Gheorghe Zane Institute for Economic and Social Research

Economy and Contemporary Society

Journal homepage: ecs-journal.ro

Empirical Article

Indicators for Assessing Resilience and Sustainability of Agricultural Production Systems in the North-East Region

Ana URSU[1]

ARTICLE INFO

Article history:
Received 29 December 2024
Revised 21 April 2025
Accepted 15 June 2025
First published online 8 July 2025

JEL classification:
Q15; Q18

Keywords:
Efficiency
Resilience
Sustainability
Policies and governance
North-East Region

ABSTRACT

Increasing agricultural production systems' resilience and sustainable development is essential to cope with climate change, natural resource degradation, and economic vulnerability. The study aims to identify and assess methods, strategies, and policies that can increase the capacity of production systems to cope with current challenges and promote sustainable agricultural practices that support food security and environmental quality. To achieve the proposed objective, several indicators of agricultural production, economic efficiency, policy, and governance, etc., will be analyzed—indicators that reflect the performance of agricultural systems in the North-East Region, and allow for an assessment of their resilience and sustainability. The research methodology is based on the following methods: analysis, synthesis, comparison, time-series analysis, and regression methods. The study contributes to the assessment and continuous monitoring of progress towards the goals of resilience and sustainable development of agricultural production systems in the North-East Region. The information base provided by the analyzed indicators contributes to the development of recommendations to promote the transition towards more sustainable agricultural practices and to support farmers in adopting resilient technologies and practices.

1. Introduction

Agricultural production systems play an important role in ensuring food security and socio-economic development. The economic, social, and environmental

[1] Researcher II, Research Institute for Agricultural Economics and Rural Development, Bucharest, Romania, ursu.ana@iceadr.ro; ORCID: 0000-0003-1822-9690

DOI: 10.59277/ECS.2025.30.1

problems faced by these systems require solutions to ensure their functioning under conditions of risk and uncertainty. The terms *resilience* and *sustainability* found in agricultural policy and governance documents aim to ensure the agricultural sector can cope with complex challenges and promote long-term, equitable, and resource-efficient development.

With a population of 3.228 million inhabitants (16.6% of the Romanian population), of which 1.887 million (20.8%) live in rural areas, the North-East Region manages to maintain a balanced agricultural sector in terms of resources that can be developed through investment and contribute to the modernization of rural areas and food security. However, the challenges faced by agricultural production systems as a result of the events that occurred between 2014 and 2023 (pandemic crisis, soil drought, energy crisis, geopolitical conflicts, zoonotic epidemics) raise concerns about the resilience and sustainability of these systems in the face of uncontrollable events. To assess the resilience and sustainability of agricultural production systems in the North-East Region, several indicators of economic efficiency, resilience, sustainability, policy, and governance will be analyzed. The need to conduct the study in a regional context helps to highlight the functioning of agricultural systems to identify resilience and sustainability.

2. Literature Review

In the context of current challenges – climate change, depletion of natural resources, economic volatility – resilience and sustainability of farming systems have become key concepts in the agricultural literature. Recent studies reflect a diversity of perspectives on these concepts, but also a clear trend towards their integration into a common analytical framework.

Meuwissen et al. (2019) proposes a comprehensive framework for analyzing the resilience of agricultural systems, which addresses three key capabilities: robustness, adaptability, and transformability. The approach is a mixed-method approach, combining quantitative (statistics, econometric modeling) and qualitative (interviews, participatory workshops) methods, applicable at multiple levels – from the farm to the national farming system.

A complementary approach is offered by Lien et al. (2007) and Conway (1985), who focus on economic resilience, understood as the ability of farming systems to withstand economic and environmental shocks without compromising financial viability and resource sustainability. This view is also supported by Zaman et al. (2015), who analyse economic resilience at the regional level, emphasising the reduction of vulnerability to exogenous factors.

Extending the analysis in an applied direction, Zampieri et al. (2020) propose a simple indicator of crop production resilience derived from time series of annual production. It expresses the resilience of the system to major shocks and is consistent with ecological definitions of resilience.

The systemic dimension is reinforced by Darnhofer et al. (2010), who emphasise the interdependence between resilience and sustainability in agriculture. The author emphasises that resilience becomes a vector for long-term sustainability through diversity, redundancy, and transformative capacity.

This vision is complemented by Bănică and Muntele (2015), who argue that resilience and sustainability are complementary concepts: sustainability aims at balanced development, while resilience focuses on adaptation to imbalances. Both concepts converge towards an integrative vision of sustainability, where the balance between social, economic, and environmental dimensions is essential.

Different typologies of indicators are proposed in the literature to support sustainability assessment. According to Latruffe et al. (2016), they are structured around the three pillars of sustainability – environment, economy, society – but also include qualitative elements that are more difficult to quantify, especially in the social domain.

From a decision-making perspective, Pannell and Glenn (2000) provide a conceptual framework based on Bayesian decision theory, which allows prioritisation of indicators according to the likelihood of hypotheses and associated evidence.

A specific and recognised method for measuring sustainability is the IDEA method used by Gavrilescu et al. (2012), which integrates 10 components, 41 complete indicators, and 100 aggregated indicators, quantifying the sustainability of farms based on the scores obtained.

An innovative perspective is provided by Usigbe et al. (2024), who analyses the impact of artificial intelligence on agricultural resilience. Through the integration of advanced technologies, agriculture becomes more responsive, adaptive, and efficient in the face of climate risks, contributing to the consolidation of smart and sustainable agriculture.

Finally, in the conceptual framework outlined by Bănică and Muntele (2015), they highlight the multiple meanings of the term resilience: ecological, social, economic, territorial, as well as its relationship with vulnerability and sustainability. This approach reaffirms the need for a multidimensional and cross-sectoral understanding of resilience in agriculture and territorial development.

3. Methodology

The main objective of the research is to highlight the robustness of the agricultural production systems in the North-East Region in the light of the crises that Romania has experienced in the period 2014-2023 (climate change, energy crisis, COVID-19 pandemic, war in Ukraine, epizootics, etc.). It was based on the premise that for the economy of the North-East Region, it is essential to know how these crises have influenced or are influencing the economic growth or decline of the region, and also how resilient the agricultural production systems have been, and how they are evolving. To assess the resilience and sustainability of agricultural production systems in the North-East Region, the following indicators were analyzed: regional GDP, gross value added (GVA), economic efficiency indicators (labour productivity), income in the agricultural sector, average total income per household, gross fixed capital formation, production yields, livestock, policy and governance elements, etc. Data processing was carried out using statistical functions of Excel, such as count, sum, average, max, min, stdev (standard deviation), and CV (coefficient of variability). The calculation of the annual growth rate shows how much the phenomenon in question has increased in relative magnitude, on average, over the period analyzed, from year to year (Anghelache & Manole, 2012).

The trends of change in socio-economic phenomena in the North-East Region were defined using the method of trend analysis based on linear regression and the coefficient of determination.

The limitations of the research are methodological (in the sense that a consistent methodology was not applied to include indicators from the three pillars of sustainability) and theoretical (in the sense that the theory presented is partially adequate to explain the issue studied).

4. Results and Discussion

Agriculture at the regional level is presented in comparison with other activities that are part of the regional economy. Agriculture should bring prosperity to the farming community. In this context, economic sustainability is seen as economic viability, i.e., whether an agricultural system can survive in the long term in a changing economic context. Changes in the economic context are driven by variability in output and input prices, yields, output markets, and public support and regulation. Economic viability is measured by profitability, stability, and productivity (van Cauwenbergh et al., 2007, cited by Latruffe et al., 2016).

4.1. Economic performance and labour productivity

The regional Gross Domestic Product (GDP) is an indicator of economic growth that provides an overall assessment of how the North-East Region manages its resources and generates prosperity for its inhabitants. It shows the total value of goods and services produced in the North-East Region.

