THE IMPACT OF MODERN AGRICULTURAL TECHNOLOGIES ON CEREAL PRODUCTION EFFICIENCY IN ROMANIA

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Abstract

Given the ever-increasing need for food and the challenges of climate change, as well as the availability of European funding for agriculture, it is crucial to adopt advanced agricultural technologies to maintain and improve agricultural efficiency. This study aims to assess the impact of modern agricultural technologies on the efficiency of cereal production in Romania. Using data collected from N.I.S., we examined the relationship between the implementation of technologies such as irrigation systems, farm equipment and chemical fertilizers and grain yield, assessed as the relationship between total production and area of land cultivated, using multiple linear regression. Findings indicate that agricultural technology and infrastructure significantly influence the level of production. The increase in the number of tractors, ploughs and combines indicates a trend towards modernisation and mechanisation in the Romanian agricultural sector. This is in line with farmers' efforts to respond to the growing demand for cereal products and to benefit from the opportunities offered by the NRDP.

Key words: modern technologies, production efficiency, cereals, Romania

Modern agriculture has evolved rapidly in recent decades, with innovative technologies transforming the way agricultural production is managed and optimised. In the context of globalisation and climate change, the efficiency of agricultural production has become essential to meet the growing demands of the population and to ensure food security (Dumitru *et al*, 2024). In this context, it is essential to understand how different factors, such as the use of chemical fertilisers, agricultural mechanisation and irrigation, influence grain production in Romania.

The use of chemical fertilizers, although essential for increasing production, can have economic and ecological implications if not properly managed (Iancu *et al*, 2022). For example, in Brazil, it has been observed that increased consumption of nitrogen fertilizers is associated with a significant decrease in nitrogen use efficiency in recent years, with direct implications on greenhouse gas emissions (Liu *et al*, 2021).

In China, innovation in agricultural technology has been key to improving productivity and sustainability. Rural financial development, for example, has had a significant impact on agricultural technological innovation, contributing to sustainable agricultural development (Chen *et al,* 2022). In addition, socialized agricultural services have played a crucial role in the rapid modernization of agriculture, helping farmers adopt modern farming operations and improve production efficiency (Sandhu *et al*, 2021).

In cereals, nitrogen is an essential nutrient required for proper plant growth and development. Biochemical and genetic approaches have contributed to improving nitrogen use efficiency in cereal crops, with direct implications on fertilizer costs and productivity (Pires *et al*, 2015). Also, in China, the government has launched a socialized agricultural service system to help smallholder farmers upgrade rapidly. This system has helped farmers adopt modern farming operations to meet growing food and fiber demands (Chen *et al*, 2022; Jambul Abuladze, 2022).

Agriculture is an essential area for Romania's economic and social development. In recent decades, modern agricultural technologies have played a crucial role in improving the efficiency of cereal production, with a significant impact on productivity, sustainability and resilience in food production and agriculture (Tudor *et al*, 2023). With Romania's accession to the E.U., the premise of facilitating investments in technologies was created, both in terms of purchasing high-performance agricultural

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machinery, offering the possibility to compete with other European countries in this field, but also the possibility to invest in obsolete irrigation systems dating from the communist period (Bogos I.B., Sterie C M., 2023). European integration has also allowed foreign firms access to chemical products that contribute to increasing the performance of Romanian agricultural production (Micu *et al.*, 2022; Sterie C.M., Dumitru E.A., 2021). Also, digital technologies, such as photogrammetry using drones, have been introduced in agro-tourism activities to quickly and efficiently collect data needed to implement or develop research (Călina J. *et al.*, 2022).

Modern agricultural technologies, such as robotics, are inevitable in today's agriculture. Agriculture will benefit from the revolution in information and communication technologies, which is manifested in all areas: robotics, sensory perception, smarter decision support systems, data analytics and others (Solona O., 2022). In Romania, strategies have been adopted to disseminate agricultural technologies among farmers and specialists, such as the creation of institutes dealing with the dissemination of agricultural technologies and financial support for innovations and projects that address the issue of agricultural technology dissemination (Sterie & Dumitru, 2021).

