and maintaining the functioning of state institutions, Grain exports: used as an economic weapon – Russia blocked Ukrainian ports to create global economic pressure, especially on countries in the Global South.

In conclusion, in the hybrid war in Ukraine, the economic dimension is as important as the military one, and the ability to economically support the war effort becomes decisive for the state's resilience.

Non-state groups and the underground economy is referring to Hezbollah and Al-Shabaab organizations. These organizations are relevant examples for understanding how non-state actors can build sophisticated parallel economies, supporting military and social operations. Hezbollah (Lebanon) comprised external financing support from Iran, commercial and banking activities: control over currency exchange networks and some sectors of the local economy. Social services: hospitals, schools and aid – to gain economic and political legitimacy among the population. Al-Shabaab (Somalia): taxation of transport and agriculture in controlled territories, control of ports and maritime trade routes, attacks on economic infrastructure to destabilize the Somali government.

In conclusion, the success of these groups in maintaining their influence is due not only to military force, but also to the ability to create and control alternative economic flows, in the absence of functional state structures.

CONCLUSIONS

The analysis carried out in this paper highlights the fact that the economy plays a central role in the structure, conduct and outcome of asymmetric warfare. Unlike conventional conflicts, in which traditional financial and military resources were decisive, in asymmetric warfare the following increasingly matter:

• the economic adaptability of the actors involved;

• access to alternative sources of financing (illicit, informal or decentralized);

• the use of low-cost but high-impact technology;

• the exploitation of the adversary's economic vulnerabilities as part of the strategy.

Asymmetric conflict is, increasingly, an economic war, in which:

• critical infrastructure becomes a legitimate target;

• the civilian population is directly affected by the collapse of local economic systems;

• state actors are forced to invest huge sums to counter cheap but effective attacks.

The case studies analyzed (Afghanistan, Ukraine, Hezbollah and Al-Shabaab groups) have demonstrated that:

• non-state forces can maintain long-term conflicts even in the face of opponents with superior resources;

• economic resources can be used as an offensive weapon, not just as a means of logistical support;

• technology and globalization have amplified the possibilities of asymmetric actors, creating a partial "leveling" of the battlefield.

There are some implications that are referring to the fact that:

• Security policies must include the economic dimension: control of financial flows, surveillance of the informal economy and protection of critical infrastructure.

• Combating the financing of non-state groups requires international cooperation, banking transparency and effective legal instruments.

• Investments in cybersecurity are becoming essential for economic and military defense.

• Economic resilience is increasingly important: a weak economic state is vulnerable not only financially but also geopolitically.

To deepen the subject, the following directions are recommended:

• Studying the impact of crypto-financing in modern conflicts;

• Comparative analysis between the cost of asymmetric conflicts and the efficiency of political outcomes;

• The role of artificial intelligence in modeling asymmetric war economies;

• The interaction between climate war and asymmetric economic-military phenomena (e.g. forced migration, competition for resources).

The work demonstrates that, in the modern era, the economy is no longer just the "fuel" of war, but one of its main weapons.

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KEY CHALLENGES AND TRENDS IN THE SUSTAINABLE DEVELOPMENT OF AGRITOURISM

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Abstract

Agritourism, a niche sector that integrates agriculture with tourism activities, has become a significant part of the global economy in recent years, with its market expected to continue to expand in the coming decades. Growing urbanization and increasing tourists interest for authentic experiences and sustainable and ethical travel are making this form of tourism more and more popular. Despite its essential contribution to ensuring the sustainability and stability of rural areas and communities, the development of agritourism is linked to a series of challenges that target economic, operational, social, ecological and regulatory aspects. This paper presents a review of scientific literature on the elements that may contribute to limiting the growth potential of agritourism, while also highlighting the current trends shaping the sector. There are significant regional differences due to local economic, cultural and geographical factors. Agritourism entrepreneurs must adapt to changes in consumer preferences, use modern marketing and promotion technologies and implement practices focused on sustainability. The success and expansion of agritourism businesses are conditioned by the application of effective marketing, reducing the effects of seasonal fluctuations in demand, overcoming infrastructure limitations, adequately managing the impact of tourists on farms and rural communities, promoting an appropriate policy in the field, etc. Knowing and understanding of interactions and constraints operating in this area helps stakeholders and policymakers to create the suitable framework for the specific needs of agritourism.

Key words: agritourism, challenges, trends, sustainable development

In many countries, the rural sustainable development has become a key priority, aiming to improve the quality of life of local communities in the context of environmental protection and cultural heritage conservation (Asciuto A., 2013; Marsden T., 2010). Through its contribution to the development of the rural economy, promotion of ecological practices and preservation of local traditions, customs and culture, agritourism has proven to be a viable tool for achieving these objectives (Mahmoodi M. *et al*, 2022). Within the tourism industry, agritourism represents an innovative sector, integrating tourism with various agricultural and rural activities (Fischer C., 2019), thus strengthening the connection between urban society and rural community (McGehee N.G. and Kim K., 2004). Agritourism involves farmers providing farm-based tourism services to visitors (Ndhlovu E and Dube K., 2024), such as: hospitality (food services, catering, overnight stays of farms, farmers markets, etc.), recreational activities (horse riding, fishing, self-harvest, etc.), agricultural education and training workshops (on-site processing of agricultural products), farm tours, nature observation and bird watching, etc. (Barbieri C. and Mshenga P.M., 2008; Mahmoodi M. *et al*, 2022). Statistical data indicates that agritourism is booming worldwide, becoming a significant part of the global economy. In 2024, the global agritourism market size was valued at $ 73.2 billion, with Europe holding the largest share (over 47%). A robust annual growth rate (approximately 11%) is expected for the next decade, forecasting to reach in 2033 a market size of $ 205.6 billion (IMARC Group, 2025). Its growing popularity is due to association with multiple benefits for rural areas and communities, having the potential to promote stability and sustainability (Mahmoodi M. *et al*, 2022).). However, despite the advantages and positive effects, setting up and managing an agritourism businesses can be risky and challenging for farmers.

MATERIAL AND METHOD

This paper aims, through a comprehensive analysis of the academic literature, to explore the multiple trends and challenges that arise in the sustainable development of agritourism, and to identify those most frequently mentioned in previous studies conducted in different countries.

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The review of the relevant literature for the studied topic involved a content analysis that was performed manually. The study was driven mainly on the Scopus database and covered the period 2000-2025, with the intention of focusing on more recent information.

RESULTS AND DISCUSSIONS

The concept of "sustainable tourism" refers to a responsible tourism model that ensures the achievement of economic and social benefits while protecting the environment and preserving the authenticity and cultural heritage of the tourist destination. Therefore, in order to develop sustainable tourism, its positive impact must outweigh the potential negative effects (Barbieri C., 2013). The agritourism sustainable development proposes potential solutions to numerous problems facing rural areas: unemployment, low incomes (predominantly from the agricultural sector), immigration, rudimentary infrastructure, difficulties in selling agricultural production, etc. (Ollenburg C and Buckley R. 2007). Agritourism is capable of providing economic, social and ecological benefits to all stakeholders, especially farmers, rural communities and tourists (McGehee N.G. and Kim K., 2004). Its evolution is influenced, on the one hand, by the opportunities and challenges related to impact generated, and, on the other hand, by the ability to adapt to market trends (Al Matris A.M., 2023). The benefits generated by agritourism have a positive impact on its sustainable development as well as on the rural areas, if they are distributed equitably among the all segments of the host community (Zhu Y. *et al*, 2025). Balancing the various interests of stakeholders reduces the possibility of potential social tensions, conflicts, resentments and opposition (Gursoy D. *et al,* 2002; Wang L., 2022).

Agritourism challenges. Four types of risks and challenges have been identified in previous studies on agritourism and rural development: economic, operational, regulatory and ecological. These intervene in the long-term success of agritourism and have the potential to significantly affect agricultural production, farm profitability, workforce availability and the accessibility and attractiveness of agritourism sites (Al Matris A.M., 2023; Hosseini S.N. *et al, 2025*).

- ***Economic:*** Among the primary barriers encountered by agritourism entrepreneurs are insufficient investments and *lack of financial resources* to establish, expand or maintain facilities and infrastructure (accommodations, tourist activity areas, visitor centers, etc.) necessary for attracting and ensuring the satisfaction of tourists during their stay (Yang L., 2012). Farmers' capability to invest in tourism may also be restricted by bureaucratic procedures for granting subsidies or government financial support, while the perception of agritourism as a niche sector limits access to loans and grants (Wen-Ta K. *et al*, 2025).

A significant impact on the income of agritourism farms is due to *seasonality.* The fluctuations in tourist demand and, implicitly, those of the number of visitors, affect the constancy of cash flow (McGehee N.G. and Kim K., 2004). High-peak tourist periods (typically summer months) and off-season periods require different strategies for managing agritourism businesses (Mastronardi L. *et al*, 2015). To attract tourists year-round, farmers can corelate agritourism experiences to specific agricultural cycles (such as harvest, flowering or planting periods) or focus on authentic experiences related to local culture (Barbieri C. and Mshenga P.M., 2008). These economic challenges faced by agritourism farms are amplified by *unpredictable weather conditions* and the *volatility of agricultural markets*. Fluctuations in agricultural product prices can significantly affect the stability and level of farmers' income, while unfavorable weather drives tourists away, having a negative impact on earnings, especially during peak season (Ammirato S., 2010).

- ***Operational:*** Many rural areas *lack adequate infrastructure* (access roads, communication networks, electrical power and water supplies, sanitation, medical facilities, internet access) (Wen-Ta K. e*t al,* 2025), which discourages visitors and prevents local communities from providing them with quality tourism services (Hosseini S.N. *et al,* 2025). The absence of basic elements that ensure a certain level of comfort and convenience expected by tourists can lead to negative experiences and their orientation towards more accessible and better-equipped destinations (Grillini G. *et al*, 2025). Another restrictive factor for the growth of agritourism is represented by the rudimentary understanding of its potential, with farmers having a *limited awareness of the benefits* that arise from integrating tourism with agriculture (McGehee NG, Kim K., 2004). Furthermore, farmers often *lack of tourism expertise and skills* needed to undertake successful agritourism business, such as: business operations, customer service, hospitality management, marketing and advertising, interpersonal skills (communication with visitors), etc (Grillini G. *et al*, 2025). Moreover, the *lack of professional training* does not allow agritourism operators to adequately manage tourism-related activities, which can create difficulties regarding promoting offers, tourist destination visibility, managing reservations or providing attractive tourist experiences (Streifeneder T. *et al*, 2023). Additionally, most farmers struggle to maintain a balance between agricultural operations and tourist-recreational activities (Fischer C., 2019), because they could *compete for limited resources*, such as working time, available farm space and labor (Mastronardi L. *et al.*, 2015). *Disruption of daily farming activities* (by the presence and requirements of visitors) and the trend towards expanding tourist facilities to the detriment of agricultural land have a negative impact on the efficiency and level of food production (Ollenburg C. and Buckley R. 2007). Also, running an agritourism business can limit time spent with family, having negative consequences on farmers' lifestyles (Grillini G. *et al*, 2023).

Tourism seasonality usually creates temporary jobs in rural areas, making it difficult to retain qualified workers. They might be tempted to look for more stable jobs, migrating to urban areas that offer more employment opportunities and better living conditions (Al Matris A.M., 2023). This leads to a *shortage of experienced personnel.* Although agritourism farms rely primarily on the labor force of farmer families and do not necessarily depend on certain seasons, during periods whith high tourist demand they may feel the need for additional labor to ensure the provision of consistent quality services (Shen C.C. *et al*, 2020).

Local population plays a key role in tourism, being one of the most important stakeholders (Zhu Y. *et al*, 2025). *Local community engagement and support* are essential in the sustainable development of agritourism, therefore, farmers must ensure their attainment. In order to achieve this goal, the development of agritourism must be carried out in accordance with community's values, interests and beliefs (Petrovic M.D. *et al*, 2017). Besides benefits, tourist activities in rural areas have also generated some unwanted consequences, which have led to conflicts and opposition from residents (Wang L., 2022; Zhu Y. *et al*, 2025). Negative interactions reduce the efficiency of tourism production (Ma X.L. *et al.*, 2022), but this potential negative impact of tourism-related activities could be prevented by involving the local people in the planning and decision-making process (Wang L., 2022). Residents actively participating in tourism development manifest positive perceptions and supportive behaviors, unlike those not involved (Gursoy D. *et al.*, 2019). Successful sustainable agritourism development relies on achieving a balance between the expansion of tourism in rural areas and efforts to preserve the environment and local culture, requiring close collaboration between agritourism operators, authorities and local communities (Yang L., 2012).

One of the newest challenges in agritourism is *authentic vs. commercial*. There is a growing demand for high quality standards in the agritourism market, which can lead to exaggerated and pretentious improvements in tourism infrastructure (Dubois C. *et al*, 2017). This is the context in which the concept of "commercial agrotourism" emerged (Ciervo M., 2013), focused mainly on accommodating and entertaining visitors in high-quality facilities with urban characteristics, retaining only the design of a farm. Agriculture is marginalized, ceasing to be the main activity, and agricultural lands are given other uses, especially for the leisure and entertainment of tourists (Dubois C. *et al*, 2017). Thus, the agritourism product loses its original essence, being more or less disconnected from agricultural activities, as well as authentic rural lifestyle and local rural culture (Ciervo M., 2013). In contrast, "authentic agritourism" implies a working farm, with a typical rural agricultural structure, operating in an unspoiled environment, where farming is predominant over tourist operations, preserving the rustic, authentic and traditional rural lifestyle. (Streifeneder T. *et al*, 2023). Some rural areas are already experiencing this conflict between tradition and adaptation to the market, farms transforming into hotel structures, more suitable for tourism marketing (Dubois C. *et al.*, 2017). In a few regions (e.g. South Tyrol) have even begun to appear agritourism units that offer luxury accommodation and services similar to wellness resorts (Streifeneder T. *et al*, 2023). In these situations, the farmer turns into a businessman and the farm becomes just „a stage for tourists' entertainment" (Dubois C. *et al.*, 2017).

- ***Political and regulatory framework:*** The growth and sustainability of agritourism are hampered by the *lack of government support and intervention,* the *absence of dedicated policies* and *a clear regulatory framework* that matches the potential and needs of agritourism and provides incentives to operators in this sector (Srisomyong N., 2010; Hosseini S.N. *et al, 2025*). As common challenges that arise in starting and maintaining an agritourism business, farmers often mention: insufficient government funding and guidance, bureaucratic obstacles related to obtaining permits, taxation issues, poor coordination with relevant institutions and the complexity of land use regulations (Barbieri C., 2013; Al Matris A.M., 2023; Wen-Ta K. *et al*, 2025).

- ***Ecological:*** The carrying capacity of rural areas is limited, unable to receive and manage a large number of visitors. *Overcrowding (over-turism)* puts pressure on local infrastructure and resources, negatively affecting the environment (waste generation, pollution, etc) and the residents' quality of life (Al Matris A.M., 2023). A significant challenge is represented by the protection of natural resources, tourism constituting a potential threat to them, especially when the carrying capacity of the rural area is exceeded and agritourism boarding houses are not managed sustainably (Buffa F. *et al*, 2018; Havale D.S. *et al*, 2023). Despite the small size of agritourism accommodation capacities, they can consume large amounts of energy and water (Ispas A *et al*, 2019; Zhu Y. *et al,* 2025). *Over-consumption of limited rural resources* (water, energy, etc.) has important adverse effects on the environment: resource depletion, land degradation, loss of biodiversity, etc. (Sharpley, R., 2002; Carlsen J. *et al,* 2001).

Agritourism trends.