Table 1. Regional GDP and GVA in the North-East Region

NACE Rev. 2 activities and GDP components for North-East Region	**Average 2014-2021 (EUR million)**	**% in GDP**	**Variability coefficient (%)**	**Annual growth rate (%)**
Agriculture, forestry, and fishing	1,469	7.2	18.4	6.1
Industry	3,557	17.5	10.4	3.1
Construction industry	1,348	6.6	26.7	9.5
Trade and commerce	3,661	18.1	26.3	12.7
Information and communication	709	3.5	41.5	18.9
Financial intermediation	251	1.2	14.1	5.6
Real estate transactions	2,256	11.1	13.4	6.4
Professional activities	833	4.1	20.2	9.0
Public administration and defense	3,550	17.5	27.4	7.8
Recreational activities	588	2.9	18.0	6.0
Gross regional value added (GVA)	18,222	89.9	20.1	7.9
Taxes on products	2,081	10.3	12.0	3.9
Import taxes (customs duties)	59	0.3	14.0	3.7
Subsidies by product	-46	-0.2	-16.4	4.3
Gross Regional Domestic Product (GRDP) North-East	20,274	100.0	19.3	7.6

Source: Author's elaboration based on Tempo Online statistics, NSI

Agriculture in the North-East Region accounts for 7.2% of the regional gross domestic product (GDP). Compared to other economic activities in the North-East Region, the value of agricultural production is 10.2 percentage points lower than industry, 10.9 percentage points lower than trade, and 3.9 percentage points lower than real estate transactions, etc. In terms of the variability of agricultural activities, the North-East Region is more stable than construction, trade, information and communication, professional activities, etc. For the period 2014-2021, all the economic activities of the North-East Region have favorable growth rates, ranging from 4.6%/year in the industrial activity to 20.6%/year in the information and communication activity (Table 1).

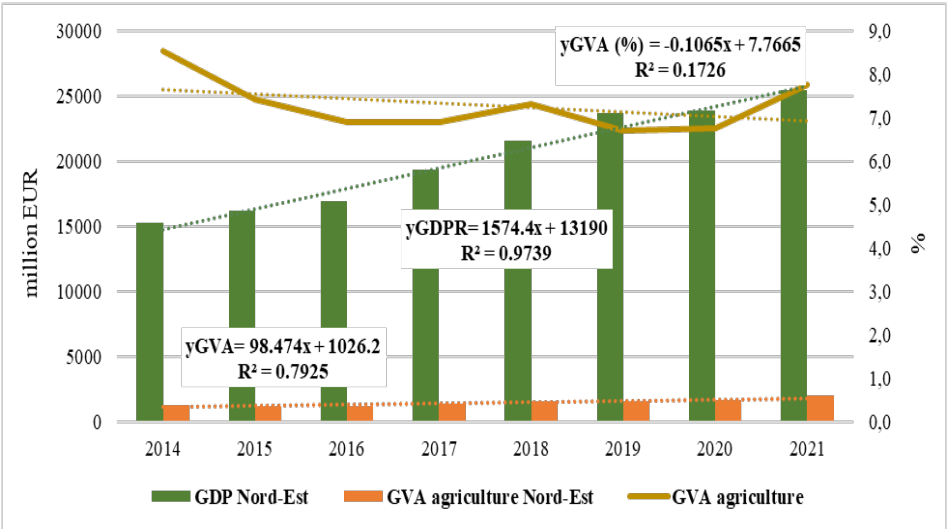

Fig. 1. Contribution of agriculture to GDP formation in the North-East Region

Source: Author's elaboration based on NIS data, Tempo Online

The GDPR of the North-East Region has increased on average by EUR 1,574.4 million per year (from EUR 15,284 million in 2014 to EUR 25,489 million), while the quantitative value contribution of agriculture to the formation of the regional GVA is on average EUR 98.474 million per year.

The share of gross value added (GVA) of agriculture in GDP is fluctuating around a downward trend. In absolute terms, the GVA of agriculture increased, from EUR 1,307 million in 2014 to EUR 1,979 million, but in relative terms, the trend decreased with the modernization and development of the economy in the North-East Region. Significant fluctuations in agricultural production contributed to the downward trend as well. The contribution of agriculture to the formation of GVA (%) in the North-East Region is decreasing, on average by -0.1065 percentage points per year (Fig. 1).

The average value of the agricultural sector production was EUR 2,905 million, in 2014-2022. Depending on climatic conditions, the share of crop production in the total value varied quite strongly (between 57.2% and 66.6%) in the analyzed period. The share of livestock production exceeded the average value of 37.4% in 2015 (41.7%), 2016 (40.9%), and 2020 (38.6%), decreased in 2021 (32.9%), and returned to 41.4% in 2022. Services share in the agricultural production was exceptionally higher in 2022 (1.4%), almost double the 2014-2022 average (Table 2).

Table 2. Agricultural production dynamics in the North-East Region 2014-2022

	2014	2015	2016	2017	2018	2019	2020	2021	2022	Average
Value of agricultural production (million EUR), from which:	2851	2546	2480	2695	2934	2912	2777	3527	3426	2905
» crop production (%)	63.2	57.6	58.5	62.0	66.6	64.8	60.6	66.3	57.2	61.9
» livestock production (%)	36.1	41.7	40.9	37.3	32.8	34.4	38.6	32.9	41.4	37.4
» services (%)	0.7	0.7	0.6	0.7	0.6	0.8	0.8	0.8	1.4	0.8

Source: Author's elaboration based on NIS data, Tempo Online

The highest value of agricultural production is achieved by Suceava County (EUR 657 million), followed by Botoșani County (EUR 540 million) and Iași County (EUR 525 million). For the period 2014-2022, the value of production of the agricultural branch at the level of the North-East Region recorded positive annual growth rates for all the counties, ranging from a minimum of 0.41%/year in Botoșani County to a maximum of 3.71%/year in Suceava County. The difference between the growth rates of the value of agricultural production can be explained by the fact that the value of the agricultural output in Botoșani County. However, it has the lowest growth rate, due to the stability of the value of production over the period analyzed. This stability is evidenced by the coefficient of variability (CV) of Botoșani County, which is 9.9%, compared to 15.0% as the coefficient of variability of agricultural production in Suceava County.

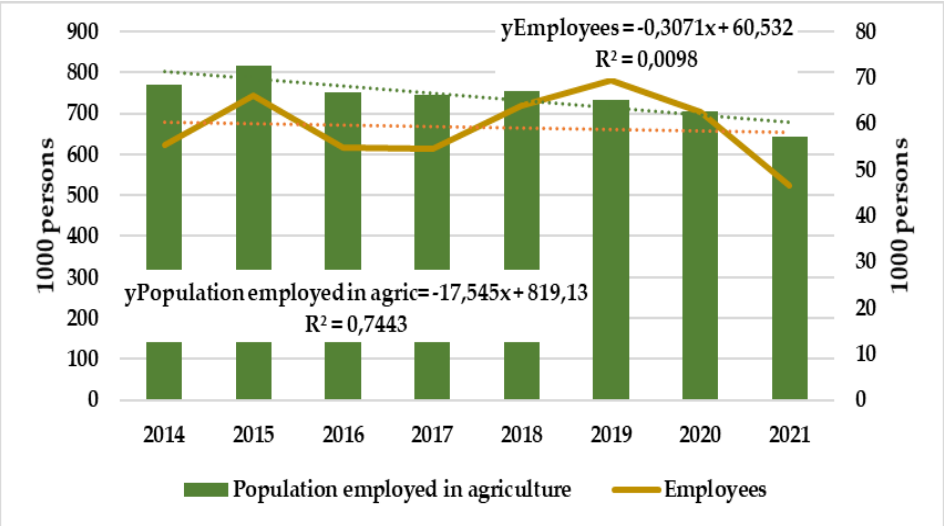

Fig. 2. Employed population and employees in agriculture in the North-East Region

Source: Author's elaboration based on NIS data, Tempo Online

In the period 2014-2021, the population employed in agriculture in Romania decreased on average by 86.511 thousand persons/year. The population employed in agriculture in the North-East Region decreased on average by 17.545 thousand persons/year, and the number of employees decreased by 0.3071 thousand persons/year. In 2021, compared to 2014, the number of persons employed in agriculture decreased by 16.4% (from 769.9 thousand persons to 644 thousand persons), and the number of employees decreased by 15.7% (from 55.3 to 46.6 thousand persons) (Fig. 2).