MATERIAL AND METHOD

The present study is based on multiple linear regression of selected variables using IBM SPSS 20 statistical software. The data were collected from the NSI database, over a period from 2013-2022, representing also the second programming period in which Romania took part. Multiple linear regression is a statistical technique used to model and analyse relationships between two or more independent variables and a dependent variable (Bondina N. *et al.,* 2022). In multiple linear regression, it is assumed that there is a linear relationship between the independent variables and the dependent variable. The mathematical model for multiple linear regression is:

- $Y = \beta_0 + \beta_1 x_{1+} \beta_2 x_{2+} \ldots + \epsilon$

Next, the selected variables were coded according to the table below *(table 1):*

Table 1

Coding of variables

Variable	Coding	Define conf. NIS
Average cereal production	A.C.P.	The ratio of total area to total cereal production.
Tractors	T	is the number of tractors and main agricultural machinery in agriculture at the end of the year.
Tractor ploughs	P	
Self-propelled combine harvesters for grain harvesting	S.C.H.G	
Agricultural area set aside for irrigation	A.A.I.	is the area irrigated at least once in an agricultural year.
Chemical fertilisers	C.F.	industrial products which according to their content can be: nitrogenous, phosphate, potassium, they can also be mixed as complex fertilizers;

RESULTS AND DISCUSSIONS

Analysing the evolution of agricultural variables between 2013 and 2022, distinct trends and fluctuations can be observed within the Romanian agricultural sector. As regards A.C.P., there are notable fluctuations, with a peak in 2018, where the value reaches 6.0 t/ha, possibly reflecting favourable weather conditions or the implementation of efficient agricultural technologies in that year. In contrast, 2020 shows a significant decrease to 3.4 t/ha, a year possibly marked by unfavourable weather conditions or other challenges in the agricultural sector.

We see a consistent upward trend in T, indicating increasing adoption and accessibility of modern agricultural technology. In 2022, the number of T reached 244.8 thousand units, showing a sustainable increase from 191.3 thousand units in 2013, suggesting continued modernization and increased mechanization in farming practices.

P shows a relatively stable evolution with incremental growth over the years, highlighting a constant need for these tools in agricultural activities. Moderate variations in the number of P can be attributed to annual fluctuations in investments in agricultural equipment or in the cropping strategies adopted by farmers.

S.C.H.G, although showing minimal fluctuations, maintains a consistency in use, suggesting a constant reliance on these machines for grain harvesting. The stability in the number of S.C.H.G. may reflect a balance between the need and availability of this equipment in the Romanian agricultural sector.

The A.A.I. shows a slight increase in the agricultural area set aside for irrigation, reaching 3,064.9 thousand ha in 2021. This indicates a growing recognition of the importance of irrigation in maintaining and increasing agricultural production, especially in the context of climate change and weather variability.

In terms of C.F., an upward trend is observed, with a significant increase in 2018 and 2021. This suggests an intensive use of chemical fertilisers to optimise cereal production, reflecting farmers' efforts to maximise yields in the context of increasing demand in the cereal market *(figure 1).*