- *fast growth and adaptability to regional context.* As a result of increasing urbanization and tourists interest in authenticity and sustainability, agritourism is growing rapidly and its market is expected to continue to expand in the coming decades (IMARC Group, 2025). This development occurs in various forms and intensities, with significant regional differences due to local economic, cultural, and geographical factors to which it must adapt (Dax T. *et al*, 2019). Thus, the well strengthened European agritourism is centered on horticultural heritage and gastronomy, while in North America predominates educational agritourism (Armesto López X.A. and Martin B.G., 2006) and in the Asia-Pacific region are preferred ecotourism and rural experiences offered by rice plantations and spice gardens (Wen-Ta K. *et al*, 2025). Agritourism possesses the ability to adapt not only to regional contexts, but also to the needs and preferences of the modern traveler and also to the global trend of rural development based on sustainability (Grillini G. *et al*, 2025).
- *growing demand for nature-based and authentic experiences.* The development of agritourism is closely dependent on market trends, such as: rising environmental awareness and the increased interest of tourists in local food systems; growing desire for recreation and education (Wen-Ta K. *et al*, 2025); prioritizing experiences that promote connection with nature, relaxation and health (Streifeneder T. *et al*, 2023); rising demand for responsible travel and authentic nature-based experiences (Petrovic M.D. *et al*, 2017). Growing concerns about healthcare, food safety and well-being are driving tourists to go beyond entertainment activities and make the most of nature's overall positive impact on their mental and physical health (Armesto López X.A. and Martin B.G., 2006). Agritourism operators strive to satisfy tourists' preferences for hands-on agricultural activities (such as grape harvesting, cheese-making, beekeeping) and to respond to market requests by diversifying their offer and linking tourism activities to seasonal events (like harvest festivals) or specific themes (eco-tourism, sustainability, etc.) (Dax T. *et al*, 2019). Thus, tourists can interact with local culture and learn about traditional cuisine, production of artisanal drinks and food, traditional farming techniques and organic farming, the use of renewable energy, rural traditions and crafts (Streifeneder T. *et al*, 2023). Farmers are turning on creating authentic experiences related to local cultural and agricultural heritage, providing tourists a direct connection to agricultural processes and ensuring their participation in workshops, cooking classes, wine tasting, farm-to-table dining, "pick your own" events or routine farm activities. (Grillini G. *et al,* 2025). Attracting a large number of visitors contributes to improving farmers' incomes and supporting the local economy (Fischer C., 2019).
- *focus on sustainability.* More and more tourists are looking for eco-friendly tourism activities and travel practices that respect natural enviroment and local cultural authenticity. They are interested in learning about sustainable farming methods, food systems and the importance of conserving biodiversity (Ispas A, 2019; Ollenburg C. and Buckley R., 2007). Farmers who carry out tourism activities are more likely to adopt extensive and sustainable agricultural practices (Mastronardi L *et al*, 2015), which have a positive impact on the environment, visitors and tourist destinations (Shen C.C. *et al*, 2020). Agritourism encourages farmers to minimize their consumption of natural resources, especially water (Carlsen J. *et al,* 2001), and to initiate actions to recover, reuse and recycle materials (Buffa F. *et al*, 2018). Farmers also often resort to composting and use of biodegradable materials (Havale *et al,* 2023), providing tourists ecological experiences and education on topics related to conservation, environmental protection and sustainability, while they benefit from lower costs, improved soil health and reduced dependence on chemical fertilizers (Streifeneder T. *et al*, 2023). At the same time, agritourism farms tend to improve their waste management systems (Grillini *et al*., 2023) and adopt green energy solutions for heating and electricity generation, such as renewable energy

sources (predominantly solar) and with reduced environmental footprints (Asciuto A. *et al*, 2013).

o *growing interes for local and organic products.* Agritourism operators are increasingly moving towards ecological practices to meet tourists' preferences for high-quality food and the growing demand for a wide range of local organic products (Mastronardi L. *et al,* 2015). Tourists' interest in safe and healthy agricultural products (Srisomyong N., 2010) and their enthusiasm for ecotourism and organic and ecological agriculture (Mastronardi L. *et al,* 2015; Shen C.C. *et al*, 2020) motivated farmers to restrict the use of pesticides and other chemicals, or even to implement integrated pest management (Srisomyong N., 2010; Barbieri C., 2013). This has the potential to attract more visitors, increase their trust in the tourism service provider and strengthen the connection consumer-producer (Shen C.C. *et al*, 2020). On the other hand, it contributes to the protection of flora and fauna (Barbieri C., 2013) and to the sustainability of agritourism businesses (Grillini G. *et al*., 2025).

o *leveraging technology and digitalization* in the management and promotion of tourist destinations allows visitors to connect more easily to local agritourism initiatives and benefit from improved access to authentic farm-based experiences (Marsden T., 2010; Wen-Ta K. *et al*, 2025). Digital marketing ensures that agritourism offers reach a wider audience (Ananya S.A., 2021). Direct booking option is preferred by more and more farms, choosing to interact with potential visitors through their own online platforms (Gretzel U., 2017; Alavion J. and Taghdisi A., 2021). Aerial drone footage and virtual and augmented reality technologies allow virtual tours and exploration of farms and their surroundings, providing interactive interaction and detailed and authentic information, on the basis of which they can more pertinently choose their tourist destination (Gretzel U., 2017). Also, social media (such as Instagram and Facebook) are increasingly used, giving the public the opportunity to better understand the agritourism offer through videos, images and reviews (Ananya S.A. 2021).

o *increasing demand for high quality standards.* In the last two decades, most European countries have experienced a rapid increase in the number of agritourism establishments (Streifeneder T. and Dax T., 2020), but some regions mark a pronounced drop in demand for lower categories, while requests for categories with higher quality standards are increasing (Streifeneder T. *et al*, 2023). This qualitative and quantitative agritourism development has been observed in various rural areas of Italy, Germany, Austria, Luxembourg and Belgium (Dubois C. *et al*. 2017; Streifeneder T. *et al*, 2023) Some agritourism entrepreneurs invest heavily in improving the quality of indoor and outdoor facilities, aiming to attract new target groups of tourists who want to benefit from the highest possible comfort conditions. But this leads to distortion of the agritourism product and could drive away classic rural tourism consumers (Ciervo M., 2013).

CONCLUSIONS

Addressing the complex issues involved in developing sustainable agritourism (inadequate infrastructure, economic constraints, social and operational challenges and environmental concerns) starts with ensuring that both entrepreneurs, tourists and host rural communities reap the benefits associated with it. Due to the dynamic nature of agritourism, its sustainable development requires continuous adaptation to market trends and the evolving preferences of modern travelers, aiming to meet their needs while preserving the environment and supporting local communities. The success and expansion of agritourism businesses are conditioned by the application of effective marketing, reducing the effects of seasonal fluctuations in demand, overcoming infrastructure limitations, adequately managing the impact of tourists on farms and rural communities, promoting an appropriate policy in the field, etc. Knowing and understanding of interactions and constraints operating in this area, helps stakeholders and policymakers to create the suitable framework for the specific needs of agritourism.

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STUDY REGARDING CROPS STRUCTURE OPTIMIZATION WITHIN FARMS USING SOLVER SOFTWARE

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Abstract

The crops' structure is an important issue for farmers as it directly influences the results obtained both in terms of production and financial indicators. Optimizing the various aspects of a farm using scientifically based methods helps to ensure the efficiency of farming and better use of available resources. The economic efficiency of farms depends not only on the volume of resources but also on the optimization of their availability, which can be achieved through economic-mathematical models specific to agricultural management and agricultural production systems. The objectives of this paper are to present the importance of an optimal crop structure for farmers, to analyze how to solve optimization problems using the linear programming method and to describe the process of obtaining the optimal solution based on the Solver add-in program in Microsoft Excel, taking into account the economic model taught in the seminars of Agricultural Production Systems and applying it to the conditions of a real farm.

Key words: crop optimization, Solver, linear programming, agricultural management

In the current context of agriculture, marked by an increasing complexity of economic, technological and environmental factors, optimizing the crop structure is a fundamental necessity to ensure the economic efficiency and productivity of agricultural holdings. The present study addresses this issue by applying linear programming methods, a powerful mathematical tool, capable of identifying optimal solutions in situations characterized by multiple variables and constraints.

Modern agriculture can be viewed as a complex production system, defined as an organized set of resources (human, material, financial, informational) and interconnected processes, which transform inputs into outputs in the form of goods or services. In this sense, the systemic approach becomes essential for understanding the interactions between the various subsystems and component structures of an agricultural holding. Managing a farm involves taking into account not only the functioning of the individual parts (economic, technological, social), but also the laws of the whole, emphasizing their organic unity.

In this complex landscape, linear programming stands out as an optimization method that allows the selection of the best variant from a set of possible options, subject to certain restrictions (Viziteu Șt. *et al*, 2022). Due to the large volume of calculations involved in the analysis of a significant number of variables, the use of electronic calculation techniques, such as the Solver program in Microsoft Excel, becomes indispensable for the efficient application of linear programming. The farm is the basic economic unit of agricultural activity (Brezuleanu S. *et al* 2017), and managerial decisions regarding the optimization of its crop structure can ensure long-term efficiency and resilience in the face of fundamental changes in the sector, thereby ensuring the farm’s functionality as an open and adaptive system (Brezuleanu S., 2008; Viziteu Șt. *et al*, 2018).

Agricultural decision-makers need to be able to predict the likely responses of specific components of the agricultural system and assess the impact of adaptation processes. The shortcomings of the analytical tools currently available limit the accuracy and precision of forecasts regarding the scale of future socioeconomic processes. This is why clear and precise tools for agricultural planning are needed (Majewski E., Was A., 2005; Viziteu Șt., 2014).

Management approaches and leadership styles have an impact on long-term technical and economic results. Addressing optimization problems using the Solver tool or any other linear

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programming tool provides a scientific basis for decision-making regarding the farm (Viziteu Șt. *et al*, 2021; Brezuleanu S. *et al*, 2017)

MATERIAL AND METHOD

This study focuses on the optimization of the crop structure within an agricultural farm, an essential application of linear programming. The main objective is to determine the most profitable combination of crops that can be grown on a given agricultural area, taking into account various limitations and requirements. These limitations may include the availability of resources (arable land, labor, financial capital, irrigation water), the consumption of resources per unit area (seeds, fertilizers, pesticides), the average yield per hectare, market requirements, crop rotation and phytotechnical aspects, as well as the specific conditions for obtaining agricultural subsidies.

The case study is based on data provided by IF Voinea, a family-owned agricultural enterprise specializing in the cultivation of cereals and oilseeds, located in the Drăgușeni commune, Galați County. The choice of this farm as a case study allows for the practical analysis of the application of linear programming in a real agricultural context in Romania, a country in which agriculture is an important economic sectorThe mathematical model includes average production, expenses, income and profit per hectare for the main crops: wheat, corn, barley, sunflower, rapeseed and peas. The objective function is the maximization of total profit. The objective function that represents the economic or technical indicator that we want to optimize, either by maximizing or minimizing.

$$F(x) = \sum_{j=1}^{n} C_j x_j \rightarrow optim \begin{pmatrix} maxim \\ minim \end{pmatrix}$$

- Cj - the value of the indicator to be optimized;
- Xj - the size of the "j" branch.

The constraints include: the total area in ha, maximum and minimum limits for each crop, the minimum required production, and the maximum limit for fertilizer consumption. The constraints define the limits or conditions that the decision variables must satisfy, these being formulated as linear inequalities or equalities and reflecting the limited availability of resources, production requirements, technological aspects, etc.

$\sum_{i=1}^{n} x_i = S$ • full use of the surface

$\sum_{i=1}^{n} x_i \gtrless S_i$ • surface limits

$\sum_{i=1}^{n} x_i q_i \lessgtr Q_i$ •production limits

- n – number of unknowns
- S – total area
- Si – marginal area of category "i"
- Xi – area of category "i"
- qi – yield of category "i"
- Qi – marginal production of category "i"

The model was solved using the Solver tool in Microsoft Excel, selecting the Simplex LP algorithm.

$$\begin{aligned} a_{11}x_1 + a_{12}x_{12} + ... + a_{1i}x_i + ... + a_{1m}x_m = b_1 \\ a_{21}x_1 + a_{22}x_2 + ... + a_{2i}x_i + ... + a_{2m}x_m = b_2 \\ a_{i1}x_1 + a_{i2}x_2 + ... + a_{ij}x_j + ... + a_{in}x_n = b_i \\ .... \\ a_{m1}x_1 + a_{m2}x_2 + ... + a_{mj}x_j + ... + a_{mn}x_n = b_m \end{aligned}$$

Figure 1 **Model of the linear programming problem**

- coefficients aij, i = 1,2, ..., m; j = 1,2, ..., n; are the technical-economic coefficients (e.g. expenses);
- unknowns (variables xj, j = 1,2, ..., n; are the quantities that are calculated and usually represent the level of production).

RESULTS AND DISCUSSIONS

During the Agricultural production systems courses, theoretical knowledge was acquired, which was later applied practically during the seminars. In collaboration with the "IF Voinea" enterprise, a mathematical model was developed.

The first stage in developing the mathematical model is to establish the unknowns, in this case the unknowns are represented by X1, X2, …, X6; these reflect the areas of the crops mentioned in the table (the Xi values are equal to 0 until the model is solved).

Crop	Xi	Average production (kg/ha)	Fertilizers (kg d.a./ha)	Turnover (lei/ha)	Expenses (lei/ha)	Advantage (lei/ha)
Wheat	X1	5100	155	2550	1530	1020
Corn	X2	7300	180	4380	2628	1752
Barley	X3	4000	146	2400	1440	960
Sunflower	X4	2400	212	2880	1728	1152
Rapeseed	X5	3022	200	2100	1930	2200
Peas	X6	2800	168	8400	5040	3360

Figure 2 **Database for the company IF Voinea**

Next, the objective function represented by profit maximization will be chosen.

$$\boldsymbol{F(x) = \sum_{i=1}^{n} x_i * Pi \rightarrow max}$$

Next, the constraints will be determined.

• the first constraint represents the integral use of the surface;
• constraints 2 – 7: surface limits;
• constraints 8 – 13: production limits;
• constraints 14: consumption limit of available resources (fertilizers).

No. of Crt.	Restrictions	U.M.	Available resources
1	Total cultivated area	Ha	= 200
2	Corn area	Ha	< 30
3	Barley area	Ha	< 35
4	Sunflower area	Ha	> 50
5	Pea area	Ha	< 7
6	Wheat area	Ha	< 100
7	Rapeseed area	Ha	< 40
8	Wheat production	kg	> 400000
9	Corn production	kg	> 100000
10	Barley production	kg	> 10000
11	Pea production	kg	> 5000
12	Rapeseed production	kg	> 50000
13	Sunflower production	kg	> 10000
14	Total amount of fertilizers used	kg	< 200000

Figure 3 **Constraints table**

In the next step, the mathematical model will be drawn up:

1. Access Data> Solver;
2. Click on Set Objective (objective function), the box will contain the formula located after "Maximize";
3. As in the image above, the following will be checked: Max, Make Unconstrained Variables Non-Negatives and Simplex Lp will be selected;
4. In the By Changing Variable Cells box, the values of the variables representing the areas of the land use categories that we need to optimize will be selected;

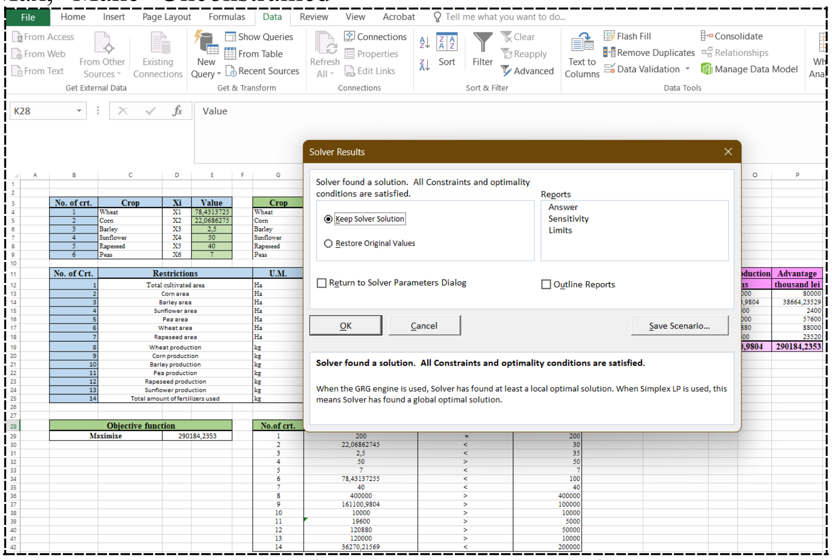


Figure 5 **The final step in using Excel Solver**

5. In the Subject to the Constraints box > click Add, the Add Constraints box will appear where the restrictions will be entered as follows:
   - in the Cell Reference box, the box with the condition will be selected;
   - the restriction sign will be selected;
   - in the Constraint box, the restriction value will be selected > OK;
6. Once all the restrictions have been entered, click Solve to solve, followed by the interpretation of the results.

Based on the linear programming model, the results indicate the optimal areas allocated to each crop, based on the profit maximization criterion. The main observations are:

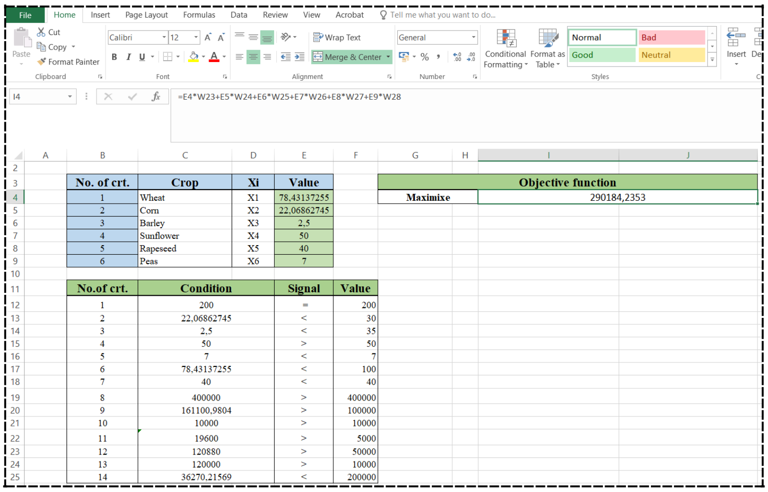
• wheat is the dominant crop in the optimized structure, which indicates that this crop is the most profitable and stable in the current economic and climatic context;

• corn, although it is the second most important crop, its area is much smaller than that allocated to wheat, which indicates a greater sensitivity to the optimization conditions;

• barley has a very small allocated area, which indicates that this crop is not a priority in the chosen model;

• sunflower and rapeseed receive significant allocations, which can be justified by the increased demand on the vegetable oil and biofuel market, as well as advantageous prices;

• peas have a smaller allocation due to lower market demand but still remain an important pillar in the crop rotation.