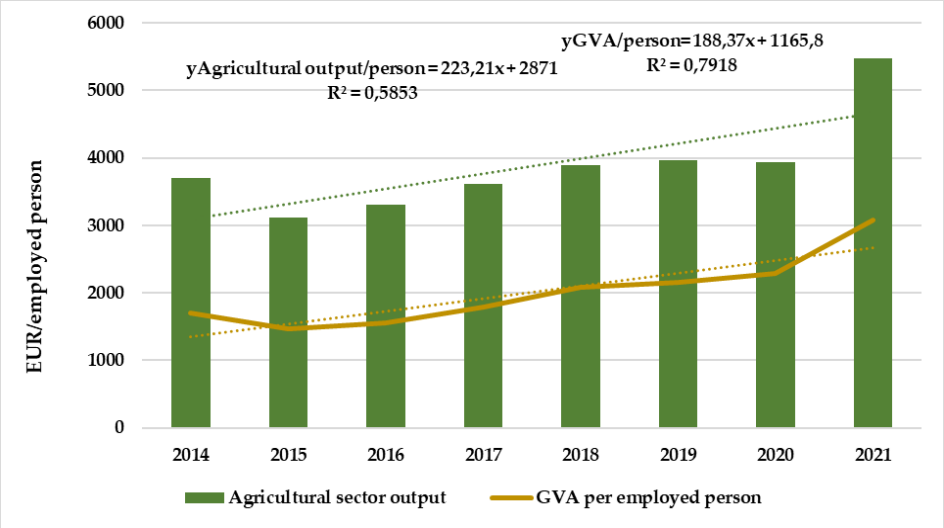

Fig. 3. Labour productivity in agriculture in the North-East Region
Source: Author's elaboration based on NIS data, Tempo Online

Fig. 3 shows the dynamics of labour productivity in agriculture in the North-East Region, based on the value data of agricultural production and gross value added obtained in agriculture in the North-East Region in the period 2014-2021. The linear regression function was used to signal the trend of labour productivity. The coefficient b of the regression equation, also called the slope of the regression line, statistically expresses the amount by which y (value of labour productivity) statistically increases with each unit increase in x. If the independent variable x increases by one year, the dependent variable y increases by EUR 223.21 per person/year in the case of value-added labour productivity and by EUR 188.37 per person/year in the case of value-added labour productivity expressed in terms of gross value added (GVA). The relationship between the dependent variable (labour productivity) and the independent variable (production year) is approximately 58.53% and 79.18%, respectively. The increase in labour productivity in 2021 is recorded against the background of a decrease in the population employed in agriculture from

706 thousand persons in 2020 to 644 thousand persons in 2021. The research on the composition of agriculture and labour productivity shows that as the economy grows and capital accumulates, the price of labour-intensive agricultural goods increases relative to capital-intensive agricultural goods (Blanco & Raurich, 2022).

Research by Tofan (2004/2005) shows that labour productivity in agriculture is 3.3 times lower than in the national economy and 5.7 times lower than in industry. Gross value added per person employed in agriculture is 2.8 times lower than in the economy and 3.5 times lower than in industry.

4.2. Agricultural income

Table 3. Employee remuneration by branches of activity in the North-East Region (€ million)

Branches of activity	Average	Minimum	Maximum	Standard deviation	Coefficient of variation	Annual growth rate
North-East Region, from which:	4,660	9,199	7,077	1,877	26.5	10.2
» agriculture	179	303	250	54	21.5	7.8
» industry	963	1,585	1,335	243	18.2	7.3

Source: Author's elaboration based on NIS data, Tempo Online

The agricultural employee remuneration indicator is defined as "the total remuneration, in cash or kind, payable by an employer to an employee in return for work done by the latter during an accounting period" (Eurostat, n.d.).

The income of employees in the North-East Region has a coefficient of variability of 26,5%, which means that in the period 2014-2021, it varies from a minimum income of EUR 4,660 million to a maximum income of EUR 9,199 million, with an annual growth rate of 10.2%. Compared to industry, the income of employees in agriculture shows a higher variability (21.5% compared to 18.2%), but both income categories of the two branches are much more stable compared to the total income of the North-East Region.

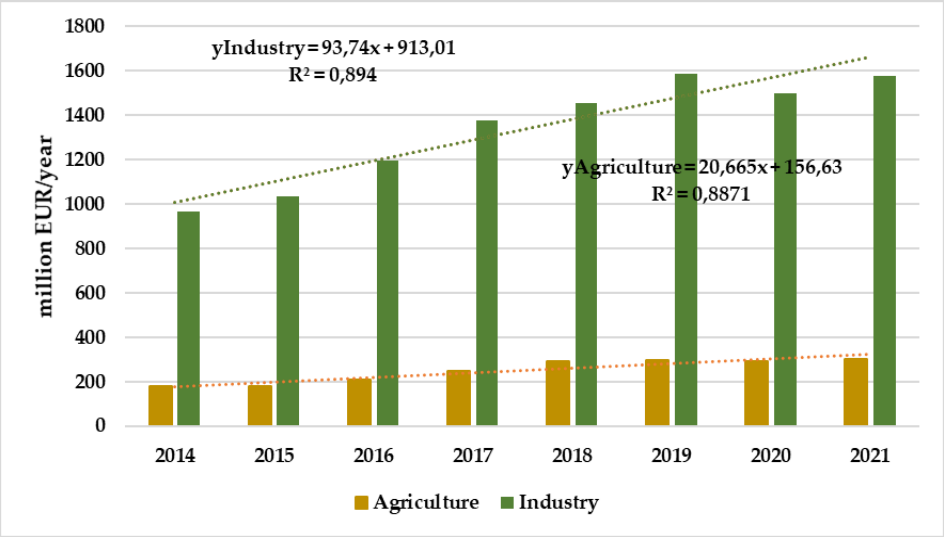

Fig. 4. Dynamics of income in agriculture compared to the dynamics of income in industry in the North-East Region

Source: Author's elaboration based on NIS data, Tempo Online

In the period 2014-2021, the incomes of agricultural workers increased by an average of EUR 20,665 million per year, while the incomes of industrial workers increased by an average of EUR 3,74 million per year, which is 4.5 times higher than the incomes of agricultural workers. For both categories of economic activity, the trend in incomes is upward, with almost the same ratio of 5:1 (Fig. 4).

4.3. Average total monthly income per household

According to the explanatory statistics of the NSI, total income per household is the total gross income made up of cash income from whatever source (excluding loans and credits, withdrawals from deposits with CEC Bank, other banks and similar institutions) and the equivalent value of income in kind (human and animal consumption of food and non-food products from the household's resources, goods and services obtained free of charge or at a reduced price from public and private economic agents) other than wages and salaries (NIS, 2024a).