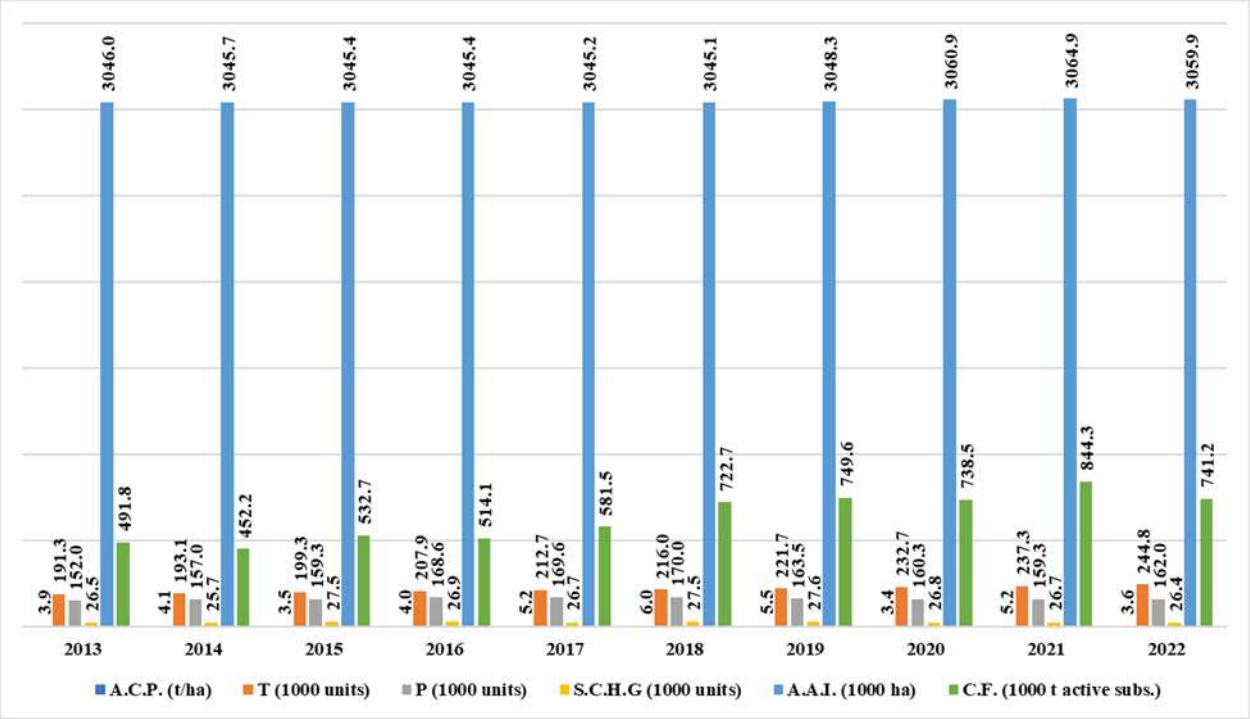

Figure 1 **Evolution of selected variables over the period 2013-2022**

During the period under review, average cereal production was around 4431.30 kg/ha. The annual variation, indicated by the standard deviation of 937.4 kg/ha suggests moderate fluctuations in cereal production over the years. The average number of physical agricultural tractors registered during the period analysed was 215671.50. A standard deviation of 18497.580 indicates a relatively constant variation in the number of agricultural tractors over the years.

For tractor ploughs, an average of 162170.80 units was observed, with a standard deviation of 5867.755, suggesting stability in the number over the period analysed. The average number of self-propelled combine harvesters was 26821.90, with a minimum standard deviation of 590.114, indicating a notable consistency in the use of this equipment in agriculture. The average consumption of chemical fertilizers was 636853.90 tonnes, with a standard deviation of 136790.773 tonnes, indicating significant variations in the use of chemical fertilizers over the period analysed.

The average agricultural area set aside for irrigation was around 3,050,675.30 ha, with a standard deviation of 7897.240 ha, reflecting a slight variation in irrigation set-asides over the years *(table 2).*

Table 1

Table 2. Descriptive statistics of the data

Variable	Mean	Std. Deviation	N
A.C.P.	4431.30	937.399	10
T	215671.50	18497.580	10
P	162170.80	5867.755	10
S.C.H.G	26821.90	590.114	10
A.A.I.	3050675.30	7897.240	10
C.F.	636853.90	136790.773	10

Average grain yield shows a moderate and positive correlation with Tractor Plows (r = 0.540), suggesting that as the number of tractor plows increases, there is a tendency for average grain yield to increase as well. This correlation is close to being statistically significant (p = 0.053). There is also a positive, but weaker, correlation between Average grain yield and Self-propelled combine harvesters (r = 0.391) and Chemical fertilizers (r = 0.415).

Physical farm tractors show a strong and positive correlation with Agricultural area set aside for irrigation (r = 0.840, p = 0.001) and Chemical fertilizer (r = 0.899, p < 0.001). This suggests that as the number of farm tractors increases, there is a tendency for agricultural area set aside for irrigation and chemical fertilizer consumption to increase as well. Agricultural area set aside for irrigation also has a strong and positive correlation with Chemical fertilizer (r = 0.752, p = 0.006) *(table 3).*

Table 3

Correlations between average cereal production and selected agricultural indicators (2013-2022)

		A.C.P.	T	P	S.C.H.G	A.A.I.	C.F.
Pearson Correlation	A.C.P.	1.000	.134	.540	.391	-.163	.415
	T	.134	1.000	.257	.128	.840	.899
	P	.540	.257	1.000	.452	-.228	.213
	S.C.H.G	.391	.128	.452	1.000	-.185	.352
	A.A.I.	-.163	.840	-.228	-.185	1.000	.752
	C.F.	.415	.899	.213	.352	.752	1.000
Sig. (1-tailed)	A.C.P.	.	.356	.053	.132	.326	.116
	T	.356	.	.237	.363	.001	.000
	P	.053	.237	.	.095	.263	.277
	S.C.H.G	.132	.363	.095	.	.304	.160
	A.A.I.	.326	.001	.263	.304	.	.006
	C.F.	.116	.000	.277	.160	.006	.