=E4*W23+E5*W24+E6*W25+E7*W26+E8*W27+E9*W28

No. of crt.	Crop	Xi	Value
1	Wheat	X1	78,43137255
2	Corn	X2	22,06862745
3	Barley	X3	2,5
4	Sunflower	X4	50
5	Rapeseed	X5	40
6	Peas	X6	7

Objective function	
Maximixe	290184,2353

No.of crt.	Condition	Signal	Value
1	200	=	200
2	22,06862745	<	30
3	2,5	<	35
4	50	>	50
5	7	<	7
6	78,43137255	<	100
7	40	<	40
8	400000	>	400000
9	161100,9804	>	100000
10	10000	>	10000
11	19600	>	5000
12	120880	>	50000
13	120000	>	10000
14	36270,21569	<	200000

Figure 6 **Results**

The model suggests an optimized farm strategy, in which wheat, sunflower and rapeseed are the main crops, and corn, barley and peas play a secondary role, either for diversification or to maintain soil health.

CONCLUSIONS

The main objective of the presented study was to apply linear programming, through the Solver program in Microsoft Excel, in order to optimize the crop structure within the IF Voinea farm. The aim of the approach was to identify the optimal allocation of arable land between various crops, in order to maximize the profit of the agricultural holding, taking into account a series of economic, agrotechnical and market restrictions. The application of the Solver program in Excel allowed obtaining the optimal solution for this model.

The linear programming model applied to the IF Voinea farm suggests an optimized strategy in which wheat, sunflower and rapeseed constitute the main crops, while corn, barley and peas play a secondary role, contributing to diversification and maintaining soil health. This study demonstrates the usefulness of linear programming as a valuable decision-making tool for agricultural farms, offering them the opportunity to evaluate different crop structure scenarios and to select the option that best meets the economic objectives of the holding. Implementing such an optimized structure can lead to profit maximization, contributing to more efficient management of available resources and increasing competitiveness in the agricultural sector.

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AGRICULTURE DYNAMICS ACCORDING TO SUSTAINABLE DEVELOPMENT GOALS

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Abstract

The scientific paper aims to assess the transformations within the agricultural sector in the context of the implementation of the 2030 Agenda and its Sustainable Development Goals (SDGs). The research adopts an integrated approach, examining agriculture from economic, social, and environmental perspectives, with a focus on resource efficiency, reduction of ecological impact, and increased farm resilience. Using sustainability indicators, the paper analyzes the progress achieved in Romanian agriculture, highlighting trends in productivity, digitalization, and the transition toward green farming practices. Furthermore, the study explores the role of agricultural management in implementing sustainable strategies, as well as the importance of public policies and European funding mechanisms in supporting farmers. The comparative analysis between regions and time periods reveals both best practices and persistent challenges related to climate change adaptation and social equity. The conclusions emphasize the need for an integrated managerial vision oriented toward innovation, efficiency, and responsibility, as a foundation for a real transition toward a sustainable and competitive agricultural system.

Key words: sustainable development, agriculture dynamics, farm management, green farming practices

Agriculture is a vital area of human society's evolution, and its dynamics must be monitored as closely as possible in order to identify ways of making this sector more efficient, using its resources rationally, and ensuring its development in line with the principles of sustainable development. Sustainable development protects the foundation of healthy agricultural development rather than limiting or hindering it. Ensuring that development trends remain sustainable can demonstrate social and economic responsibility for the future of society.

The most well-known definition of sustainable development is undoubtedly the one provided by the World Commission on Environment and Development (WCED) in its report "Our Common Future" also known as the Brundtland Report: "Sustainable development is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs."

Sustainable development seeks to establish a stable theoretical framework for decision-making in any situation involving a human-environment relationship, whether in the natural, economic, or social spheres (Brezuleanu C.O., Robu A.D., Viziteu St., Brezuleanu S., 2022). The Sustainable Development Goals (SDGs) are key missions in order to guide common global development efforts over the subsequent years (Pogge, T., Sengupta M., 2015). There are 17 global SDGs (*figure 1*) that form the basis of the work strategy (U. N., 2025).

Figure 1 ***The Sustainable Development Goals***

The National Strategy for Sustainable Development of Romania 2030 (SNDDR), like the 2030 Agenda for Sustainable Development, takes a firm stance with its commitment to leave no one behind. The SDGs in the strategy are designed to take society to another level and reflect important aspects that it wishes to protect, such as a clean and safe environment, access to opportunities and services, human rights, strong and accessible institutions, inclusive economies, diverse communities that support inherited culture. Each SDG includes targets that must be measured to assess whether the goal has been achieved. Under the 17 SDGs of the SNDDR, there are 104 targets for the 2030 horizon (Romaniuc Carmen Aurelia, Anastasiu Daniela *et al*, 2023).

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Agriculture is one of the fundamental sectors capable of ensuring sustainable development due to its primary characteristic as an expanding field - namely, because it focuses on rural areas where agricultural practices are carried out, where wildlife and vegetation coexist harmoniously, and where the relationship between the environment, human and economy requires a balance that aligns these forces with sustainable principles.

Factors like adverse climatic conditions (Viziteu St., 2011), economic growth and foodsecurity (Boghiţă E. *et al*, 2021), management practices and changing technology (Viziteu St. *et al*, 2022) impacts the level of agricultural development, as its evolution and performance depend on maintaining this balance, which is the foundation of sustainable development. Agricultural dynamics are determined by changes in technical and economic indicators related to cultivated areas, yields, turnover, profits, labor productivity, etc. (Viziteu St. *et al*, 2024); however, this paper will analyze the indicators that are directly linked to the relevant SDGs.

Developing policies designed to promote sustainable agricultural development requires an understanding of the complex dynamics of agricultural systems, both at the farm level and at the regional level. This includes how farmers make management decisions, the effects of these decisions on soil fertility and crop and livestock production, as well as the consequences of these production levels on prices (Bontkes T., van Keulen H., 2003; Viziteu Șt., 2020).

Romania's National Strategy for Sustainable Development 2030 (SNDDR) and the 2030 Agenda for Sustainable Development, are documents that ensure the implementation of sustainable development. The Sustainable Development Goals (SDGs) outlined in the strategy are designed to elevate society to a new level and reflect key aspects that the country aims to protect, such as a clean and safe environment, access to opportunities and services, human rights, strong and accessible institutions, inclusive economies, and diverse communities that support cultural heritage.

Each SDG includes targets that must be measured to assess whether the goal has been achieved. Under the 17 SDGs of the SNDDR, there are 104 targets for the 2030 horizon. In this context, it is necessary to direct efforts toward the implementation of the Sustainable Development Goals, which form the basis for a resilient, equitable, and sustainable recovery.

MATERIAL AND METHOD

This paper is based on literature related to sustainable development and its objectives, as well as on how these objectives (broken down into targets) are reflected in the agricultural sector.

The study focused on Romania, analyzing data provided by the National Institute of Statistics to highlight the evolution of analytical indicators and the current situation in relation to the proposed objectives.

The analysis of statistical indicators and their presentation in tabular or graphical form provides a clear, comprehensive picture of agricultural dynamics in relation to sustainable development goals.

RESULTS AND DISCUSSIONS

The paper analyzes the situation specific to Romania, starting, of course, with the general characteristics of how sustainable development goals are reflected in agriculture.

The main SDGs among the 17 are Goal 2 (Zero hunger), goal 9 (Industry, innovation, and infrastructure) and goal 15 (Life on land). Within these goals, several sector-specific targets were analyzed. For Romania within goal 2: zero hunger one of the target was completion of the agricultural cadastre. The area of registered land (*figure 2*) represents the total area of land for which an owner has been identified and a land registry has been established. Land registration contributes to the growth and social development of regions, facilitates infrastructure development, and promotes social inclusion through a range of multidimensional measures and actions.

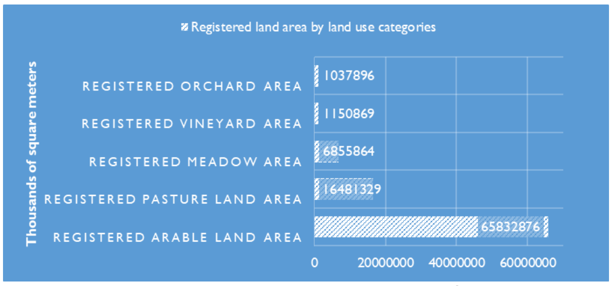

Figure 2 **Target 2 - Economic - Area of registered land by land use category – 2024**

The registered land use structure reflects a farm with a predominantly crop-based profile (cereals/industrial crops), supplemented by pasture.

Registered arable land area is the dominant category, covering 6,58 milion hectares. Registered pasture land area ranks second, with an area of 1,64thousand square meters. Meadows occupy an intermediate area of 0.68 thousand square meters used for forage production. Target 3 is also analyzed in the same section: doubling the share of agriculture in Romania's GDP (*figure 3*) compared to 2018 The percentage epresents the ratio of the gross value added of the agriculture sector to the gross domestic product, multiplied by 100.

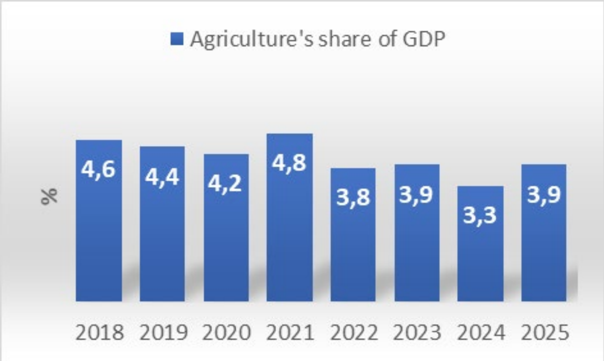

Figure 3 **Target 3 - Economic - Share of Romania's agri-food exports and imports in GDP**

The share of agriculture in GDP for the period 2018–2025 shows a general downward trend, from 4.6% to approximately 3.9%, marked by annual fluctuations, with a peak in 2021 and a low in 2024, followed by a slight recovery.

Target 5, which aims to increase the utilization of domestic agricultural production, analyzes imports and exports of agri-food products (*figure 4*).

Figure 4 **Share of Romania's agri-food exports and imports in GDP, by intra-EU and extra-EU regions**

Exports of goods include all goods that, whether for consideration or free of charge, leave the country's economic territory destined for the rest of the world. Imports of goods include all goods that, whether for a fee or free of charge, enter the country's economic territory from the rest of the world. The chart shows that the share of Romania's agri-food imports in GDP is consistently higher than that of exports during the 2020–2024 period, with both reaching a peak in 2022, followed by a decline through 2024, indicating a continuing trade deficit in the agri-food sector, both within the EU and with non-EU countries. Agricultural output (*table 1*) is determined in accordance with the accounts for agriculture and includes: the value of all agricultural production (including the value of wine produced on farms that do not have industrial winemaking facilities) and the value of agricultural services provided by specialized units.

Table 1

Value of agricultural production (thousand lei)

Development regions	**2022**	**2023**	**2024**
Romania	109567691	109891931	100546291
North-West	12838232	14053777	12911682
Center	12178395	13451428	13283265
North-East	16896228	18138713	15464966
South-East	17007101	16661377	14626751
South-Muntenia	24279130	20670479	20177153
Bucharest-Ilfov	1947782	2091456	2351277
South-West Oltenia	13576194	13089584	10734973
West	10844629	11735117	10996224

The total value of agricultural production saw a marginal increase of approximately +0.3% in 2023 compared to 2022, followed by a significant decline of about -8.5% in 2024, a trend reflected at the regional level by sharp declines in South-West Oltenia (-18%) and South-East (-12%), while Bucharest-Ilfov stands out with a steady increase of approximately +21%, highlighting the deepening of regional imbalances.

Organic agriculture as target 6 (*figure 5*) refers to agricultural products, including yeast and products obtained through aquaculture. It covers all stages of the production process, from seeds to final processed foods.

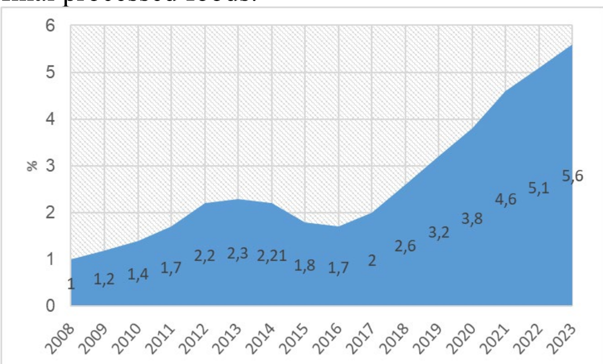

Figure 5 **Target 6 - Share of organic agricultural production in total agricultural production**

The indicator is calculated as the percentage of organic agricultural production in conventional agricultural production. The share of organic agricultural production in the total rose from approximately 1.2% at the start of the period to 5.6% in 2023 (+367% overall), with relatively slow growth until 2016, followed by a significant acceleration after 2017.

Within SDG 9 (Industry, innovation, and infrastructure) Target 4 is highlighted - Budget allocation for research and development in agriculture (*figure 6*). Support for R&D in the agricultural and rural development sectors aims to facilitate the adaptation of new technologies to production conditions in Romania and to find viable solutions for the conservation and sustainable use of agricultural resources.

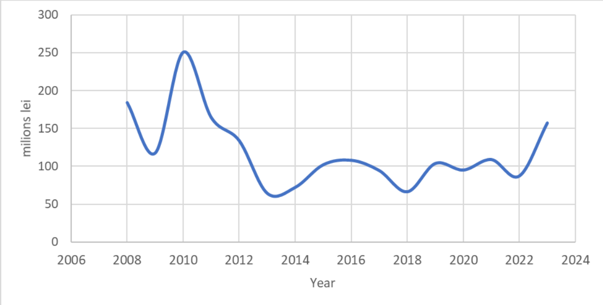

Figure 6 **Budget allocation of funds for research and development in agriculture**

Budget allocations for research and development in agriculture for Romania have fluctuated over time, peaking around 2010, followed by a sharp decline and a period of relative stagnation, before a slight recovery in recent years, suggesting instability in the prioritization of funding for this sector.

For SDG 15 (Life on land) it was taken into consideration irrigated area (*table 2*) which refers to all works carried out to ensure a controlled water supply to agricultural crops with the aim of increasing agricultural production and ensuring its independence from weather conditions.

Table 2

Target 7 - Environment - Area of land improved through land improvement and soil erosion control works, by land use category (ha)

Land use	2022	2023	2024
Total improved area	2280188	2280474	2280475
Improved agricultural area	2134215	2134251	2134078
Arable land	1222379	1222264	1222093
Natural pastures	514037	514014	514012
Natural hayfields	200240	200716	200716
Vineyards	81556	81019	81019
Orchards	116003	116238	116238

The total improved agricultural area remained nearly constant stagnated, arable land recorded a minor decline (−0.02%), natural hayfields increased slightly (+0.2%), and vineyards decreased marginally (−0.7%), while orchards recorded a slight increase indicating overall stagnation in land improvement works.

CONCLUSIONS

Agriculture is a key sector for achieving the Sustainable Development Goals, either directly through specific indicators or indirectly through secondary or tertiary sectors. The pace of progress toward the targets and indicators is still below the established level but efforts are being made to improve the situation year after year. From the perspective of the Sustainable Development Goals, there is a significant discrepancy between the dynamics of agriculture and those of other economic sectors, such as services, trade and tourism, because the level of performance indicators falls short of what is needed to achieve these goals, even though progress has been identified through the analysis conducted.

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FARM MANAGEMENT IN THE ERA OF DIGITALIZATION: THE GEOFOLIA SOFTWARE SOLUTION

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Abstract

Digitalization has become a fundamental component of modern farm management, enabling farmers to optimize operations, improve decision-making, and enhance productivity. Modern tools for farm management and managerial decision-making are increasingly being applied in the agricultural sector to improve performance and resource utilization, particularly by increasing productivity. This study analyzes the role and applicability of the Geofolia software, a digital management tool developed by ISAGRI and used by over 135,000 farmers worldwide. Through documentation, case study analysis, and simulation of a full production cycle, the research highlights how Geofolia supports parcel mapping, activity recording, input management, and economic reporting. The results show that the software increases operational efficiency, reduces manual errors, ensures traceability, and provides valuable insights for technological and economic optimization. Overall, Geofolia proves to be an accessible and effective solution for the digital transformation of agricultural practices.

Key words: farm management, digital agriculture, Geofolia, smart farming, software systems

The transformation of agriculture through digitalization is one of the most significant developments of the past decade. Traditional agricultural systems, once dependent on manual observations and fragmented information, are increasingly being replaced by data-driven decision-making and integrated management tools. This evolution is supported by the rapid advancement of technologies such as cloud computing, remote sensing, artificial intelligence, GPS-guided machinery, and IoT-based monitoring devices. These tools enable farmers to collect real-time data, optimize resource allocation, and respond more effectively to environmental and economic variability.

Global agriculture faces major challenges, including climate unpredictability, soil degradation, labor shortages, and the rising demand for food. According to international projections, agricultural production must increase by approximately 70% by 2050 to meet global food requirements. Digital tools therefore become essential in guiding farmers toward more efficient, precise, and resilient production systems. Integrated software systems also support the implementation of sustainable practices by reducing waste, improving traceability, and promoting a clearer understanding of crop performance.