Table 4. Average total monthly income per household, by income category, in North-East Region (2014-2023) (EUR/month/household)

Income categories	Average	Minimum	Maximum	Standard deviation	Coefficient of variation	Annual growth rate	%
Total revenue	478	1,169	763	237	31.1	10.5	100
Money income	362	1,022	656	224	34.2	12.2	86.0
Gross salaries and other salary rights	178	630	403	161	39.8	15.1	61.5
Income from agriculture	22	39	29	6	19.7	5.3	4.4
Income from sales of agri-food products, animals, and birds	15	27	19	4	20.2	4.8	3.0
Income from performing some agricultural work	6	12	9	2	21.5	6.3	1.4
Income from independent non-agricultural activities	14	37	21	7	31.7	11.0	3.2
Income from services	3	7	5	1	21.8	2.0	0.8
Income from trades	7	28	13	6	48.6	17.5	2.0
Income from social benefits	122	267	168	49	29.3	9.1	25.7
Income from the sale of household assets	15	36	23	6	26.9	10.4	3.6
Income in kind	86	147	107	18	16.9	5.5	14.0
Counter value of consumption from own resources	79	130	99	14	14.5	2.0	92.4

Source: Author's elaboration based on NIS data, Tempo Online

Table 4 shows the categories of average monthly income per household earned in the North-East Region during 2014-2023. The statistical data are presented according to the descriptive statistics analysis model, i.e., the mean per income category, the minimum function, the maximum function, the standard deviation of the data from the mean, the coefficient of variability, and the annual growth rate. The analysis of the descriptive statistical indicators helps to identify stability or

imbalances in the income categories in the context of the social, economic, and environmental transformations that have taken place during the period 2014-2023. Total income is divided into two categories: cash income with a share of 86.0% and income in kind with a share of 14.0%. (Table 4). Wage income has a high coefficient of variability of 34.2%, which signals the transition from a minimum income of EUR 362 per month (in 2014) to a maximum income of EUR 1,169 per month (in 2023), which represents an average annual increase of 12.2%. The income from agriculture has a coefficient of variability of 19.7%, which means that there are no significant variations from one year to another, except in 2020 (EUR 33 per month), 2022 (EUR 36 per month), and 2023 (EUR 39 per month), when the income exceeded the average value of EUR 29 per month/household.

Another income category that shows stability compared to the other income categories is income in kind, whose coefficient of variability is 16.9% and which will increase from a minimum of EUR 86 per month (in 2015) to a maximum of EUR 147 per month (in 2023), with an annual growth rate of 5.5%. Within this income category, the counter value of consumption from own resources is even more significant, with a coefficient of variability of 14.5%, the lowest of all the income categories presented. The thresholds for the counter value of consumption from own resources of EUR 99 per month/household are a minimum of EUR 79 per month (in 2015) and a maximum of EUR 130 per month (in 2023), with an annual growth rate of 2.0%/year. This income category represents 92.4% of the income in kind, which means that the value of household consumption has increased, influenced by the increase in the price of food (caused by the increase in inflation). An income category that accounts for a significant share (25.6%) of cash income is income from social benefits (Table 4). The report "National Sustainable Development Indicators – Horizon 2030" states that the level and structure of a household's income is determined by the number of income earners, in particular the number of people in work and the type of work they do. An increase in monthly income per household contributes to reducing the risk of poverty and increasing social inclusion, while a decrease in this indicator increases the risk of poverty and social exclusion (NIS, 2023, pp. 204, 208).

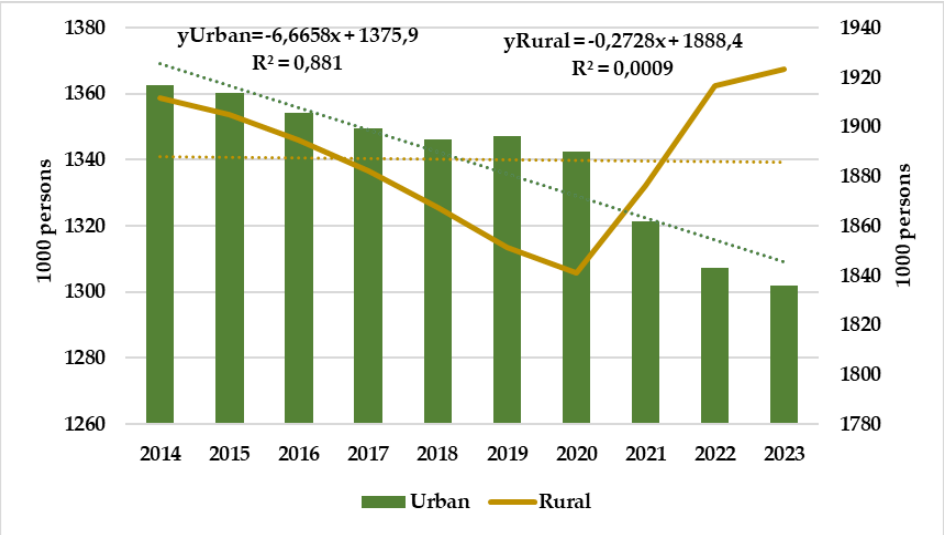

Fig. 5. Population of the North-East Region

Source: Author's elaboration based on NIS data, Tempo Online

The population of the North-East Region is the highest compared to the other regions of the country (3.228 million compared to 2.944 million in the South-Muntenia Region, 2.556 million in the North-West Region, and 2.413 million in the South-East Region, etc.). For the period 2014-2023, both the urban population decreased by an average of 6.6658 thousand persons per year and the rural population by an average of 0.2728 thousand persons per year. The population of the region is characterized by two periods: the simultaneous decrease of the urban and rural population until 2020, although there is no significant decrease in the urban population. However, in 2020, the urban population decreased from 1343 thousand people in 2020 to 1302 thousand people in 2023, and the rural population increased from 1841 in 2020 to 1923 in 2023. This phenomenon can be explained by the migration of the urban population to rural areas, which is a complex and rather rare phenomenon, but it could be interpreted as being due to the pandemic situation that created this temporary effect, generating job flexibility, orientation towards a more balanced life, temporary migration for safety and health, increased interest in sustainability, etc. The increase in the rural population can also be correlated with the increase in the employed population in rural areas. Interest in rural areas has increased, mainly due to pandemics, but also because people were concerned about healthy food and being in nature. Migration to rural areas does not mean that all those who move to rural areas become farmers, but many are involved in agricultural activities such as gardening or raising animals for their consumption. For others, migration to rural areas could also be linked to an increased interest in organic farming. The North-East Region has a tradition of developing rural tourism, in

counties such as Suceava, Neamț, and Bacău, as mentioned in the North-East Regional Development Strategy (North-East RDA, 2006, pp. 15-16), where agrotourism and ecumenical tourism are being developed with some efficiency. Such an approach allows income diversification by offering visitors authentic experiences, such as participation in traditional agricultural activities.

4.4. Gross fixed capital formation (GFCF)

GFCF is a statistical indicator of the National Accounts, which consists of the acquisitions fewer disposals of fixed assets by resident producers during a given period, plus certain additions to the value of non-produced assets realized as a result of the productive activity of producers or institutional units.

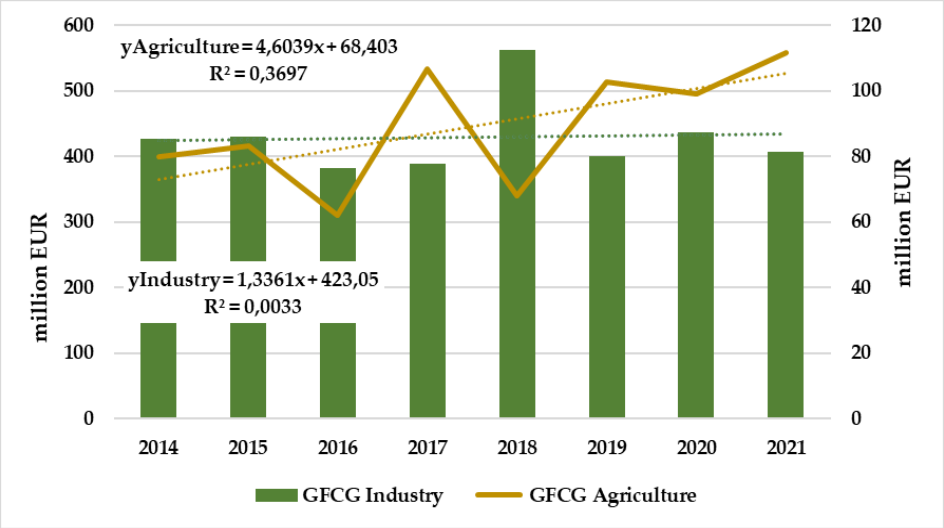

Fig. 6. Gross fixed capital formation in agriculture and industry in the North-East Region

Source: Author's elaboration based on NIS data, Tempo Online

In the period 2014-2021, the investments realised in the North-East Region have an average growth value of 46,039 million EUR/year in agriculture and 13,361 million EUR/year in industry (Fig. 6).

Table 5. Share of GFCF in agriculture and industry in North-East Region (%)

	2014	2015	2016	2017	2018	2019	2020	2021	Average (%)
Share of GFCF of North-East Region in the GFCF of Romania	6,4	6,3	6,0	6,6	7,4	8,1	7,5	8,4	7,1
Share of GFCF in agriculture in Romania	10,6	9,9	9,8	10,4	11,7	10,8	11,0	11,8	10,8
Share of GFCF in the Romanian industry	5,7	5,8	5,6	6,3	5,9	6,9	7,2	6,8	6,3

Source: Author's elaboration based on NIS data, Tempo Online

GFCF in the North-East Region represents, on average, 7.1% of GFCF at the national level (3,282 million EUR against 45,502 million EUR). Investments in the North-East Region agriculture account for 10.8% (EUR 206 million compared with EUR 1915 million) of the investments made in the agricultural sector in Romania. Investments in industry in the North-East Region represent 6.3% of the total investments in the industry in Romania (EUR 656 million compared with EUR 10,493 million). Although in percentage terms agriculture is 4.5 percentage points ahead of industry, in volume terms the quantitative values of investments in industry in the North-East Region are on average 3.2 times higher than those realised in agriculture. GFCF in agriculture plays an important role in increasing productivity, modernizing production processes, and improving competitiveness. The value of the coefficient of variability is 29.3% for the North-East Region of the total economy, which means that the data are relatively statistically stable. The best stability of the GFCF indicator is found in industry with 17.9% compared to 24.1% for agriculture. Investment in agriculture is lower than investment in industry for several reasons related to the specificity of agricultural activities, the risks involved, and the perception of investors. Agriculture is a sector with fluctuating incomes due to climatic, seasonal, and market factors. Harvests vary from one year to the next, and agricultural product prices are often volatile. In agriculture, profits are lower than in industry, which discourages large-scale investments. Agriculture requires a longer recovery time for investments, given that most production cycles are seasonal. In industry, production cycles can be shorter and continuous, allowing for faster recovery of investments. Agriculture is seen as a risky sector, which limits access to credit and makes financing more expensive. Climate and environmental risks are less present in the industry compared to agriculture, where farmers are directly affected by weather conditions, and climate change increases the risks, leading to unexpected droughts, floods, or frosts. To counteract the effects of climate change, additional investments are needed in irrigation systems or infrastructure to protect against natural disasters,

thus increasing costs for farmers. Land fragmentation also limits the adoption of advanced technologies and the attraction of capital because investments cannot be exploited to their full potential. Cooperation between farmers and the creation of associations is limited, which reduces bargaining power for obtaining financing and discourages investment in large-scale projects.

The investment gap between agriculture and industry is caused by factors specific to the agricultural sector, such as high risks, slow returns on investment, and difficult access to technology and finance. These conditions make agriculture less attractive to investors compared to industry, where production cycles are more stable, risks are more controllable, and profitability and returns are more predictable. However, as agriculture modernizes and becomes more sustainable, these gaps are likely to narrow, especially through government support and policies to support investment in agricultural technologies.

4.5. Evolution of agricultural yield

Considering that the Romanian Sustainable Development Strategy sets a 2030 target to double the share of agriculture in Romania's GDP to 8.6% compared to 2018, the evolution of agricultural yield is an additional indicator to measure the implementation of the 2030 target. The indicator is part of the sustainable development objectives: *Objective 2 Zero Hunger*. In this context, the evolution of production yield in the North-East Region is analyzed (NIS, 2023, pp. 31, 33, 204, 208). The yield evolution fluctuates during the analyzed period. In 2023, compared to 2020, a decrease in yield is observed for most crops, due to the prolonged drought in recent years. Other factors that contributed to the reduction in production yield are related to the level of technological development and crop irrigation. In 2023, compared to 2020, the following agricultural products had the largest increases in yields: rye (+14.9%), wheat (+28.4%), barley (+46.6%), corn (+6.2%), sorghum (+1.6%), peas (+37.4%), rapeseed (+30.5%), soybeans (+11.3%), winter potatoes (+10.8%), and the largest decreases were recorded in tobacco (-59.2%), watermelons and melons (-33.5%), tomatoes (-31.6%), dried onions (-29.9%), white cabbage (-24.0%), dried garlic (-23.6%), peppers (-20.2%), alfalfa (-17.3%), perennial fodder (-16.2%), beans (-11.0%), green table clover (-9.2%). Compared to 2018, in 2023 in the North-East Region, the best yields were recorded for oilseed flax (+53.6%), rapeseed (+18.7%), rye (+12.1%), pea (+3.9%), winter potatoes (+1.5%).

Table 6 presents the descriptive statistics indicators. The minimum and maximum values of production yield, average values, standard deviation from the average, coefficient of variability, as well as the annual rate of yield growth for the

period 2014-2023 are presented. Positive annual increases are reported for cereals (rye, common wheat, durum wheat, barley, and barley), hemp, and winter potatoes, and negative values for the rest of the crops (Table 6).

Table 6. Yield for the main crops in the North-East Region, 2014-2023 (kg/ha)

	Minimum	Maximum	Average	Standard deviation	Coefficient of variation	Annual growth rate
Rye	2,494	3,280	2,779	287	10.3	+1.46
Common wheat	2,921	4,507	3,656	586	16.0	+1.29
Durum wheat	2,658	5,140	3,978	928	23.3	+7.00
Barley and barley	2,098	3,525	2,922	458	15.7	+2.51
Barley	2,771	4,521	3,654	522	14.3	+2.19
Oats	1,712	2,235	1,977	180	9.1	-1.02
Corn grain	2,862	7,098	4,601	1,423	30.9	-3.14
Sorghum	1,098	5,652	3,043	1,342	44.1	-5.62
Pea grain	1,125	2,519	1,738	443	25.5	-1.58
Beans grain	896	1,454	1,190	206	17.3	-3.40
Hemp for fiber	727	5,167	1,656	1,446	87.3	+10.90
Sunflower	1,474	3,165	2,125	591	27.8	-1.44
Rapeseed	1,793	2,631	2,216	276	12.5	-0.95
Soybean grain	1,126	2,486	1,819	442	24.3	-3.27
Flax for oil	682	3,306	1,721	759	44.1	+5.24
Sugar beet	30,141	42,501	36,202	4,073	11.3	-2.65
Tobacco	400	1,235	772	330	42.8	-0.30
Early, mid-early, and summer potatoes	9,196	13,317	11,127	1,562	14.0	-3.14
Winter potatoes	11,375	19,822	16,146	2,839	17.6	+0.04
Tomatoes	12,520	19,510	15,058	2,216	14.7	-2.16
Dried onions	9,374	13,554	11,092	1,533	13.8	-3.26
Dried garlic	5,091	6,689	5,801	575	9.9	-1.94
White cabbage	18,266	24,541	21,328	2,341	11.0	-2.75
Peppers	9,085	13,994	10,847	1,410	13.0	-1.46
Green and yellow melons	13,712	23,558	19,293	2,738	14.2	-3.83
Perennial forages	10,127	16,646	13,140	1,956	14.9	-5.37
Alfalfa (in green mass equivalent)	9,834	17,285	13,211	2,254	17.1	-6.07
Clover (in green mass equivalent)	11,715	16,932	13,609	1,572	11.5	-4.01
Annual green forages	11,994	18,783	15,047	2,402	16.0	-4.51
Green fodder corn	17,748	29,608	23,159	3,763	16.2	-4.46

Source: Author's elaboration based on NIS data, Tempo Online

To analyze the yield stability degree of crops in the North-East Region in the period 2014-2023, crops were grouped using the coefficient of variability (Dănciulescu, 2016). It can be appreciated that the yield of crops is stable when the CV is less than 10%, relatively stable when the CV is between 10% and 20%, relatively unstable when the CV is between 20% and 30%, and unstable when the CV exceeds 30% (Table 7).