The agricultural sector plays a global and fundamental role in society, serving as the cornerstone for food security, employment, and rural development (Coca Oana *et al*, 2023; Boghiţă E. *et al*, 2021). In this context, farm management software plays a central role by organizing the operational complexity of agricultural production. Geofolia, developed by ISAGRI, represents one of the most widely used digital platforms in Europe, with over 135,000 farm users worldwide. It provides detailed field mapping, equipment tracking, input management, operational journaling, and economic analysis tools. Unlike traditional management approaches, which rely heavily on paper records and individual experience, Geofolia centralizes information and transforms it into accessible digital reports that improve the quality of managerial decisions. Furthermore, the software supports compliance with phytosanitary, environmental, and administrative regulations, which are increasingly demanding (Viziteu Șt. *et al*, 2022).

Managementul ete o știință fundamentată pe date concrete, modele matematice, prognoze precise și analize detaliate (Brezuleanu S., 2004;

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Ciurea I.V. *et al*, 2001; Viziteu Șt., 2020), prin urmare diversificarea activităților în exploatațiile agricole necesită strategii specifice adaptate contextului și evoluției tehnologiei (Donosă D., Donosă Raluca-Elena, 2011; Ungureanu G., 2008).

Innovation in the agri-food sector and a shift toward digitalized agricultural practices can serve as a source of productivity growth in this field (Viziteu Șt. *et al*, 2019). Precision agriculture practices - from optimized fertilization to real-time monitoring of field conditions - can be integrated within the software's functionalities (Baciu Mădălina Andreea *et al*, 2024). These elements highlight the importance of digital tools not only as record-keeping systems but also as strategic instruments that shape the long-term development of agricultural enterprises and helps improve key performance indicators for farms (Viziteu Șt. *et al*, 2017).

MATERIAL AND METHOD

The aim of this paper is to inform and familiarize stakeholders and potential users with the usage, functions, and applications of a management software program designed for agricultural farms (Geofolia). The specific objectives were:

- Analysis of digital systems in agriculture
- Describing the main features and functions of the Geofolia software;
- Analyzing how the program influences technological and management processes and how it can be implemented;
- Highlighting the advantages and ease of use from the user's perspective

The methodological approach used in this study combines documentation, case study analysis, and simulation in order to evaluate the digital management capabilities of the Geofolia platform.

First, extensive documentation was conducted regarding the evolution of digital agriculture, smart farming technologies, and software systems currently implemented in farm management. Particular attention was given to systems that integrate cartographic tools, input registries, and economic indicators, as these components form the basis of Geofolia's structure.

Second, a case study evaluation was applied to analyze Geofolia's functionalities, user interface, and practical applicability. Each module—parcel mapping, equipment database, input management, operational journals, and economic reports—was examined individually to determine its contribution to improving workflow efficiency. Third, a simulation of a complete crop production cycle was performed within the software environment. This simulation included defining parcels, uploading maps, assigning machinery, entering fertilizer and pesticide applications, recording fieldwork operations, and generating economic performance indicators. Through this procedure, it was possible to evaluate not only the software's technical accuracy but also the clarity of its outputs and the ease with which users can navigate the system.

The evaluation also considered criteria derived from agricultural management theory, including traceability, decision support, regulatory compliance, economic analysis, and adaptability to different farm structures. These methodological steps ensured a comprehensive assessment of Geofolia as a modern tool for farm digitalization.

RESULTS AND DISCUSSIONS

The results reveal that digital tools significantly enhance the efficiency and organization of agricultural management. There is a clear need to transform traditional agriculture into smart agriculture.

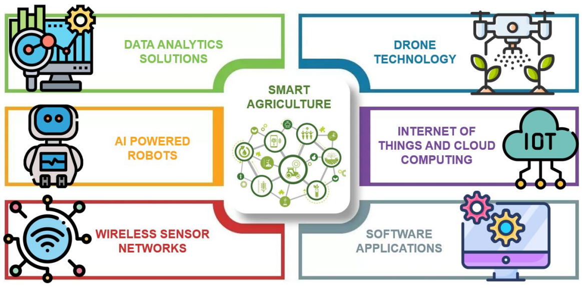

Figure 1 **Smart agriculture**

Technologies such as cloud computing, the Internet of Things, systems integration, augmented reality, artificial intelligence, wireless sensor networks, and others are becoming increasingly prevalent in farm operations.

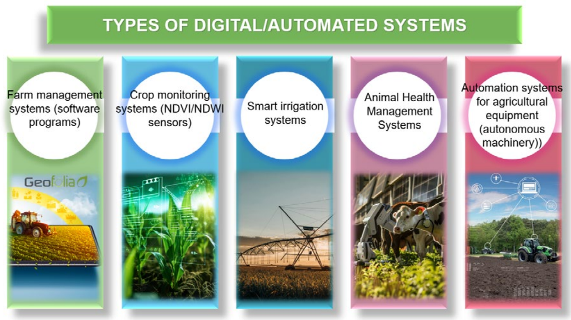

Figure 2 **Types of digital systems**

The chart shows the main categories of digital and automated systems in agriculture, including management software, sensor-based crop monitoring, smart irrigation, animal health management, and autonomous machinery, which are key pillars in optimizing production processes and informing strategic decisions in a technologically competitive agricultural environment. This approach aims to increase operational efficiency by providing the comprehensive overview needed to address global challenges through the integration of cutting-edge technologies and automation.

FARM MANAGEMENT SOFTWARE – FEATURES

	VIEW PARCELS AND CROPS	SATELLITE INDICES(NDVI /NDWI)	CROP STAGES	REPORT PREPARATION	MANAGEMENT OF ON-FARM ACTIVITIES	MACHINERY AND EQUIPMENT FLEET MANAGEMENT	NVENTORY AND PRODUCTION MANAGEMENT
FARMERP	✓	✓	✓	✓	✓	✓	✓
TRIMBLE AG	✓	×	✓	✓	✓	✓	✓
AGROCITY	✓	×	✓	✓	✓	✓	✓
AGROVIR	✓	✓	✓	✓	✓	✓	✓
AGRIVI	✓	×	✓	✓	✓	✓	✓
SATAGRO	✓	✓	✓	✓	✓	✓	×
SASAGRO	✓	✓	×	×	×	✓	×
365 FARMNET	✓	✓	✓	✓	✓	✓	✓
GEOFOLIA	✓	✓	✓	✓	✓	✓	✓

Figure 3 **Main features of farm management softwares**

The table provides a comparative analysis of the features offered by various farm management software solutions, highlighting the platforms that provide full integration of satellite monitoring (NDVI), task management, and machinery fleet management to optimize decision-making in precision agriculture.

Geofolia is an agricultural management software developed by ISAGRI (France) with over 135,000 farmers using it worldwide. It is a software solution for the digital management of farms that ensures compatibility with computers, tablets, and smartphones, as well as accessibility both in the office and in the field. Its main features include

- 3D mapping & orthophotos
- Comprehensive farm management
- Integrated reports

Multi-user & multi-farm access The main contribution of Geofolia lies in its ability to centralize operational data and transform it into structured, easily interpretable information. This approach reduces dependency on fragmented documentation and minimizes the risk of losing essential information during the production cycle.

One of the key results is the high precision of the software's parcel mapping functionality.

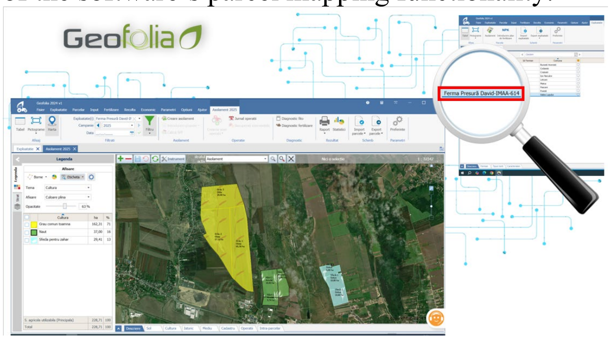

Figure 4 **Creating parcels in Geofolia**

By combining 3D cartography with orthophotographic imagery, Geofolia allows farmers to visualize field boundaries accurately, detect variations in field shapes, and plan activities based on real geographic parameters. This improves the distribution of fertilizers, pesticides, and field operations, contributing to resource optimization and the prevention of overlapping applications.

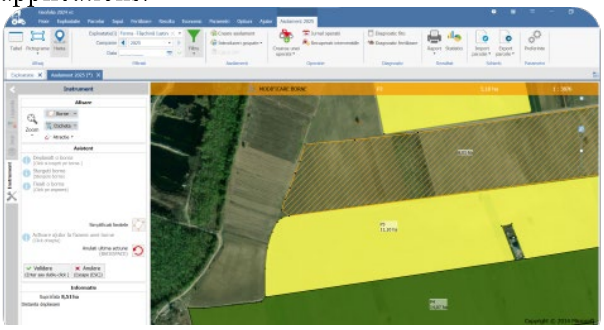

Figure 5 **Surveying and demarcating parcels**

The input management module provides traceability for fertilizers, pesticides, seeds, and other materials used during the production cycle. The software automatically stores quantities, doses, acquisition dates, suppliers, and compliance-related information.

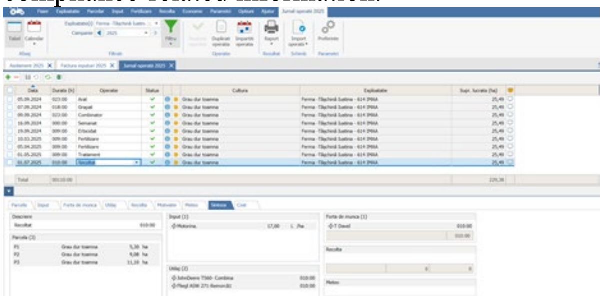

Figure 6 **Operations log for the crop**

This module is particularly important in the context of increasingly strict European regulations regarding chemical input use and traceability requirements. Farmers can generate input reports instantly, facilitating inspections and audits.

The activity journal represents another important result, allowing detailed documentation of every field operation, from soil preparation to harvesting. This contributes to improved technological discipline and enables retrospective analysis of interventions that may have influenced yield performance. When combined with the parcel mapping tool, the journal becomes a valuable reference for evaluating technological efficiency. The economic reporting functionality demonstrated the strongest influence on managerial decision-making.

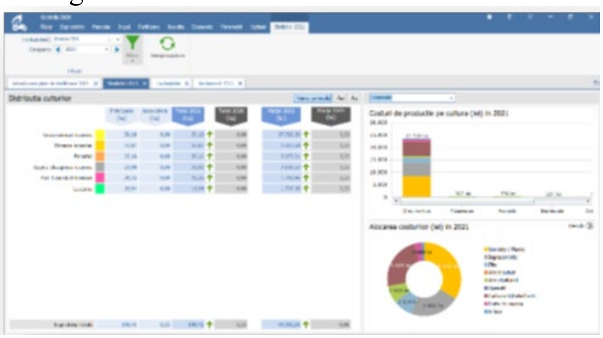

Figure 7 ***Chart showing the economic efficiency of each crop***

By generating profit graphs, cost analyses, and parcel-level comparisons, Geofolia provides farmers with a clear view of which crops or technologies offer the highest return on investment.

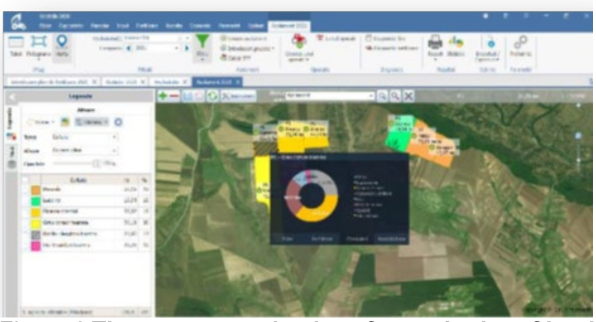

Figure 8 **The gross margin chart for each plot of land**

These indicators support long-term strategic planning and help determine the optimal allocation of resources.

Compared to traditional management methods, which rely on intuition or scattered notes, Geofolia enables evidence-based decision-making. The software also enhances communication among workers, agronomists, and managers, as all information is updated in real time and accessible from multiple devices.

The results align with trends highlighted in similar studies where structured data analysis significantly improved production planning and economic performance. Digital platforms such as Geofolia thus represent not only an administrative tool but a core component of modern agricultural strategy.

CONCLUSIONS

The study concludes that digitalization plays a critical role in the development of efficient, sustainable, and competitive agricultural systems. Geofolia demonstrates considerable applicability as a management tool that integrates cartographic, technological, and economic information within a single platform. Its modules support operational planning, traceability, regulatory compliance, and performance evaluation, making it suitable for both small and large farms.

By simplifying documentation and providing detailed insights into production processes, the software helps farmers improve decision-making and economic outcomes. Moreover, Geofolia contributes to the broader goal of precision agriculture by enabling more targeted interventions and reducing unnecessary resource use.

Digital tools such as Geofolia will play an increasingly important role as agriculture faces growing challenges related to climate variability, labor shortages, and market volatility. The adoption of such systems supports long-term strategic planning and ensures that agricultural units can adapt effectively to modern requirements.

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FOSTERING INTERDISCIPLINARY LANGUAGE LEARNING WITH AI: LESSONS FROM THE LANGVET-IA PROJECT

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Abstract

The integration of artificial intelligence (AI) into language education is reshaping the way languages for specific purposes (LSP) are taught and learned. The LANGVET-IA project, conducted from July 2024 to July 2025 across four partner countries (Romania, Moldova, Georgia, and Croatia), provides a unique case study of how interdisciplinary collaboration can enhance the design and implementation of AI-assisted language learning resources in the field of veterinary medicine. This article examines the pedagogical, technological, and terminological dimensions of the project, highlighting how experts in linguistics, veterinary science, and computer science jointly developed interactive manuals and multilingual terminological databases with the support of generative AI tools. The co-creation process involved the extraction and validation of specialized terminology, the design of adaptive learning activities, and the production of digital textbooks in French, English, and Romanian. The study argues that interdisciplinary approaches, when supported by intelligent technologies, offer fertile ground for reimagining LSP instruction and advancing inclusive, responsive, and forward-looking language education practices.

Key words: interdisciplinary collaboration, language for specific purposes, artificial intelligence, veterinary education, multilingual resources

In recent years, the accelerating development of artificial intelligence (AI) has triggered profound transformations across educational domains, including language education. While the application of AI to general language learning has received increasing scholarly attention, the integration of intelligent technologies into languages for specific purposes (LSP) instruction remains underexplored. LSP teaching, by definition, requires a careful balance between linguistic accuracy, disciplinary knowledge, and the communicative needs of learners operating in highly specialized contexts. The dynamic interaction of these elements poses unique pedagogical challenges that traditional approaches have only partially addressed. Against this background, the incorporation of AI-assisted methodologies opens new pathways for enhancing the design, delivery, and accessibility of LSP learning resources, particularly in professional fields where precise terminology and domain-specific discourse are essential.

The LANGVET-IA project (July 2024–August 2025), a collaborative initiative across Romania, Moldova, Georgia, and Croatia, constitutes a compelling case study of this emerging trend. Situated at the intersection of applied linguistics, veterinary medicine, and computer science, the project exemplifies the potential of interdisciplinary cooperation in reimagining LSP pedagogy. The project's central objective is to harness AI-based tools, including generative models, for the creation of innovative and interactive learning resources tailored to the veterinary domain. In doing so, LANGVET-IA contributes not only to advancing the pedagogical landscape of veterinary language education but also to the broader discourse on how AI technologies can be meaningfully embedded into higher education curricula.

The novelty of the project resides in both its methodological design and its collaborative ethos. First, it emphasizes the co-creation of resources by experts from diverse disciplinary backgrounds. Linguists, veterinary specialists, and computer scientists jointly engaged in the extraction, validation, and systematization of specialized terminology, ensuring both linguistic precision and disciplinary authenticity. This collaborative process culminated in the development of multilingual terminological databases and adaptive learning materials that respond to learners' varied needs. Second, the project employed generative AI technologies not merely as tools for automation but

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as catalysts for creativity and pedagogical innovation. By supporting the design of digital textbooks in French, English, and Romanian, AI enhanced both the inclusivity and the reach of the educational outputs.

Beyond its immediate pedagogical outcomes, LANGVET-IA also raises broader questions concerning the evolving role of AI in language education. The project demonstrates that intelligent technologies, when carefully integrated, can facilitate not only efficiency but also inclusivity and responsiveness in LSP instruction (Velescu, 2024). Moreover, it illustrates that interdisciplinary collaborations offer fertile ground for rethinking traditional paradigms of language education. Rather than replacing human expertise, AI can augment it, enabling educators and domain specialists to co-develop resources that are more contextually relevant, learner-centered, and technologically robust.

This article situates the LANGVET-IA project within the wider academic conversation on AI-assisted LSP education. It begins by reviewing the theoretical and methodological foundations of LSP instruction and recent trends in AI-enhanced pedagogy. It then presents the design and implementation of the LANGVET-IA project, detailing the processes of terminological extraction, resource development, and digital textbook production. Finally, the article reflects on the pedagogical, technological, and terminological dimensions of the project, drawing out implications for the future of LSP teaching and for the broader integration of AI in language education. By doing so, it seeks to contribute to ongoing debates on how intelligent technologies can support innovative, inclusive, and forward-looking practices in specialized language education.

MATERIAL AND METHOD

The LANGVET-IA project was designed as a cross-border initiative involving institutions from Romania, Moldova, Georgia, and Croatia with the central aim to integrate artificial intelligence (AI) into Languages for Specific Purposes (LSP) education, with a focus on veterinary medicine. The project was structured to highlight interdisciplinarity, combining expertise in linguistics, veterinary science, and computer science to produce multilingual terminological databases and AI-assisted educational resources.

1. Participants and Working Teams

The consortium was composed of interdisciplinary teams organized around three core areas: linguistics, veterinary sciences, and computer science. The linguistic teams were responsible for terminological research, corpus building, and glossary development. Veterinary specialists provided domain expertise and validated the accuracy of extracted terms. Computer scientists contributed by designing AI tools and proposing immersive technologies such as virtual reality simulations.

Each team worked both independently and collaboratively. Regular meetings—onsite and online—ensured the alignment of activities, while cross-validation procedures guaranteed coherence across the different disciplines. The organizational structure facilitated flexibility and adaptability, crucial for coordinating activities across multiple countries and institutional contexts.

2. Technological Tools and Resources

The methodological framework relied on a blend of traditional linguistic research methods and innovative AI-based approaches. A large corpus of authentic veterinary materials was collected, including manuals, textbooks, glossaries, databases, and scientific articles. These documents provided the foundation for terminology extraction.

An AI-powered tool, based on large language models, was developed to identify specialized terms within the corpus. This tool extracted keywords, generated short glosses, and annotated metadata such as frequency, grammatical category, and context of use. The tool's outputs were subsequently reviewed and refined by the linguistic and veterinary teams.

In addition to corpus analysis, the project explored digital technologies for pedagogical innovation. Proposed solutions included virtual reality scenarios for clinical simulations, AI-assisted platforms for LSP immersion, and open-access databases for multilingual resources.

3. Terminology Extraction and Validation Methodology

After initial discussions, the sensory system was selected as the first thematic field for analysis, while additional areas such as veterinary training, animal classification, and clinical consultations were also identified.

The corpus was systematically processed using the AI extraction tool. An initial batch of 100 terms was generated, followed by a second batch later the same year. The results were refined by applying stricter selection criteria to balance high-frequency items with less frequent but pedagogically significant terms.

The validation phase involved both domain experts and students of veterinary medicine, who assessed the relevance, clarity, and accuracy of the extracted terminology. Their feedback informed adjustments to the glossary, ensuring that it addressed both professional and educational needs.

A template for terminological entries was also designed, tailored to the project's requirements. Each entry was multilingual (English, French, and Romanian) and included linguistic, terminological, and pedagogical information. This model was iteratively revised based on peer and user feedback, providing a standardized format for the project's glossary.

4. Development of Educational Resources

The validated terminological database became the foundation for the development of teaching materials. Each terminological entry functioned as both a linguistic reference and a pedagogical unit. These entries were integrated into digital textbooks, interactive exercises, and AI-generated adaptive activities such as case studies, role-play scenarios, and quizzes.

To enhance learner engagement, proposals included embedding terminology into virtual reality simulations. Such immersive scenarios allowed learners to practice professional communication in simulated veterinary contexts (Velescu, 2024). By making the resources available in multiple languages, the project addressed diverse learner needs and promoted inclusivity.

5. Pilot Testing and Feedback

Pilot testing took place in the four participating countries. Veterinary students evaluated the extracted terminology and engaged with prototype learning materials, while instructors provided expert validation. The evaluation process highlighted the importance of adjusting the balance between specialized terminology and more widely applicable vocabulary.

Challenges included delays in revising terminological entries and limited availability of students during exam periods. Solutions involved closer supervision of the review process, revised timelines, and curricular integration of activities to encourage student participation.

The pilot phase confirmed the feasibility of integrating AI-assisted tools into LSP pedagogy, while also emphasizing the necessity of human oversight in ensuring quality and contextual accuracy.

6. Ethical Considerations and Scientific Validation

All stages of the project adhered to principles of academic integrity, accessibility, and inclusivity. AI outputs were systematically supervised and corrected by experts to ensure reliability and avoid the propagation of errors. Ethical attention was also given to the transparency of methods, the equitable involvement of all partners, and the open accessibility of the resulting resources.

Validation procedures combined expert review with student feedback, ensuring that the terminological resources were both academically rigorous and pedagogically effective. This dual approach guaranteed that the materials not only reflected disciplinary standards but also responded to learner needs.

RESULTS AND DISCUSSIONS

The results of the LANGVET-IA project, achieved during its second phase (January–June 2025), reflect the tangible impact of artificial intelligence (AI) on the development of language resources for veterinary education. Building on the terminological foundations established in the first phase, the consortium successfully designed pedagogical materials, organized a major international conference, and disseminated its findings through a collective scientific publication. These outcomes highlight not only the project's academic contributions but also its role in strengthening intercultural and interdisciplinary collaboration.

Development of AI-Based Educational Resources

The core achievement of the project was the creation of educational units specifically tailored for veterinary students learning foreign languages. Five thematic areas were prioritized: the veterinary profession, the classification of animals, the structure of the veterinary clinic, clinical consultation and diagnosis, and professional integration into the labor market. Each unit was constructed using authentic documents sourced from publicly available materials and adapted with the support of AI-based tools.

The pedagogical design combined traditional didactic approaches with intelligent technologies. Generative AI facilitated the reformulation of materials for different proficiency levels, ensuring adaptability and inclusivity. Chatbots were used to simulate professional situations, such as job interviews, enabling students to practice communication in realistic contexts. Moreover, AI supported the creation of interactive exercises, which enriched the learning process by offering adaptive feedback and varied formats.

These efforts resulted in the publication of three specialized digital textbooks *AI for Veterinary French: An Interactive Manual for Students*, *Mastering Veterinary English with AI: An Interactive Textbook for Students*, and

Romanian as a Foreign Language for Veterinary Students. Each was designed to respond to the specific needs of learners in different linguistic contexts.

Organization of the International Conference

Another major result was the organization of the LANGVET-IA international conference, entitled *Didactic and Terminological Interconnections in Specialized Languages: Transdisciplinary Innovations in the Age of Artificial Intelligence*. Hosted in March 2025, the event brought together participants from multiple countries, including Romania, Moldova, Georgia, Croatia, Algeria, and Albania.

The conference served as both a dissemination platform for the project's outputs and a forum for dialogue on the broader implications of AI in LSP education. Sessions were structured around scientific presentations, technological demonstrations, and practical workshops. Key themes included the integration of AI and virtual reality in medical and veterinary French, the role of digital tools in LSP learning, multilingual terminological research, ethical and intercultural issues in educational technologies, and transdisciplinary approaches to applied linguistics.

The academic significance of the project was further reinforced through the publication of the conference proceedings. Edited and published by the Georgian partner university press, the volume, *Proceedings of the Conference: Didactic and Terminological Interconnections in Specialized Languages: Transdisciplinary Innovations in the Age of Artificial Intelligence*, compiled contributions from researchers across Central and Eastern Europe and beyond.

The collection was structured around three main themes: didactics of specialized languages, terminological research, and ethical/intercultural issues in AI-assisted education. It provided a comprehensive overview of the challenges and opportunities associated with the integration of intelligent technologies into LSP contexts, while also serving as a reference for future research (Velescu, Cogeanu-Haraga & al., 2024).

CONCLUSIONS

The impact of the project extended beyond its immediate objectives, as demonstrated by multiple international recognitions. The interactive digital textbook *Le français à l'usage des vétérinaires et des zootechniciens* received gold and silver medals at innovation exhibitions in Chișinău and Iași, while *Mastering Veterinary English with AI* earned a bronze medal in the books category. In addition, the project as a whole was awarded a bronze medal and a special diploma for excellence at an International Innovation and Technology Transfer Exhibition from Chișinău, on 11th-12th September 2025.

These distinctions highlight the project's innovative character and its contribution to rethinking language education for specific purposes. More importantly, they underscore the value of interdisciplinary collaboration, international cooperation, and the creative integration of intelligent technologies into higher education. The project's legacy lies not only in its tangible outputs but also in the durable networks and forward-looking practices it has inspired.

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TOURIST MOTIVATION INSIGHTS FOR ENHANCING TOURISM COMPETITIVENESS

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Abstract

This study examines tourists' motivational factors as a critical determinant of the competitiveness of Romanian tourism, analyzing both stated preferences and actual consumption behaviors. Data were collected through a structured questionnaire capturing socio-demographic characteristics, types of packages purchased, travel motivations, decision-making processes, the influence of social networks and electronic word-of-mouth, as well as satisfaction and loyalty levels. The findings reveal notable discrepancies between the motivations expressed by tourists and the attributes that genuinely drive satisfaction and behavioral loyalty. Perceptions of quality are shaped by cultural capital, income, and the aesthetic dimension of the experience, which is increasingly mediated through digital and social media platforms. A growing subset of tourists prioritizes experiences with high visual appeal and strong potential for online dissemination—so-called "instagrammable experiences"—reflecting a shift toward social validation rather than purely intrinsic personal fulfillment. Although this segment remains relatively narrow, it exerts a disproportionate influence on market perceptions and emerging trends in tourism development. These results highlight the necessity of a nuanced understanding of tourists' authentic motivations and behaviors as a strategic foundation for designing sustainable, differentiated, and culturally grounded tourism offerings. The study offers both theoretical insights and practical guidance for enhancing the competitiveness and strategic positioning of Romanian tourism destinations.

Key words: tourist motivation, tourism competitiveness, consumer behavior, social media influence, destination choice

The development of digital social networks has substantially transformed the logic of tourist choice, introducing a dimension of social validation and identity construction into the formation of preferences, tourism decision-making processes, and the communication of travel experiences. User-generated content contributes to the co-creation of destination images and influences visitation intentions, loyalty, and digital word-of-mouth, primarily by shaping the cognitive and affective dimensions of destination image (Asyraff M. A. et al., 2023). Platforms such as Instagram, TikTok, or Facebook function as arenas of symbolic competition, where the display of tourism experiences contributes to the construction of identity and social status, stimulating processes of social comparison and behaviors associated with the phenomenon of travel bragging.

For emerging destinations in Central and Eastern Europe, including Romania, understanding the digital dynamics associated with social media represents an essential prerequisite for achieving competitiveness and, subsequently, for consolidating it, as well as for developing tourism products aligned with new consumption patterns. Within this framework, social media and destination branding are closely interconnected and mutually influential (Lequeux-Dincă A. et al., 2025). Research on rural, mountain, and heritage tourism in Romania highlights that aligning the tourism offer with visitors' motivations and expectations—including functional factors such as infrastructure, safety, and price, alongside experiential factors related to cultural, spiritual, and adventure attractions—is a key determinant of destination attractiveness, tourist satisfaction, and revisit intention (Poruțiu A. et al., 2021; Dobre C. et al., 2024; Petrescu-Mag R. et al., 2025).

In this context, identifying the relationships between tourist motivations, social media use, actual consumption behaviors, and satisfaction levels becomes essential for designing authentic, sustainable, and differentiated tourism experiences. Such experiences are capable of responding to emerging consumption patterns while integratively leveraging both the cultural and digital potential of Romanian tourism (Popa I. et al., 2025; Ionescu A.-M. & Sârbu F., 2024).

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MATERIAL AND METHOD

he research was designed as a quantitative, cross-sectional study aimed at identifying the motivational factors influencing tourist consumption behaviors and examining how these factors are reflected in destination competitiveness. The methodological design is grounded in the specialized literature on travel motivation, consumer behavior, and the experience economy—conceptual frameworks that were operationalized into a research instrument adapted to the Romanian context and regional specificities. Data were collected through a structured questionnaire designed and administered by the authors, whose development included a preliminary pretesting phase to assess item clarity and internal consistency, thereby ensuring content validity and measurement reliability.

The questionnaire comprised sections addressing respondents' sociodemographic profile, consumption behaviors, travel motivations, information sources and booking channels, the influence of social media, satisfaction levels, and recommendation intention. Perceptions were measured using an eight-point Likert scale, allowing for the quantification of the importance attributed to each motivational factor and their hierarchical comparison across tourist segments.

Data collection was conducted between June and September 2025 through face-to-face interviews with tourists visiting Bucovina, a region representative of Romania's mountain, rural, and cultural tourism. The sample, selected using a non-probabilistic convenience sampling method, included both domestic and international tourists, traveling either in transit or for overnight stays. The sample size was adequate for the application of multivariate statistical analyses. All research procedures complied with ethical research principles and ensured data confidentiality.

Data analysis was performed in two stages. Initially, descriptive statistics (frequencies, means, and standard deviations) were employed to outline the respondents' profile and identify general behavioral trends. Subsequently, Pearson and Spearman correlation analyses were applied to investigate relationships between motivational variables, actual consumption behaviors, and declared satisfaction levels. To reduce dimensionality and identify latent motivational structures, exploratory factor analysis was conducted, followed by cluster analysis, which enabled the segmentation of tourists into distinct groups defined by specific combinations of motivations and behaviors. This integrated methodological framework supports a detailed and nuanced interpretation of the relationships between stated motivations, experienced satisfaction, and the influence of the digital environment on tourist consumption behavior, providing a robust basis for strategic recommendations and the development of competitive tourism products.

RESULTS AND DISCUSSIONS

For more than two decades, the academic literature has documented a shift from the traditional consumption of tourism services toward a preference for authentic and meaningful tourism experiences. In the contemporary context, this trend has intensified and become increasingly visible, as digitalization and the online exposure of tourism experiences have contributed to the consolidation and awareness of this phenomenon. In line with the principles of the "experience economy" formulated by Pine and Gilmore, the emotional, participatory, and interactive dimensions of the tourism experience have become predominant over the strictly functional attributes of tourism services (Paulauskaite et al., 2017; Pine & Gilmore, 1998). The perceived value of a trip depends increasingly less on the material characteristics of the tourism package and increasingly more on the emotional, narrative, and relational intensity of the experience—core components of memorable and authentic tourism experiences. In this context, the tourist becomes a "co-creator" of the experience, actively involved in shaping the meaning of their journey through interactions with hosts, technology, and other participants, within a real-time co-creation ecosystem. From a Bourdieusian perspective, cultural practices, including tourism, function as forms of symbolic capital and instruments for asserting status, taste, and social belonging—an idea reiterated in recent analyses addressing the negotiation and display of "authenticity" in tourism contexts.

The analysis of the collected data confirms respondents' orientation toward authentic and meaningful tourism experiences. The majority of respondents originate from urban environments (71%), where exposure to digital stimuli, accelerated lifestyles, and the effects of cultural globalization facilitate the transition from service-centered tourism to experiential and authenticity-oriented tourism. The 25–44 age group (54%) dominates active tourism and demonstrates the highest receptiveness to visual content and social media communication, in line with the literature on younger social media users and the role of visual platforms in destination choice. Respondents over the age of 45 tend to favor cultural and relaxation tourism, indicating a motivational gradient associated with age and leisure-time capital, consistent with international tourism research trends. Gender dynamics reveal a slight predominance of women (57%), who exhibit a stronger interest in experiential aesthetics and comfort, aligning with studies on experiential marketing and the role of emotional–aesthetic components in consumption decisions.

Levels of cultural and financial capital significantly influence tourism preferences. Over 60% of respondents hold university or postgraduate degrees, and 65% report monthly incomes exceeding 5,000 RON, outlining a sophisticated segment willing to invest in authenticity, local gastronomy, and perceived service quality. This profile aligns with findings in the literature indicating that tourists with multiple motivations and a strong orientation toward culture and nature exhibit higher levels of satisfaction and loyalty (Carvache-Franco et al., 2022), while also fitting competitiveness models in which experiential quality and perceived value represent central sources of sustainable competitive advantage (Zhang et al., 2019).

Correlation analyses reveal significant relationships between declared motivations and overall satisfaction. Experience authenticity is positively correlated with satisfaction ($r = 0.61$, $p < 0.01$) and recommendation likelihood ($r = 0.57$, $p < 0.05$), supporting the hypothesis that authenticity functions as a primary determinant of tourist loyalty, simultaneously influencing brand perception and experienced value (Paulauskaite et al., 2017). Aesthetic orientation—reflected in the appreciation of "Instagrammable" potential—correlates with increased travel frequency ($\rho = 0.43$, $p < 0.05$) but shorter stays ($\rho = -0.48$, $p < 0.05$), suggesting a fragmented temporal pattern characteristic of micro-tourism among active generations, strongly shaped by social media dynamics. In this context, travel decisions are increasingly mediated by algorithms, visual content, and social validation within the digital ecosystem.