Table 7. Grouping of crops according to yield variation in the North-East Region based on the coefficient of variability (CV%) in the period 2014-2023

CV < 10%	**2 crops: oats, dried garlic**
10% < CV < 20%	19 crops: rye, white cabbage, sugar beet, clover (in green mass equivalent), rapeseed, pepper, dried onion, early, mid-early and summer potatoes, green and yellow watermelons, barley, tomatoes, perennial fodder, barley and barley grass, annual green fodder, common wheat, green fodder corn, alfalfa (in green mass equivalent), beans, winter potatoes
20% < CV < 30%	4 crops: durum wheat, soybeans, peas, sunflowers
30% < CV	1 crop: corn, tobacco, oil flax, sorghum, hemp for fiber

Source: Author's elaboration based on NIS data, Tempo Online

Table 8 presents the descriptive statistics indicators of the livestock sector in the North-East Region. During the period 2014-2022, increases were recorded in the category *bees* (+3,25%/year), and with small increases in the categories *sheep*, *ewes and ewe lambs*, *goats*, and *she-goats*. In the other categories, reductions in livestock numbers were recorded (Table 8).

Table 8. Livestock numbers, by animal category in the North-East Region (1000 heads)

	Minimum	**Maximum**	**Average**	**Standard deviation**	**Coefficient of variation**	**Annual growth rate (%)**
Bovine animals	408	534	479	45	9.4	-3.22
Cows, female buffaloes, and heifers	261	316	292	21	7.0	-2.26
Heifers	21	30	26	4	16.2	-4.36
Cows and female buffalo	240	285	266	17	6.2	-2.06
Pigs	375	549	453	60	13.2	-4.66
Sows for breeding	34	43	37	3	7.4	-1.06
Gilts for reproduction	3	5	4	1	22.0	-3.13
Sheep	1,370	1,444	1,399	26	1.9	0.02
Ewes and ewe lambs	1,208	1,279	1,234	21	1.7	0.16
Goats	223	249	233	8	3.6	0.28

She-goats	170	194	181	9	5.1	0.75
Horses	99	138	122	15	11.9	-4.43
Work horses	97	126	114	10	8.8	-3.23
Poultry	13,183	14,736	13,814	519	3.8	-0.51
Adult laying poultry	5,608	7,868	7,132	705	9.9	-1.77
Bees (thou families)	193	252	224	24	10.6	3.25
Rabbits	54	79	74	8	11.0	-4.14

Source: Author's elaboration based on NIS data, Tempo Online

Livestock populations have low variability. In 11 categories, the coefficient of variability is below 10%, which means that the livestock sector in the North-East Region contributes to reducing the imbalance compared to the crop sector (Table 9).

Table 9. Grouping of animal categories in the North-East Region based on the coefficient of variability (CV%) in the period 2014-2022

CV < 10%	11 categories: ewes and ewe lambs; sheep; goats; poultry; she-goats; cows and female buffaloes; cows, female buffaloes, and heifers; sows for breeding; work horses; bovine animals; adult laying poultry
10% < CV < 20%	5 categories: bees, rabbits, horses, pigs, heifers
20% < CV < 30%	1 category: gilts for reproduction

Source: Author's elaboration based on NIS data, Tempo Online

Regarding the density of livestock per 100 ha, it is presented as follows:

Bovines have a higher density on average in the North-East Region, with 68.5% more animals per 100 ha of land compared to the national average (25 bovines per 100 ha in the North-East Region, compared to 15 bovines per 100 ha nationally). The North-East Region includes counties with mountainous areas, which favour livestock farming. The county with the highest bovine density per 100 ha is Suceava (38.7 bovines per 100 ha of land), followed by Neamț (26.3 bovine per 100 ha), Botoșani (26.3 bovine per 100 ha), Iași (23.4 bovines per 100 ha), Bacău (18.2 bovines per 100 ha) and Vaslui (15.6 bovines per 100 ha). The category *cows, female buffaloes and heifers* is 57.7% higher than the national average (15.3 head per 100 ha compared to the national average of 9.7 head per 100 ha). The regional average density for the categories *pigs* (35.8 head per 100 ha) and *sheep and goats* (86.6 head per 100 ha) is not significantly different from the national average. However, there are counties in this region where the livestock density differs significantly from the regional and national average. In the category *pigs*, the counties Neamț (75.5 animals per 100 ha) and Bacău (48.6 animals per 100 ha) recorded significant variations in livestock density; in the category *gilts for breeding*, Neamț (5.5 animals per 100 ha) and Suceava (3.8 animals per

100 ha) and in the category *sheep and goats*, Neamț (93.9 animals per 100 ha) and Iași (93.7 animals per 100 ha) counties are above both the national average (89.2 animals per 100 ha) and the average for the North-East Region (86.6 animals per 100 ha).

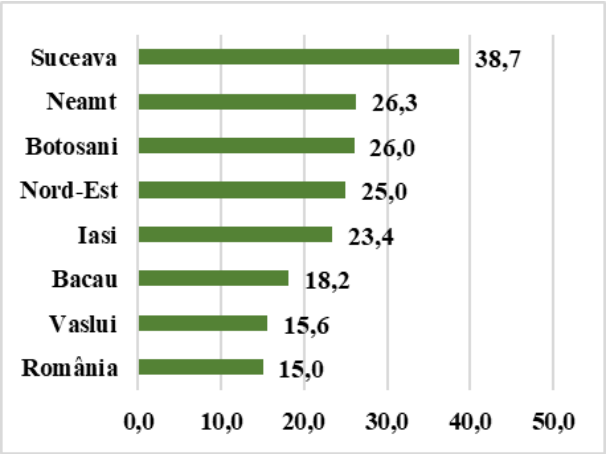

Fig. 7. Bovines, average density per 100 ha, 2014-2023 (number)

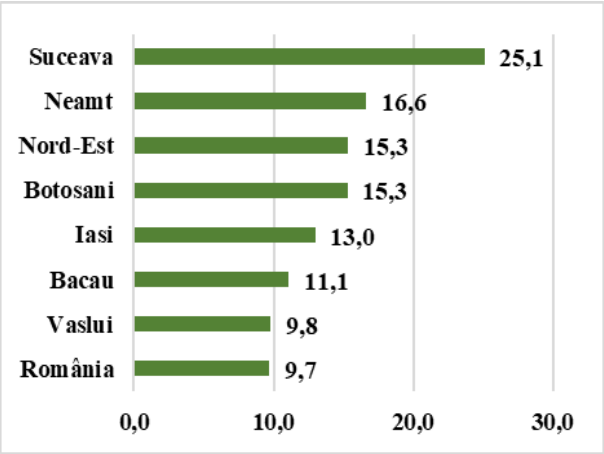

Fig. 8. Cows, buffaloes and heifers, average density per 100 ha, 2014-2023 (number)