Exploratory factor analysis identified three main motivational dimensions, explaining 68.4% of the total variance. The "experiential" factor encompasses variables related to authenticity, local gastronomy, and community interaction, reflecting motivation for authentic and memorable experiences (Paulauskaite et al., 2017). The "aesthetic–digital" factor aggregates items associated with visual attractiveness and social media influence, expressing the need for self-representation and accumulation of visual symbolic capital, consistent with studies emphasizing the role of social media and influencers in shaping destination image (Eleni et al., 2023; Maria-Irina & Istudor, 2019). The "pragmatic" factor integrates dimensions related to cost, safety, and comfort, mirroring motivational structures identified in international segmentation studies (Luo et al., 2021). Cluster analysis led to the identification of three distinct tourist segments: "Authentic Explorers" (34%), "Image Seekers" (43%), and "Comfort-Oriented Pragmatists" (23%), a typology consistent with profiles of multi-motivated tourists oriented either toward experience and novelty or toward efficiency and essential services (Poruțiu et al., 2021).

Social media plays a decisive role in tourism behavior: for 38% of respondents it represents the primary source of inspiration, while 54% report that online reviews consistently influence their final travel decision. This dynamic highlights the role of social media not only as an information channel but also as a mechanism for shaping tourism intentions, including impulsive ones. Within this framework, a form of "parallel life" emerges, in which direct experience is doubled by digitally mediated experience, and tourist motivations are calibrated according to social visibility and online sharing potential (Ramdan et al., 2025; Iglesias-Sánchez et al., 2020). Consequently, destinations are selected not only for their intrinsic attractiveness but also for their capacity to amplify tourists' image capital, generating what may be conceptualized as "performative authenticity"—deliberate, mediated, and negotiated experiences whose meaning is constructed through social media display and associated social validation.

Although overall satisfaction ($M = 6.8/8$) and declared loyalty ($M = 7.1/8$) remain high, the analysis of open-ended responses reveals tensions between the desire for authentic experiences and perceptions of excessive commercialization. Respondents call for more genuinely local activities, less commercialized experiences, and a clearer alignment between price and perceived value, reinforcing the literature that emphasizes the importance of authenticity, storytelling, and contextual embeddedness in tourism experience construction (Álvarez et al., 2022; Álvarez et al., 2025).

In the long term, the success of tourism operators depends on their ability to maintain a balance between authenticity, perceived quality, and aesthetic experience, while integrating social media as credible communication tools rather than mere spaces of simulation. The detailed analysis of tourist behavior and motivations reveals both opportunities and challenges for Romanian hospitality operators, particularly those specializing in active, cultural, and gastronomic tourism. Traditional product strategies must therefore be complemented by integrated approaches centered on user experience and the strategic valorization of image and visual capital, ensuring that digital communication aligns with actual tourist expectations and behaviors while reinforcing perceived authenticity and experiential relevance.

The segmentation of tourists into three motivational groups—Authentic Explorers, Image Seekers, and Comfort-Oriented Pragmatists—provides a robust framework for tourism product customization, consistent with the literature emphasizing the relevance of motivation-based and socio-demographic segmentation.

Authentic Explorers, typically highly educated and with moderate-to-high budgets, seek genuine cultural and gastronomic experiences. For this segment, packages incorporating traditional elements, community interaction, and hands-on activities (craft workshops, tastings, immersive tours) maximize memorability and loyalty, confirming the role of experiential engagement and personalization in generating perceived authenticity.

Image Seekers are predominantly young, digitally active, and strongly oriented toward visual and "Instagrammable" experiences. For this segment, integrating photogenic locations, short and dynamic routes, viewpoints, and themed photo areas into tourism products—alongside facilitating social media sharing—is essential. This group can function as a vector of organic marketing, generating virality and social validation through user-generated content.

Comfort-Oriented Pragmatists prioritize safety, comfort, and value-for-money. Packages targeting this group should include comfortable accommodation, easy transport access, clearly structured itineraries, and relaxing activities, catering to tourists oriented toward efficiency and essential services. Although less receptive to innovation, this segment contributes to financial stability and long-term loyalty (Alén et al., 2014; Kim et al., 2022).

The implementation of differentiated offers tailored to tourists' motivational profiles enhances satisfaction and loyalty, reduces tensions arising from heterogeneous expectations, and maximizes resource efficiency. This approach strengthens marketing effectiveness and product personalization, transforming online visibility pressure into a sustainable competitive advantage rooted in authenticity and cultural relevance (Kim & Thapa, 2018).

In this context, the concept of visual symbolic capital gains particular relevance: tourism experiences acquire value not only through direct consumption but also through their potential for online dissemination and social validation, leveraging landscapes and self-representation on visual platforms such as Instagram and TikTok. Studies on user-generated content demonstrate that shared images and videos function as symbols of quality and status, influencing motivations, visitation intentions, and electronic word-of-mouth behaviors.

The preference of the majority of respondents (75%) for short stays of 1–4 nights indicates a clear orientation toward micro-tourism, characteristic of active generations and associated with frequent, proximity-based escapes focused on creativity and intense experiences within limited timeframes. Adapting the tourism offer therefore requires:

– Designing flexible weekend and short-break packages that maximize experiential intensity;

– Integrating outdoor, cultural, and gastronomic activities to generate coherent and memorable experiences, aligned with the experience economy and the roles of aesthetics, escapism, and entertainment in quality evaluation;

– Optimizing logistics and transportation to reduce downtime and enhance comfort, particularly for the pragmatic segment sensitive to efficiency and safety.

Socio-economic factors such as income and education significantly shape experience preferences. Tourists with above-average incomes (≥5,000 RON) and higher education display a strong preference for cultural, gastronomic, and wellness experiences, similar to quality-oriented segments identified in the literature. Consequently, operators should adjust pricing and service levels to:

– Offer premium experiences with high symbolic and aesthetic value, including gastronomic and lifestyle components;

– Ensure competitive value-for-money for more economically sensitive segments, including family-friendly packages;

– Educate and inform tourists through clear communication regarding authenticity, sustainability, and experiential benefits, thereby enhancing perceived value and satisfaction.

For operators, these findings translate into concrete operational recommendations:

– Developing modular itineraries combining cultural, outdoor, and gastronomic tourism, aligned with motivational segments and trends in micro-adventures and creative tourism;

– Creating digital loyalty programs based on reviews, photographs, and online recommendations, leveraging content-sharing motivations and the role of eWOM;

– Investing in visual and aesthetic infrastructure (“photo spots”), transforming landscapes and gastronomy into visual storytelling resources without compromising authenticity;

– Optimizing digital booking channels and social media presence for younger segments through engaging imagery, emotional framing, and constant interaction;

– Implementing differentiated premium and family-friendly packages based on income levels and family composition, with tailored pricing and communication strategies.

Through these strategic directions, tourism operators can respond more effectively to the behavioral and motivational diversity of tourists, strengthen their competitiveness in the domestic market, and secure long-term positioning, in line with the principles of the experience economy, digital marketing, and sustainable tourism focused on micro-tourism and symbolically charged experiences.

CONCLUSIONS

The present research confirms that Romanian tourism is undergoing a phase of profound structural transformation, driven by the interaction between the experience economy, the accelerated digitalization of consumer behavior, and the conversion of cultural capital into visual symbolic capital. The analysis of tourist motivations reveals not only a significant diversification of preferences and consumption typologies but also a subtle tension between the authenticity of tourism experiences and the performative imperative imposed by the contemporary digital environment.

Empirical findings indicate that declared motivations—often oriented toward authenticity, tradition, and local experiences—do not always align with the actual factors that determine satisfaction and behavioral loyalty. In many cases, consumption decisions are more strongly influenced by online visibility, experiential aesthetics, and social validation, generating an emergent form of “performative authenticity,” whereby tourism experiences are evaluated and consumed through their capacity to be symbolically represented and valorized within the digital space.

The segmentation of tourists into categories such as Authentic Explorers, Image Seekers, and Comfort-Oriented Pragmatists represents a key contribution, both theoretically and, more importantly, from an applied perspective. It highlights the ways in which tourism motivations manifest in complex and interdependent configurations, shaped not only by cultural capital, income levels, age, and digital exposure, but also by the subtle interactions among these dimensions, which often produce unpredictable preferences and behaviors. In this context, segmentation analysis exposes the limitations of uniform tourism development approaches and underscores the need for differentiated offerings carefully calibrated to the characteristics and expectations of each segment, ensuring both experiential relevance and strategic efficiency.

The research also highlights the strategic potential of agritourism and rural tourism, where authenticity constitutes a living resource deeply embedded in local communities. At the same time, it reveals the risk of excessive aestheticization and the “festivalization” of rural spaces, which may lead to the simplification and standardization of traditions, ultimately undermining authentic cultural capital and long-term differentiation capacity.

Consequently, the sustainable competitiveness of Romanian tourism cannot be supported solely through digital marketing logics; it must instead be grounded in a strategic balance between lived experience and digitally mediated experience. Social media should be conceived as instruments for amplifying authentic value—capable of conveying meaning, narrative, and cultural depth—rather than merely producing images.

The proposed development directions advocate a transition from consumption-based tourism to participation-based tourism, through the active involvement of tourists in the visual and demonstrative stages of traditional activities, undertaken jointly with hosts. Participation is intentionally limited and carefully calibrated, allowing tourists to engage with cultural and gastronomic processes in a participatory manner while preserving the integrity and final outcomes of the activities. The products to be consumed are sourced from prior production cycles, thereby ensuring experiential authenticity, visitor satisfaction, and operational efficiency simultaneously.

In parallel, the professionalization of the aesthetics of authenticity is recommended through conscious experiential design, integrating minimally invasive infrastructure and coherent visual storytelling without distorting the lived experience. Tourist education becomes essential for fostering an appreciation of the distinction between authenticity and simulacrum, transforming rural tourism into a space of reflection, reconnection, and critical appreciation of local cultural heritage.

Finally, the role of small and medium-sized operators embedded within local communities proves crucial in mediating between cultural heritage and the demands of the contemporary market. These actors possess the capacity to innovate authentically without compromising local identity. Romanian tourism thus stands at the intersection of the paradigm of rapid visibility and symbolic consumption and that of deep value, constructed through authentic experiences and genuine relationships. Its long-term success will depend on the ability to intelligently integrate these dimensions.

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TURISM SUSTENABIL PRIN EXPERIENȚE LOCALE INTEGRATE

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Abstract

This study explores strategies to enhance tourism sustainability by leveraging local experiences. It examines how the combination of active tourism, culinary tourism based on products from local markets with short supply chains and accommodation facilities applying sustainable practices generates notable economic, social and cultural benefits for mountain communities, while maintaining a stable ecological footprint per unit of value. The analysis relies on data from two Sustainability Innovation Projects (SIPs) developed within the ETSM 2030 framework, which enabled the design of digitized, integrated, and sustainability-focused tourism packages, placing local communities at the heart of the visitor experience. Member companies of these SIPs centralized and monitored data on tourists, local producers, accommodations, and client feedback, optimizing interactions among stakeholders and enhancing economic and environmental efficiency. Findings indicate that promoting authentic experiences, supported by digital tools and continuous evaluation of visitor satisfaction, increases community income, strengthens social cohesion, and protects cultural heritage, while effectively utilizing natural resources and local traditions. This approach provides a replicable model of sustainable tourism capable of balancing economic development, environmental conservation, and community identity, offering an innovative framework for optimizing integrated and digitized tourism offerings.

Key words: sustainability, tourism, innovation, digitalization, mountain tourism

Sustainable tourism based on integrated local experiences is increasingly emerging as a central paradigm for the sustainable development of mountain and rural communities, in the context of growing pressures from globalization, standardization, and intensifying tourist flows (Álvarez et al., 2025). This approach goes beyond the traditional logic of exploiting tourism resources, proposing a development model that integrates natural and cultural heritage with economic and social benefits equitably distributed at the local level, while simultaneously contributing to the preservation of territorial identity and the enhancement of host community resilience (Alén et al., 2014).

Within this framework, active tourism, culinary experiences rooted in local products and short supply chains, as well as accommodation facilities adopting sustainable practices, are not merely operational components but structural elements of a tourism system oriented towards long-term value. Maintaining a controlled ecological footprint thus becomes inseparable from the quality of the tourist experience, and authenticity is no longer defined exclusively by the traditional character of practices, but by the coherence between local resources, production processes, and the ways in which these are mediated to visitors (Álvarez et al., 2025).

The integration of digital technologies and advanced information systems plays a crucial role in this reconfiguration, enabling the development of personalized and flexible tourism packages capable of responding to the motivational diversity of contemporary tourists. Digitalization functions not only as a promotional tool but also as a vector for organizing the experience, placing the local community at the center of value creation and supporting the adoption of sustainable practices through transparency, traceability, and direct communication between hosts and tourists.

The specialized literature increasingly emphasizes the importance of local community involvement, regional collaboration, and innovation in the design of tourism experiences as key factors for achieving a functional balance between economic development, environmental conservation, and the protection of cultural identity (Alén et al., 2014). Nevertheless, the ways in which these dimensions can be coherently integrated into an operational framework that simultaneously manages tourist expectations, local community constraints, and pressures generated by the contemporary digital environment remain insufficiently explored.

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In this context, the present study aims to contribute to a deeper understanding of sustainable tourism through integrated local experiences by analyzing the interaction between tourist motivations, experiential design, and digital mediation mechanisms (Álvarez et al., 2025). Through an approach that combines theoretical perspectives with applied analysis, the study seeks to provide conceptual benchmarks and practical tools relevant for the development of tourism models capable of generating economic, cultural, and social value without compromising authenticity and long-term sustainability (Alén et al., 2014).

MATERIAL AND METHOD

The research adopts a qualitative, exploratory design to evaluate the outcomes and perceived impact of actions implemented within Project Information Systems (PIS) developed under the ETSM 2030 project, in the context of limited access to primary quantitative data (Mason et al., 2010; Ponelis, 2015). This approach allows for capturing complex social processes, decision-making dynamics, and experiential knowledge that are difficult to quantify, particularly in pilot-level interventions (Ponelis, 2015). The study aims to achieve an in-depth understanding of how PIS-supported initiatives are interpreted and integrated into organizational practices by the directly involved actors, without pursuing statistical generalization (Mason et al., 2010).

The unit of analysis comprises two PIS developed by small and medium-sized enterprises (SMEs) in the tourism sector, organized in transnational tandems. These systems were created within cooperation projects, promoting co-creation and co-implementation across organizational and territorial boundaries. The cases reflect the practical application of knowledge acquired through coaching and training activities, under the supervision of sustainability experts. The PIS were designed for the systematic collection and utilization of customer data, with the aim of profiling clients and developing tourism packages aligned with demand, while integrating social, cultural, economic, and environmental sustainability considerations (Marulanda et al., 2022).

Data were collected through focus groups and semi-structured interviews with representatives of organizations involved in the design, implementation, and use of the PIS. These methods enabled the acquisition of in-depth insights into the relevance, effectiveness, and impact of the interventions, as well as the processes of implementation and organizational learning. Discussion guides focused on perceived outcomes, the extent to which objectives were achieved, facilitating and inhibiting factors, and the contribution of the PIS to the strategic goals of the participating organizations (von Thiele Schwarz et al., 2020).

Analysis followed a thematic framework: open coding, aggregation of codes into higher-order themes, and interpretation in relation to the study objectives. Data triangulation, through comparison of actor perspectives and correlation with secondary sources (project reports and syntheses), enhanced the credibility of the findings. This approach is appropriate in complex contexts with limited data, offering insights into internal processes and mechanisms that go beyond strictly measurable outcomes.

Methodological limitations include the qualitative and exploratory nature, which constrains generalizability; reliance on the perceptions of directly involved actors, mitigated through triangulation; the limited number of cases, which restricts systemic extrapolation but allows for detailed analysis of co-creation dynamics; and the recent implementation of the PIS, which precludes assessment of long-term impact, a limitation that can be addressed in future research employing longitudinal designs and quantitative indicators (Budhathoki, 2023; Kamariotou & Kitsios, 2020; Ghanem et al., 2020).

Building on this methodological framework, the following section presents the empirical findings, organized thematically, highlighting how customer profiling, sustainability considerations, and organizational learning processes intersect in practice, revealing both facilitating mechanisms and constraints that influence innovation and competitiveness in tourism SMEs.

RESULTS AND DISCUSSIONS

The research findings highlight that integrating active tourism, culinary tourism, and sustainable accommodation within a coherent offering generates significant economic, social, and cultural benefits for local communities. However, participant perceptions indicate that these benefits do not arise automatically from the mere coexistence of diverse resources, but from how they are correlated, coordinated, and adapted to demand. The synergy between components emerges from a deliberate co-creation process, supported by collaboration, learning, and continuous adjustment—a dimension often underexplored in the literature.

These findings align with studies emphasizing the potential of integrated approaches to amplify tourism's positive impact on local development, while adding insight into the concrete mechanisms through which such synergies are constructed. Within the PIS analyzed, the integration of active and culinary tourism resulted not from a pre-defined formal strategy but from an iterative process of testing offers, collecting feedback, and adapting products continuously. This reflects a pragmatic entrepreneurial logic where sustainability serves as an operational decision criterion rather than an abstract goal.

Culinary tourism emerged as a central element of the tourist experience, differentiating offerings and strengthening connections between tourists and local communities. Farm-to-table practices were perceived as both product innovations and mechanisms reconnecting tourism with the local economy. Consistent with literature on culinary tourism's role in promoting authenticity and satisfaction, results indicate that such practices foster trust, transparency, and responsibility within the tourist experience.

Beyond this symbolic and experiential function, culinary tourism also served as a tool for collecting and using data on customer behavior and preferences. Direct interactions between tourists and producers facilitated information gathering, subsequently integrated into the adaptation of tourism packages. This ability to convert culinary experiences into actionable knowledge represents a novel contribution, illustrating how culinary tourism can support entrepreneurial decisions that are simultaneously sustainable and economically efficient.

Active tourism, through physical and recreational rural activities, strengthened the socio-cultural dimension of sustainability. Participants emphasized its role in transmitting local values and fostering community involvement. Consistent with literature on active tourism preserving cultural identity and stimulating participation, the analysis shows that impact depends on the degree of functional integration within the offering.

Within the PIS, active tourism acted as a catalyst for local cooperation, enabling co-creation between operators, guides, and community members, and transforming recreational activities into structured tourism products with economic and cultural value. Thus, active tourism transcends its complementary status, becoming a strategic component capable of generating long-term benefits and supporting replicable models in other rural destinations.

Digital technologies played a key role in developing and promoting integrated tourism packages. Participants emphasized their importance for coordinating stakeholders and managing customer relationships. The analysis shows that technology went beyond promotion, contributing to internal learning, planning, and strategic adaptation. Within the PIS, digitalization integrated data from tourist interactions and supported continuous product adjustments according to market demand, reflecting a pragmatic approach aimed at optimizing resources and minimizing environmental impact.

Regional and transnational collaboration was essential for supporting sustainable development. PIS created a framework for knowledge exchange and innovation, with participants viewing transnational cooperation as a learning opportunity enhancing SMEs' capacity to respond to market challenges. Unlike predominantly strategic approaches in the literature, the analyzed PIS embedded regional collaboration directly into co-creation and implementation processes, allowing testing and adjustment of sustainability practices across contexts and increasing relevance and transferability.

Regarding community-based tourism, active local involvement in co-creation and implementation reduced economic leakage and enhanced destination competitiveness. The study highlights how participation can be structured and supported through mechanisms integrated into PIS, promoting equitable benefit distribution and greater social acceptance.

Overall, the results demonstrate that PIS provide a coherent and practical framework for integrating active tourism, culinary tourism, digitalization, and regional collaboration within a functional sustainable tourism development strategy. The study contributes by highlighting PIS as operational mechanisms translating theoretical knowledge into concrete entrepreneurial practices capable of generating economic, social, and cultural value sustainably. Insights from directly involved actors complement existing literature and offer relevant guidance for both research and practice.

CONCLUSIONS

The research validates the hypothesis that sustainable tourism based on integrated local experiences can constitute a viable and replicable model for the development of rural and mountain communities when grounded in clear operational principles and the active involvement of local actors. The value of tourism extends beyond the mere increase in visitor flows, deriving instead from the balanced generation of economic, social, and cultural benefits tailored to the local context.

The integration of active tourism, culinary tourism, and digital solutions proved essential for creating authentic, relevant experiences that meet tourist expectations, thereby enhancing the competitiveness of destinations. Community involvement in co-creation strengthens social acceptance, reinforces cultural identity, and ensures equitable benefit distribution.

Digital technologies facilitated the coordination of stakeholders, the collection of tourist data, and the continuous adaptation of offerings, functioning as a catalyst for operational sustainability. Concurrently, regional and transnational collaboration supported the exchange of good practices, mutual learning, and the adaptation of solutions to diverse contexts, thereby enhancing the resilience of local actors.

From a theoretical perspective, the study highlights PIS as practical mechanisms for translating knowledge into concrete practices, moving beyond purely normative approaches. From a practical standpoint, it provides guidance for entrepreneurs and policymakers regarding the conditions necessary to develop sustainable and competitive tourism products.

The main limitations relate to the qualitative nature of the study and the limited number of PIS analyzed, which may constrain generalizability. Nevertheless, the depth of the analysis provides a solid foundation for future research, which could incorporate quantitative, mixed-method, or cross-destination comparative approaches.

In conclusion, integrated local tourism, built on co-creation, collaboration, and the responsible use of resources, represents a strategic instrument for sustainable development, generating authentic, valuable experiences that are responsive to the contemporary challenges of the tourism industry.

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MODELS FOR ORGANIZING ORGANIC FARMS IN SUSTAINABLE AGRICULTURAL DEVELOPMENT

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Abstract

The organizational models of organic farms play a crucial role in the transition towards sustainable agriculture, offering solutions adapted to current needs regarding environmental protection, food safety, and the economic viability of farmers. In the context of climate change, the degradation of natural resources, and the growing demand for healthy products, the study of functional models for organic farms has gained strategic importance. This paper analyzes various organizational forms — individual, associative, and cooperative — in correlation with farm size, type of production (crop and/or livestock), market access, and integration into sustainable value chains. Furthermore, the advantages of applying these models are assessed within the framework of the Common Agricultural Policy (CAP), which supports farmers through subsidies, agri-environmental measures, and incentives for regenerative practices. The results highlight that well-structured organizational models can enhance economic profitability, strengthens resilience to climate-related risks, and fosters technological innovation in agriculture. The study underscores the importance of adapting these models to the specific socio-economic and agro ecological conditions at the local level in order to effectively support the sustainable development of organic farming.

Key words: organic farms; sustainable; agriculture; organizational models; climate resilience

The evolution of modern society has triggered significant transformations in agriculture, driven by growing consumer demands for food security, environmental protection, and economic efficiency (Pretty, 2008; Gliessman, 2015; Niggli et al., 2009). In its pursuit of higher productivity and profit margins, conventional agriculture has increasingly distanced itself from natural systems, relying heavily on mechanization, synthetic inputs, irrigation, and genetic engineering (Altieri, 1995; Tilman et al., 2002). While these advancements have led to increased yields, they have also contributed to serious environmental degradation — including soil erosion, reduced biodiversity, water and air pollution, and climate-induced risks such as floods, droughts, and desertification (FAO, 2018; IPBES, 2019; Reganold & Wachter, 2016). These challenges are further compounded by the rise of health disorders in humans, animals, and plants, often linked to intensive farming practices and the excessive use of agrochemicals (Lampkin, 2002; Toncea, 1997).

Despite reducing labor requirements in agriculture, the shift toward industrialized farming has significantly increased dependence on external energy inputs — including fossil fuels, electricity, synthetic fertilizers, pesticides, and livestock feed additives (Pimentel et al., 2005). One of the most harmful consequences remains the widespread application of chemical treatments, which has raised growing concerns about food quality, human health, and long-term sustainability (IFOAM, 2005; Willer & Lernoud, 2019).

In contrast, the organic farming system offers an ecologically balanced alternative that aligns with the principles of environmental stewardship, food integrity, and sustainable rural development (Gomiero et al., 2011; Niggli et al., 2009). Organic farming seeks to produce food that is not only safe and nutritious but also flavorful and authentic, while maintaining harmony with natural ecosystems. This is achieved through the exclusion of genetically modified organisms (GMOs), and by severely limiting or eliminating the use of synthetic fertilizers, pesticides, hormones, antibiotics, and intensive animal husbandry methods (Gliessman, 2015; Altieri et al., 2015).

The interdependence between agriculture, human health, and environmental sustainability is now more evident than ever. A growing body of research and consumer awareness links modern diseases to improper nutrition stemming from intensive farming practices (FAO, 2018; IPES-

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Food, 2016). As a result, there is a rising demand for organic products and a renewed focus on rethinking farm structures and organizational models that support sustainable food systems (Willer & Trávníček, 2023; Moraru et al., 2022).

This paper explores functional models for organizing organic farms — including individual, associative, and cooperative forms — with an emphasis on production type, market integration, and adaptation to local socio-economic and agro ecological conditions. By evaluating the impact of these models within the framework of the Common Agricultural Policy (CAP), the study highlights their potential to improve farm viability, increase resilience to climate risks, and foster innovation in organic agricultural development (European Commission, 2021; Moraru & Simion, 2023).

MATERIAL AND METHOD

The main bibliographic references include specialized books authored by nationally and internationally recognized experts, scientific articles indexed in national and international databases, as well as official publications issued by institutions such as the Monitorul Oficial or the Ministry of Agriculture and Rural Development.The collected information was systematically analyzed to trace the evolution of organizational models in organic farming and to identify key patterns, trends, and implications. Both qualitative and quantitative methods were used to assess the functionality and sustainability of various organizational forms (individual, associative, cooperative) in relation to production structure, market access, and policy support.

For the processing and visualization of data, Microsoft Excel was employed to generate tables and graphical representations that support the interpretation of results and the formulation of evidence-based conclusions.

To investigate perceptions and identify key barriers associated with organic food consumption and farm organization, the study employed a mixed-methods approach, including the use of a structured questionnaire. The survey was conducted in North-East Romania — the country's second most economically significant development region. In 2024, a total of 367 questionnaires were distributed to a diverse sample of respondents. The collected data were subsequently analyzed using descriptive statistics and principal component analysis (PCA) to extract the main dimensions influencing consumer attitudes and farm-level decision-making.

RESULTS AND DISCUSSIONS

Organic agriculture has emerged as a viable and essential alternative to conventional farming methods, especially in response to growing concerns about environmental sustainability. This approach offers long-term benefits such as environmental protection, climate change mitigation, healthier lifestyles, and biodiversity conservation, while strictly avoiding genetically modified organisms and promoting eco-friendly practices.

This paper illustrates the objective function of agro-ecological systems, emphasizing the trade-off between input intensity and two core goals: maximizing agricultural production (Q) and minimizing negative side effects (SE). As inputs increase, agricultural output follows a concave curve, reflecting diminishing marginal returns (Altieri, 1995; Gliessman, 2015). In contrast, environmental side effects—such as soil degradation, water pollution, and biodiversity loss—follow a convex path, intensifying disproportionately with increased input use (Tilman et al., 2002; IPBES, 2019). Consequently, agro-ecological systems, constrained by ecological principles, operate below the yield potential of conventional high-input agriculture (Ponisio et al., 2015; Reganold & Wachter, 2016). Nevertheless, they offer enhanced resilience and reduced externalities, aligning with long-term sustainability and food system stability (Wezel et al., 2009).

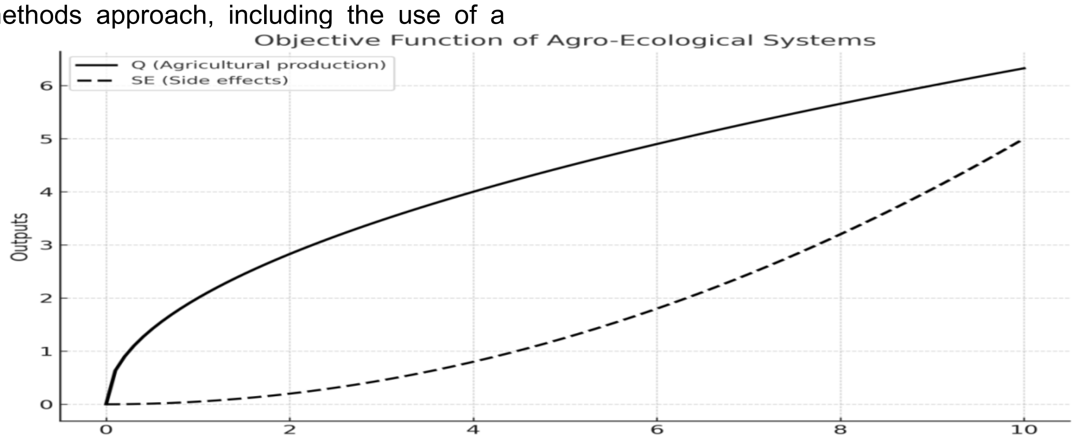

Figure 1 **The objective function graph of agro-ecological systems. Source: Own interpretation**

This case study draws on data collected through a survey conducted in North-East of Romania in 2024, aiming to explore key perceptions and barriers related to organic food consumption and farm organization. Insights were obtained from 367 respondents and analyzed using descriptive and multivariate statistical methods. The findings reveal that the main barriers to organic food consumption are: High prices, perishability, and limited availability. Additionally, lack of consumer trust and insufficient promotion were also identified as significant deterrents.

The survey also highlighted the strengths of the associative model adopted by organic farms in the region.

Table 1

Results obtained from the application of the questionnaire

Strengths	Yes/No	Remarks
Per-hectare productivity is close to that of conventional farming due to the use of organic fertilizers, natural inputs, and irrigation	Yes	Significant benefit compared to conventional methods due to reliance on natural inputs
The farm has the necessary machinery to ensure proper implementation of organic production technologies	Yes	Adequate mechanization for organic agricultural processes
The farm has an irrigation system	No	The absence of irrigation may negatively affect yields during drought conditions
The creation of seed production plots within the farm would reduce dependence on suppliers and halve seed costs	No	Currently dependent on external suppliers for seed material
Input procurement at the association level enables price negotiation and lower costs; inputs are sourced collectively from internal and external suppliers	Yes	Economic advantage through cost reduction from collective purchasing
The region has a livestock complex, which serves as the main source of organic fertilizer	Yes	Easy access to organic fertilizers from own sources
Storage spaces are provided by the association, each member having separate storage cells to prevent cross-contamination	Yes	Minimizes contamination risks and maintains product quality
Samples for laboratory testing are taken from each cell; acceptance of production for sale is not dependent on other members	Yes	Strict quality control for each individual producer
Collective selling through the association enables price negotiation and higher selling prices	Yes	Enhances market competitiveness through coordinated sales
The association secures the market, finds clients, organizes farm visits, and facilitates sales	Yes	Increases product visibility and market access
The entire production is exported	Yes	Access to international markets, but exposure to price and demand volatility
Production from all members is delivered in bulk shipments via sea freight, the most cost-effective transportation method	Yes	Optimized logistics and reduced transportation costs

Source: Questionnaire

This model brings notable economic and organizational advantages, particularly through joint input procurement, centralized storage, and collective sales, leading to economies of scale, better market access, and stronger negotiating power. However, to fully capitalize on these benefits, the system requires further investment in infrastructure, local market development, and coherent public policies supporting organic farmers. Organic agriculture in in North-East of Romania holds significant potential for development due to its fertile soils and long-standing agricultural tradition. Local farmers have begun adopting organic practices, and the area cultivated under organic management has increased considerably in recent years. Favorable factors include support from European funding and APIA subsidies, growing national and international demand for organic products, and cooperation between local farmers and organic distribution networks. However, several challenges remain, such as limited access to external markets due to strict certification requirements, high certification costs, the absence of local organic processing facilities, and a low level of education and awareness regarding the benefits of organic farming. In the context of sustainable agricultural development, the organizational models of organic farms must be evaluated not only from a structural perspective but also in terms of the balance between benefits and costs. The table below provides a synthesis of the main economic, social, and environmental advantages associated with organic farming, along with the implicit costs of transitioning to and maintaining an organic production system.

Table 2

Cost-benefit analysis of organic farming

Benefits (B)	Costs (C)
B1. Increased farm income due to the higher market price of organic products.	C1. High initial costs for land conversion and organic certification.
B2. Reduced environmental impact through lower soil and water pollution.	C2. Higher costs for organic fertilizers and eco-friendly crop protection methods.
B3. Higher employment in rural areas due to more labor-intensive manual practices.	C3. Need for a stable market and consumer education about the benefits of organic products.
B4. Rural development through diversification of economic activities.	C4. Increased administrative costs related to certification and regular inspections.
B5. Access to subsidies and EU funding specifically allocated for organic agriculture.	C5. Potential yield losses due to the absence of effective chemical pesticides.
B6. Improved employment, sustainable production, and farmer income due to the expansion of organic agriculture activities.	C6. Short-term losses in production and income during the transition from conventional to organic farming.
B7. Reduced rural migration as organic agriculture creates new local economic opportunities, revitalizing rural communities.	C7. Additional infrastructure costs required for the conversion to organic systems (e.g., processing units, certification bodies, distribution centers).
B8. Lower public and private expenditures for addressing environmental and health problems caused by intensive chemical use.	C8. Costs related to changing production methods and relocating conventional farms unable to adopt organic practices.
B9. Environmental protection through reduced air, water, and soil pollution and the preservation of biodiversity.	C9. Increased costs for implementing and complying with strict environmental regulations.
B10. Enhanced economic equity by supporting small and medium-sized farms, providing them with market access and transition support.	C10. Administrative costs related to certification, monitoring, and compliance with organic standards.
B11. Political benefits by strengthening the appeal of sustainable policies that support rural development and reduce dependence on intensive agriculture.	C11. Political costs arising from changes in agricultural policy, including resistance from large-scale conventional producers and other industry stakeholders.

Source: Viorel Morarescu (2023) – Report: "Organic Agriculture – Sustainability, Innovation, and Environmental Protection"RRN-PAC Publication (PDF)

Table 2 provides a comprehensive overview of the main benefits and costs associated with organic farming, highlighting the economic, environmental, and social trade-offs involved in transitioning to and maintaining organic production systems.

Table 3 presents the numerical evolution of certified organic operators in Romania between 2017 and 2021, alongside the total area cultivated organically and its share in the national agricultural surface. The data illustrate a steady increase in both the number of operators and the organic farming area, suggesting a positive dynamic in response to market demand, European policy incentives, and awareness of agro ecological principles.