Source: Author's elaboration based on NIS data, Tempo Online

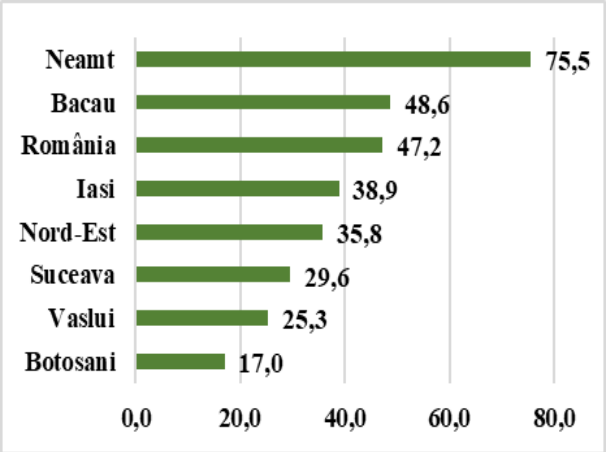

Fig. 9. Average density of pigs per 100 ha, 2014-2023 (number)

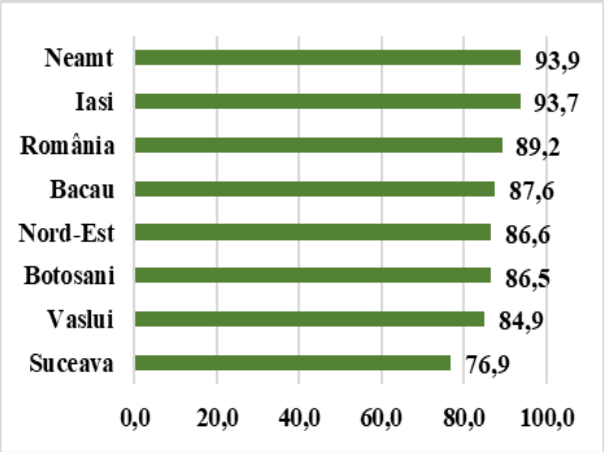

Fig. 10. Sheep and goats, average density per 100 ha, 2014-2023 (number)

Source: Author's elaboration based on NIS data, Tempo Online

Land use intensity was determined by analyzing the indicator of animal density returning per 100 hectares of land. Compared to other development regions, the North-East Region ranks first for bovine density at 100 hectares, followed by the North-West Region (20.8 heads per 100 hectares) and the Centre Region (20.1 heads per 100 hectares). For pigs, it ranks fourth after București-Ilfov, North-West, and Centre, and for sheep, it is sixth. The density of 38.7 animals per 100 hectares indicates extensive land use, where animals can mainly be reared on natural pastures,

promoting a more natural and healthier environment for both animals and better products for consumers.

4.6. Strategies and policies that lead to increased resilience and sustainability of agricultural production systems

Agriculture and rural areas play an important role in the European Green Deal, and the Common Agricultural Policy (CAP) 2023-2027 is the financial instrument that will contribute to the achievement of the objectives of the Farm to Fork Strategy and the Biodiversity Strategy, to strengthen resilience by reorienting the current EU food system towards a sustainable model (European Commission, n.d.). Particular attention is paid to priority areas and tasks for the implementation of the targets set by the Sustainable Development Strategy of Romania – Horizon 2030.

Assessing the impact of the different Common Agricultural Policy instruments to support farmers is important to understand the effectiveness of these policies and to make appropriate improvements to achieve economic, social and environmental objectives.

In Table 10, concrete measures are presented that will contribute to increasing the resilience and sustainability of the agricultural production systems.

Table 10. Measures to increase resilience and sustainability of agricultural production systems

Interventions	Contribution to resilience and sustainability
Pillar I includes income and conditionality linked to good environmental practices and economic support	
Direct payments	It helps *stabilize farmers' incomes* by protecting them from market price fluctuations
Basic Income Support for Sustainability (BISS)	*Sustainability* through cross-compliance – farmers comply with cross-compliance rules to receive payments
Complementary Redistributive Income Support for Sustainability (CRISS)	*Economic resilience* contributes to the viability of small and medium-sized farms
Complementary income support for young farmers	Generational resilience and *long-term sustainability* encourage innovation and farm modernization
Eco-scheme	Important intervention for the environment and climate – supports green practices such as soil cover, grassland, and organic farming
Coupled income support	*Sector resilience* – supporting key sectors for food security
Fruit and vegetable interventions	*Integrates sustainability* into the food chain – supports green investments in cooperatives and processing
Cross-compliance (GAEC; SMR)	Pillar I sustainability foundation – makes all payments

	conditional on respect for the environment and animal welfare
Pillar II contributes to financing investments, compensation, and direct innovation for climate, environment, and rural development	
DR - 10 - Agri-environment and climate	*Sustainability* with direct environmental impact – payments for biodiversity, soil, and water conservation
DR-11 - Organic farming	Green transition – supports eco-friendly farms throughout the chain
DR-13 - Disadvantaged areas	*Territorial resilience* – prevents abandonment in mountainous or vulnerable areas
DR-15 - Risk management	*Adaptive crisis response* – insurance, mutual funds, climate risk
DR-22 - Irrigation infrastructure	Drought resistance and water efficiency – support for modern, energy-efficient irrigation
DR-24 - Forestry technologies	*Resilient forest ecosystems* – supporting biodiversity and forest adaptation
DR-26 - Short and local chains	*Economic and social sustainability* – promotes local selling and cooperation between farmers

Source: National Strategic Plan (NSP) 2023-2027

Knowledge of the common agricultural policy instruments to support farmers is important to understand the effectiveness of these policies and to make appropriate improvements in order to achieve economic, social, and environmental objectives.

Policies and governance have the role of creating a favourable environment for the development of sustainable and resilient agriculture. The efficiency of subsidy policies can be assessed by the rate of adoption of sustainable technologies.

Promoting sustainability in agriculture could be seen in terms of policies from the perspective of allocating funds to promote organic and sustainable agriculture through the application of organic practices, waste management, protection of water resources, afforestation, etc.

Adaptation to climate change is determined by adaptation plans and measures that aim to promote drought-resistant crops and flood protection measures by facilitating farmers' access to meteorological information and short- and long-term forecasts to support cultivation decisions.

Equity policies target programs dedicated to young farmers to help them enter the agricultural sector, as well as support for small farmers through subsidies, access to credit, training programs, and infrastructure, with the aim of reducing economic disparities between large and small farms.

The extent to which farmers benefit from training and technical assistance through government programs is determined by the capacity of agricultural policies

to allow access to agricultural extension services to receive training and technical assistance.

Integrated approach to regulations, financial support, collabouration between the public and private sectors, technological innovation, social equity, etc., all of which can significantly contribute to increasing the resilience of agricultural systems in the face of current challenges.

5. Conclusion

In this paper, a series of growth and economic efficiency indicators were analyzed. Based on the analyzed indicators, the conclusions regarding the resilience and sustainability of agricultural production systems in the North-East Region can be summarized as follows:

▪ Both regional GDP and GVA in agriculture are increasing, which means a positive contribution of agriculture to regional economic development, but relative GVA is decreasing, signifying the modernization and development of the economy in the North-East Region.

▪ Labour productivity in the North-East Region is showing an upward trend. In 2021, this increase is explained by the reduction of the population employed in agriculture, but it can also be explained by the accumulation of capital due to the development of the regional economy. Although labour productivity in agriculture is increasing, it continues to be low compared to industry.

▪ The remuneration of employees in agriculture compared to the remuneration of employees in industry is increasing in both areas, but wage levels in agriculture are lower than in industry, which could lead to labour migration and a decrease in the population employed in agriculture.

▪ Rural household income from agriculture represents a small percentage of total household income, which means a dependence on other resources. The lack of income diversification in rural areas makes households more economically vulnerable.

▪ Gross fixed capital formation (GFCF) highlights a lower level of investment in agriculture, which means a weak modernization and a lack of confidence in the long-term viability of the sector. The difference between agriculture and industry is due to the specifics of agricultural activities, the risks associated with agricultural activities, but also to the perception of investors.

▪ Production yields in field crops: the variability of the yield assessed by the coefficient of variation signals vulnerabilities to climate change or can be determined

by problems related to access to inputs, such as access to water resources, fertilizers, or seeds, etc.