Although the total agricultural area remained relatively stable, the percentage of land under organic farming rose from 3.1% in 2017 to 6.3% in 2021, almost doubling in five years. This evolution signals not only an expansion of the sector but also greater institutional engagement in facilitating organic certification and supporting sustainable practices among Romanian farmers. The data presented in the table highlight a steady and significant growth in both the number of certified organic operators and the total area under organic farming in Romania between 2017 and 2023. This trend aligns with broader European Union objectives regarding the transition to sustainable agricultural systems, as outlined in the European Green Deal and the Farm to Fork Strategy (European Commission, 2020).

Table 3

Numerical Distribution of Romanian Organic Certified Operators (2010–2023)

Year	Number of Organic Certified Operators	Total Organic Farming Area (ha)	Total Agricultural Area (ha)	Percentage of Organic Area
2017	8434	258471	8307344	3.1%
2018	9008	32626	8300000	3.9%
2019	9821	395228	8300000	4.8%
2020	11021	468887	8300000	5.6%
2021	11029	520	8300000	6.3%
2022	1326	64452	8300000	7.8%
2023	13260	693	8,300,000	8.3%

Sources: Ministry of Agriculture and Rural Development (MADR):Dynamics of organic operators and surfaces in Romania, 2010–2023. Viorel Morarescu (2023) – Report:"Organic Agriculture – Sustainability, Innovation, and Environmental Protection"RRN-PAC Publication (PDF)

Between 2017 and 2023, the number of certified organic operators increased by over 57%, from 8,434 to 13,260. Simultaneously, the organic farming area nearly tripled, from 258,471 ha to

693,000 ha. This suggests not only the expansion of existing organic farms but also a growing interest and participation of new operators in ecological agriculture.

The percentage of organic farmland relative to total agricultural area rose from 3.1% in 2017 to 8.3% in 2023, indicating a systemic shift toward sustainable land use. While still below the EU average (estimated at ~10.5% in 2022), the Romanian trajectory is encouraging and demonstrates alignment with EU strategic targets (Eurostat, 2023).

Structural Drivers and Policy Influence

Several factors explain this positive dynamic:

- National and European subsidies under the Common Agricultural Policy (CAP), including agri-environmental and climate measures, have incentivized conversion to organic farming (Morarescu, 2023; MADR, 2023).

- Consumer demand for healthier, chemical-free products continues to rise, both domestically and across EU markets (Willer & Lernoud, 2021).

- Policy alignment through Romania's National Strategic Plan 2023–2027, which emphasizes organic farming as a pillar of sustainable development (MADR, 2023).

According to Altieri (1995) and Gliessman (2015), organic agriculture not only contributes to food security but also plays a crucial role in preserving agroecosystem health, biodiversity, and soil fertility.

Despite this progress, challenges remain:

- The absolute surface share (8.3%) is still below EU targets, which aim for 25% organic farming by 2030.

- The growth is not yet matched by a proportional increase in organic processing capacity and market organization, which can limit the economic benefits for farmers (IFOAM EU, 2021).

- The educational and advisory infrastructure for organic farming remains underdeveloped in several regions (Dobay, 2020).

Literature highlights three main drivers of organic farming expansion: CAP and national subsidies (MADR, 2021), changing consumer behavior favoring health and sustainability (Willer & Lernoud, 2020), and stronger farmer involvement in associations to reduce costs and improve market access. In North-East Romania, the sector shows positive growth, supported by stable funding, crop diversification, and better sales channels. Strengthening producer groups and short supply chains remains essential for resilience and sustainability.

Table 4

Predominant types of organic crops

Crop Type	North-East Region (%)	Romania (%)
Cereals (wheat, maize)	40%	50%
Vegetables (potatoes, carrots, onions)	15%	12%
Fruits (apple, pear, plum orchards)	20%	15%
Vineyards	5%	10%
Fodder and oilseed crops	20%	13%

Source: Ministry of Agriculture, APIA, RRN-PAC, North-East Regional Development Agency (ADR Nord-Est)

The distribution of organic crops in the North-East Region of Romania reflects both an adaptation to local agro-climatic conditions and a tendency among farmers to focus on crops that are in demand on domestic and international markets. According to Toncea (1997) and Bîlteanu (2011), cereals such as wheat and maize remain the foundation of organic agriculture in areas with large fields and appropriate mechanization. The 40% share in the North-East Region is slightly below the national average, suggesting a more balanced crop diversification in this area, which is beneficial for biodiversity (IFOAM, 2021).

Fruits (20%) and vegetables (15%) hold a significant share, especially in counties like Iași and Suceava, where horticultural traditions are well established. Vineyards are less represented (5%) in the North-East compared to Romania's renowned wine regions, such as Dealu Mare or Dobrogea.

Table 5

Yields and productivity: organic vs. conventional farming

Crop	Organic Yield (t/ha) – North-East Region	Conventional Yield (t/ha) – North-East Region
Wheat	3.2	4.8
Maize	5.0	7.5
Potatoes	18.0	25.0
Apples	12.0	18.0

Source: Ministry of Agriculture, APIA, RRN-CAP, North-East Regional Development Agency (ADR Nord-Est)

According to FAO (2013), yields in organic farming are, on average, 20–30% lower than those in conventional agriculture. However, the higher quality and premium prices of organic products can often compensate for these differences. Table 5 confirms this trend: for example, organic wheat in the North-East Region yields 3.2 tons/ha compared to 4.8 tons/ha in conventional systems, while organic maize yields 5 tons/ha compared to 7.5 tons/ha.

The distribution of organic products in the North-East Region is relatively balanced: 35% are sold on local markets, 25% are exported, 25% go to specialized organic stores, and 15% are distributed through supermarkets. According to Padel & Foster (2005), access to local markets and specialized shops offers the advantage of direct interaction with consumers—an essential factor in building trust and loyalty in the organic sector.

Table 6 illustrates the main distribution channels for organic products in the North-East Region compared to national trends, reflecting how organic supply chains are structured across different market outlets. The data reveal a strong presence of local markets and specialized stores in the North-East, emphasizing the importance of short supply chains and direct consumer access. In contrast, supermarkets play a more significant role at the national level. Export remains an equally important channel in both cases, suggesting that international demand continues to support the sector's growth.

Table 6

Distribution channels and supply chains

Distribution Channel	North-East Region (%)	Romania (%)
Local markets	35%	30%
Specialized stores	25%	20%
Supermarkets	15%	25%
Export	25%	25%

Source: Ministry of Agriculture, APIA, RRN-CAP, North-East Regional Development Agency (ADR Nord-Est)

Differences between minimum and maximum farm sizes confirm the lack of consolidation among organic farms, especially in southern regions, where there is little dimensional diversity. The larger size of some conventional farms (up to 20 ha) indicates opportunities for expansion and intensive exploitation, while organic farms remain constrained by limited access to capital, markets, and processing infrastructure (IFOAM, 2022).

Table 7

Distribution of organic and conventional farms in North-East Romania and Nationally (%)

Farm Category	< 2 ha	2–4.9 ha	5–7 ha	8–10 ha	>10 ha	Number of Respondents
Organic farmers (North-East Region)	67.76%	38.23%	0%	0%	0%	134
Conventional farmers (North-East Region)	58.73%	34.92%	2.65%	1.59%	0.12%	289

Source: Ministry of Agriculture, APIA, RRN-CAP, North-East Regional Development Agency (ADR Nord-Est)

In the North-East Region, most organic farms (over 67%) are under 2 hectares, and the remaining 32% fall within the 2–4.9 ha category. None exceed 5 ha. In comparison, conventional farms display a slightly more diverse distribution. Although small farms dominate this category as well (58.73% under 2 ha, 34.92% between 2–4.9 ha), a small percentage of larger farms is also present.

According to Toma & Dobre (2015), this excessive fragmentation limits the potential for mechanization, reduces economic efficiency, and hinders access to EU funding. Furthermore, Willer & Lernoud (2021) argue that small organic farms face greater difficulties in meeting certification standards due to poor infrastructure and limited access to technical advisory services.

In order to highlight and better understand the models for organizing organic farms in the context of sustainable agricultural development, we conducted a comparative analysis of two crop-based organic farms in Romania: S.C. Orgapic S.R.L. (Farm A) and S.C. Agriela Sad S.R.L. (Farm B). These farms were selected based on their distinct structural and operational characteristics, which reflect contrasting approaches to resource use, value chain integration, and production management.

Table 8 presents a comparative SWOT analysis of the two farms, located in Iași and Botoșani Counties, showcasing the differences between an associative organizational model and a horizontally integrated structure. The comparative SWOT analysis of S.C. Orgapic S.R.L. and S.C. Agriela Sad S.R.L. highlights essential differences in how organizational models shape the performance and resilience of large-scale organic crop farms. Four key dimensions—strengths, weaknesses, opportunities, and threats—offer insight into their strategic positioning within the organic agriculture sector. Farm A (Orgapic), operating within an associative model, benefits from shared resources, collective procurement, and coordinated export logistics. These elements enhance its efficiency and stability, compensating for a smaller cultivated area. Strengths such as own seed lots, input negotiation through the association, and a strong quality control system support higher yields that approach conventional levels. However, challenges remain in terms of input costs, water use, and workforce availability.

Farm B (Agriela Sad), based on horizontal integration with family farms, leverages internal synergies to optimize input use and reduce transaction costs. Although it has advantages in infrastructure and scale, it faces substantial weaknesses, including high labor costs, pest sensitivity, and exposure to fluctuating regulations. Its operational model allows for flexibility in processing and packaging, yet the lack of seed autonomy and dependency on external clients create vulnerability. On the other hand, S.C. Agriela Sad S.R.L. capitalizes on synergies with family-run farms to streamline certain costs but is more vulnerable to labor intensity and legislative uncertainty (Tabel 8).

Table 8

Comparative SWOT analysis of two organic crop farms (Iași and Botoșani Counties)

Category	S.C. Orgapic S.R.L. (420 ha, associative model – Iași)	S.C. Agriela Sad S.R.L. (750 ha, horizontally integrated – Botoșani)
Strengths	- Yields close to conventional due to irrigation and organic inputs - Own irrigation system and equipment - Seed lots reduce dependence and costs - Collective input procurement and storage via association - Export-oriented, bulk delivery by ship - Strict quality control, separate storage units	- Fully equipped with irrigation and storage silos - On-site packaging; client handles sampling and transport - Exports most production; rest used as feed - Family-integrated farms offer cost advantages
Weaknesses	- Lower yields than conventional - High water consumption - Higher costs for organic inputs and labor - Difficulty in workforce availability - Limited insurance coverage and low subsidies - Input buyers offer low purchase prices	- Very high labor costs due to day workers - No own seed production - More sensitive to pests - High operating costs - Frequent legislative changes create uncertainty
Opportunities	- Rejected production used as fertilizer or feed - New storage facility under construction - Access to EU funding projects - Permanent consultancy and collective decision-making	- Inputs sourced through family farms at lower prices - Unsold production can be redirected as conventional - Knowledge exchange within producer association
Threats	- Risk of contamination due to rented silos - Difficult access to structural funds	- Entire production may be rejected due to quality noncompliance - Poorly explained and changing regulations can lead to penalties

Source: Own interpretation

Next, we aim to carry out a comparative analysis of the economic efficiency achieved by two organic farms, using the performance indicators previously examined. The objective is to highlight the similarities and differences between the two operations in order to diagnose potential economic and financial issues specific to the organic sector, both in crop and livestock production. The conclusions drawn from this comparison seek to identify the strengths and financial vulnerabilities that influence the functioning and development of the analyzed organic farms. The table below summarizes the main economic and financial indicators of the two farms during the period 2020–2024, with a focus on the structure of revenues and expenses, profitability, efficiency in resource utilization, and self-financing capacity.

Table 9

Comparative Economic and Financial Overview of Two Organic Crop Farms (Adjusted Data)

Indicator	S.C. Orgapic S.R.L. (Farm A – 420 ha, Iași)	S.C. Agriela Sad S.R.L. (Farm B – 750 ha, Botoșani)	Observations
Share of production sales in turnover	89.5%	63.2%	Farm B complements revenues by selling organic inputs
Subsidies as share of total income	25.7%	5.2%	Lower subsidy share in Farm B
Raw materials and inputs	33.8%	19.4%	Farm A uses cooperative input procurement
External services	21.2%	15.9%	Farm B achieves efficiency through scale
Energy and water	3.4%	4.1%	Higher irrigation costs in Farm B
Labor costs	9.1%	5.8%	Farm A relies more on seasonal labor
Net profit (RON)	398,750	-183,920	Farm A remains profitable; Farm B registers losses due to lower productivity

Source: Own interpretation

Table 9 provides a comparative overview of the key economic and financial indicators for two organic crop farms—S.C. Orgapic S.R.L. (Farm A) and S.C. Agriela Sad S.R.L. (Farm B)—based on adjusted data. The table highlights differences in revenue structure, cost allocation, and profitability, reflecting the influence of organizational models and resource management strategies.

Farm A, operating within an associative model, shows a strong reliance on production sales (89.5% of turnover) and benefits from a substantial share of subsidies (25.7%), which support its financial stability. It also incurs higher input and labor costs, largely due to its cooperative procurement and use of seasonal workers, but manages to maintain a healthy profit margin (RON 398,750).

In contrast, Farm B, despite its larger scale and more efficient use of external services, struggles with profitability (recording a loss of RON 183,920). Its lower subsidy support and dependence on selling inputs rather than maximizing crop yield contribute to weaker financial performance.

Overall, the analysis underscores how organizational structure, scale, and strategic use of resources significantly impact the financial sustainability of organic farms. To better understand the structural dynamics and performance disparities within the organic farming sector, a comparative table has been included. This table highlights key indicators such as resource allocation, profitability, and farm size distribution, with a focus on representative farms or regional patterns relevant to sustainable development goals.

Table 10

Resource use (2020–2024)

Indicator	Farm A	Farm B	Interpretation
Profit per 1,000 RON of fixed assets	↑	↓	A: efficient, B: inefficient
Inventory turnover	↓	↑	A: inefficient, B: efficient
Average receivables recovery time	↑	↓	A: slower, B: faster
Labor productivity	↑	↓	A: higher productivity
Total cost per 1,000 RON operating revenue	↓	↑	A: lower costs
Raw materials cost per 1,000 RON revenue	↓	↓	Efficient in both
External services cost per 1,000 RON revenue	↑	↓	A: less efficient

Source: Own interpretation

The data presented in the table underline the advantages of associative models in terms of input efficiency and financial stability. Despite differences in farm size, associative farms demonstrate greater adaptability and access to subsidies, while individually operated units face higher operational risks and market volatility. These findings emphasize the strategic value of cooperation and institutional support in fostering resilient organic farming systems.

Table 11

Profitability Evolution (2020–2024)

Indicator	Trend Farm A	Trend Farm B
Commercial margin rate	↓	↓
Gross operating margin	↓	↓
Net operating margin	↑	↓
Value added margin	↓	↓
Economic profitability	↑	↓
Gross accumulation margin	↓	↓
Capital turnover ratio	↓	↓
Net economic asset profitability	↓	↓
Net financial profitability	↑	↓
Pre-tax financial profitability	↑	↓
Profit rate (2024)	27.4%	6.7%

Source: Own interpretation

Farm A shows higher economic resilience and profitability despite its smaller size, mainly due to superior per-hectare productivity, access to inputs through associations, and stronger subsidy support. Farm B, by contrast, records low profitability as a result of limited subsidies, lower productivity, and inefficiencies in operational and financial management.

The analysis indicates that farms integrated into associative systems achieve more stable profitability, while independently operating farms remain profitable only in years with favorable climatic conditions. Economic pressures, rising costs, marketing constraints, and insufficient subsidies have significantly affected Agriela Sad, with profit margins dropping below 1% in some years. Conversely, Orgapic improved its performance steadily, reaching a profit rate of 27.4% in 2024 through association-based distribution, quality inputs, and higher productivity.

CONCLUSIONS

The research conducted in the North-East Region of Romania in 2024 provides valuable insights into consumer perceptions, barriers to organic food consumption, and the organizational performance of organic farms. Based on a survey of 367 respondents and a comparative analysis of two representative crop-based farms—S.C. Orgapic S.R.L. (Farm A) and S.C. Agriela Sad S.R.L. (Farm B)—the study identifies key strengths, challenges, and future directions for the development of organic agriculture in the region.

The survey results highlight that the main barriers to organic food consumption remain high prices, limited availability, perishability, and a lack of consumer trust. Moreover, insufficient promotion and limited consumer awareness further constrain the growth of the organic market. These findings emphasize the need for targeted education campaigns and improved communication strategies to build consumer confidence and drive demand for organic products.

From an organizational perspective, Farm A, operating within an associative model, achieves higher financial performance, resilience, and profitability despite its smaller size, due to shared resources, collective input procurement, coordinated sales, and access to stable markets. Farm B, although larger and family-run, shows weaker results because of high labor costs, greater exposure to climatic and regulatory risks, and limited institutional support.

The cost–benefit analysis highlights that organic farming delivers important environmental, social, and economic benefits, but also entails higher costs and transitional risks that can undermine profitability without efficient organization and adequate policy support. Overall, the study emphasizes that the long-term success of organic farms depends on effective resource management, adaptation to local conditions, and participation in associative structures. Strengthening short supply chains, local processing, and access to EU funding emerges as essential for improving the competitiveness and sustainability of organic agriculture in Romania.

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