▪ The declining livestock populations in the North-East Region could be viewed from the perspective of insufficient subsidization of the sector, but also due to the decrease in interest in livestock, which can affect the diversity of production and the resilience of agricultural systems.

▪ The National Strategic Plan 2023-2027 has an important role in the development of the agricultural sector and contributes to its stability. Inadequate or fragmented support contributes to poor performance in the sector. Local government has an important role in developing an integrated agricultural development plan, which would contribute to strengthening the resilience of agricultural systems.

The study could be improved with an analysis of agri-environmental indicators that demonstrate the resilience of agricultural production systems to climate change in the North-East Region, and from a social point of view, the study will also include an analysis of factors related to rural migration, access to education, and technology etc. In addition to aspects related to conjunctural factors (drought, COVID-19 pandemic, economic and geopolitical crises, etc.), it is also useful to assess sustainability to determine the competitive position of the North-East Region with other regions in Romania.

References

Ait Sidhoum, A., Dakpo, K. H., & Latruffe, L. (2022). Trade-offs between economic, environmental, and social sustainability on farms using a latent class frontier efficiency model: Evidence for Spanish crop farms. *PLoS One*, *17*(1), e0261190. https://doi.org/10.1371/journal.pone.0261190

Anghelache, C., & Manole, A. (2012). Seriile dinamice/cronologice (de timp). Prezentare teoretică, structură, relațiile dintre indici [Dynamic/chronological (time) series: Theoretical presentation, structure, relationships between indices]. *Romanian Statistical Review*, *10*, 68-77. https://www.revistadestatistica.ro/wp-content/uploads/2014/02/RRS_10_2012_A5_ro.pdf

Bănică, A., & Muntele, I. (Eds.). (2015). *Rezilienţă şi teritoriu. Operaţionalizare conceptuală şi perspective metodologice* [*Resilience and Territory: Conceptual Operationalization and Methodological Perspectives*]. Iași: Terra Nostra. https://www.researchgate.net/publication/321973568

Blanco, C., & Raurich, X. (2022). Agricultural composition and labor productivity. *Journal of Development Economics*, *158*, 102934. https://doi.org/10.1016/j.jdeveco.2022.102934

Brooks, N. (2003). *Vulnerability, risk, and adaptation: A conceptual framework* (Tyndall Centre Working Paper No. 38). Norwich: Tyndall Centre for Climate Change Research. https://www.researchgate.net/publication/200032746

Conway, G. R. (1985). Agroecosystem analysis. *Agricultural Administration*, *20*(1), 31-55. https://doi.org/10.1016/0309-586X(85)90064-0

Darnhofer, I., Fairweather, J., & Moller, H. (2010). Assessing a farm's sustainability: Insights from resilience thinking. *International Journal of Agricultural Sustainability*, *8*(3), 186-198. https://doi.org/10.3763/ijas.2010.0480

Dănciulescu, D. (2016). *Analiza seriilor de repartiție* [Material de curs] [*Analysis of frequency distribution series* [Lecture notes]]. University of Craiova. http://inf.ucv.ro/documents/danciulescu/curs4-curs-5-curs6.pdf

European Commission. (n.d.). The common agricultural policy at a glance. https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cap-2023-27_en

Eurostat. (n.d.). Glossary: Compensation of employees. https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Compensation_of_employees (Accessed 6 July 2025)

Gavrilescu, C., Toma, C., & Turtoi, C. (2012). Assessment of the sustainability degree of agricultural holdings in Macroregion 1 using the IDEA method. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Horticulture*, *69*(2), 122-130. https://journals.usamvcluj.ro/index.php/horticulture/article/view/8588

Latruffe, L., Diazabakana, A., Bockstaller, C., Desjeux, Y., Finn, J., Kelly, E., Ryan, M., & Uthes, S. (2016). Measurement of sustainability in agriculture: A review of indicators. *Studies in Agricultural Economics*, *118*(3), 123-130. https://ageconsearch.umn.edu/record/252980/?v=pdf

Lien, G., Hardaker, J. B., & Flaten, O. (2007). Risk and economic sustainability of crop farming systems. *Agricultural Systems*, *94*(2), 541-552. https://doi.org/10.1016/j.agsy.2007.01.006

Meuwissen, M. P. M., Feindt, P. H., Spiegel, A., Termeer, C. J. A. M., Mathijs, E., de Mey, Y., Finger, R., Balmann, A., Wauters, E., Urquhart, J., Vigani, M., Zawalińska, K., Herrera, H., Nicholas-Davies, P., Hansson, H., Paas, W., Slijper, T., Coopmans, I., Vroege, W., Ciechomska, A., Accatino, F., Kopainsky, B., Poortvliet, P. M., Candel, J. J. L., Maye, D., Severini, S., Senni, S., Soriano, B., Lagerkvist, C.-J., Peneva, M., Gavrilescu, C., & Reidsma, P. (2019). A framework to assess the resilience of farming systems. *Agricultural Systems*, *176*, 102656. https://doi.org/10.1016/j.agsy.2019.102656

Ministry of Agriculture and Rural Development. (2023). *Planul Național Strategic 2023–2027 (PNS) al României* [*Romania's National Strategic Plan 2023–2027 (NSP)*]. https://www.madr.ro/planul-national-strategic-pac-post-2020/implementare-ps-pac-2023-2027/ps-pac-2023-2027.html

National Institute of Statistics (NIS). (2023). *România durabilă. Indicatori naționali pentru dezvoltare durabilă. Orizont 2030* [*Sustainable Romania: National Indicators for Sustainable Development. Horizon 2030*]. Bucharest: National Institute of Statistics Publishing House. https://insse.ro/cms/files/POCA/Raport-INDD-Orizont2030-27042023.pdf

National Institute of Statistics (NIS). (2024a). *Precizări metodologice* [*Methodological Notes*]. https://insse.ro/cms/files/statistici/comunicate/com_anuale/venituri_si_cheltuieli/precizari_metodologice_2024.pdf

National Institute of Statistics (NIS). (2024b). http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table

North-East Regional Development Agency. (2006). *Strategia de Dezvoltare Regiunea Nord-Est* [*North-East Region Development Strategy*]. https://www.adrnordest.ro/user/file/library%20strategic%20ro/Strategia%20de%20Dezvoltare%20Regionala%20Nord-Est3.pdf

Pannell, D. J., & Glenn, N. A. (2000). A framework for the economic evaluation and selection of sustainability indicators in agriculture. *Ecological Economics*, *33*(1), 135-149. https://doi.org/10.1016/S0921-8009(99)00134-2

Tofan, A. (2004/2005). Productivitatea muncii în agricultură [Labour productivity in agriculture]. *Analele Științifice ale Universității „Alexandru Ioan Cuza" – Științe Economice*, *50/51*, 441-447. https://ideas.repec.org/a/aic/journl/y2005v50-51p441-447.html

Usigbe, J., Asem-Hiablie, S., Uyeh, D. D., Iyiola, O., Park, T., & Mallipeddi, R. (2024). Enhancing resilience in agricultural production systems with AI-based technologies. *Environment, Development and Sustainability*, *26*, 21955-21983. https://doi.org/10.1007/s10668-023-03588-0

Zaman, G., Georgescu, G. (Eds.), Goschin, Z., Antonescu, D., & Popa, F. (2015). *Dezvoltarea economică endogenă la nivel regional. Cazul României* [*Endogenous Economic Development at the Regional Level: The Case of Romania*]. Bucharest: Expert. https://www.researchgate.net/publication/282124806

Zampieri, M., Weissteiner, C. J., Grizzetti, B., Toreti, A., van den Berg, M., & Dentener, F. (2020). Estimating resilience of crop production systems: From theory to practice. *Science of the Total Environment*, *735*, 139378. https://doi.org/10.1016/j.scitotenv.2020.139378