The regression model revealed by our analysis shows a strong relationship between the selected independent variables and Average Grain Production, with a coefficient of determination (R Square) of 0.943. This suggests that our variables explain about 94.3% of the variation in grain production. Moreover, after adjusting for the number of predictors, this value remains impressive at 87.1%.

These results can be understood in the broader context of Romanian agriculture. Increased demand for cereal products, together with the incentives offered by the National Rural Development Programme (NRDP), has led farmers to invest more in technology and agricultural infrastructure. This is evident in the increased number of tractors, ploughs and combine harvesters, as well as the expansion of irrigated areas. In addition, the increased use of chemical fertilisers reflects farmers' efforts to maximise production to meet growing demand.

The F-test, with a value of 13.199 and a significance of 0.013, confirms that our model is statistically significant. In addition, the Durbin-Watson value close to 2 suggests that the model is robust with no significant autocorrelation in the residuals.

In conclusion, our analysis highlights the positive impact of investment and innovation in agriculture on grain production in Romania.

The ANOVA table gives us an insight into the overall significance of the regression model. With a sum of squares for the regression of 7,456,494,221 and a sum of residual squares of 451,949,879, our model shows significant variation explained by the independent variables.

The F-value of 13.199 is an indicator of the power of our model to predict Average Grain Production based on the selected variables. A p-value (Sig.) of 0.013, below the standard threshold of 0.05, confirms that our model is statistically significant. This means that there is a very low probability that the relationships observed in the data are due to chance.

Although one might expect more tractors to lead to increased grain production, the model indicates a slight decrease of 0.069 units for each additional tractor. This can be interpreted in the context of possible technology saturation in some regions, where adding more tractors no longer brings significant benefits.

Reflecting the importance of land preparation for sowing, we observe that for each additional plough, output increases by 0.079 units. This highlights the need for appropriate equipment to maximise yields (Table 4).

Table 4.

Detailed multiple line regression analysis for average cereal production (2013-2022) by selected agricultural indicators

Model Summary[b]										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.971[a]	.943	.871	336.136	.943	13.199	5	4	.013	3.166

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7456494.221	5	1491298.844	13.199	.013[b]
	Residual	451949.879	4	112987.470		
	Total	7908444.100	9			

Coefficients[a]									
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	309129.603	166051.352		1.862	.136			
	A.C.P.	-.069	.026	-1.361	-2.704	.054	.134	-.804	-.323
	T	.079	.037	.494	2.126	.101	.540	.728	.254
	P	-1.002	.297	-.631	-3.375	.028	.391	-.860	-.403
	S.C.H.G	-.094	.053	-.790	-1.760	.153	-.163	-.661	-.210
	A.A.I.	.016	.002	2.349	6.585	.003	.415	.957	.787

Although irrigation is essential for crop production, the model shows a slight decrease in yield with increasing irrigated area. This may reflect the need to upgrade irrigation systems or inefficient use of water. Confirming the importance of nutrients for the soil, for each additional unit of chemical fertiliser, yield increases by 0.016 units. This is a clear indicator of the benefits of chemical fertilisers in modern agriculture *(table 4)*

CONCLUSIONS

Analysis of data from 2013-2022 provides an in-depth insight into the factors influencing average cereal production in Romania. The statistical results highlight a number of significant trends and relationships between selected variables and cereal production.

First, it is evident that agricultural technology and infrastructure have a significant impact on production. The increase in the number of tractors, ploughs and combines indicates a trend towards modernisation and mechanisation in the Romanian agricultural sector. This is in line with farmers' efforts to meet the growing demand for cereal products and to benefit from the opportunities offered by the National Rural Development Programme (NRDP).

However, there are also some ambiguous results, although one might expect more tractors to lead to increased production, the data suggest otherwise. This can be interpreted as a possible saturation of technology in certain regions or as farmers are buying new and efficient agricultural machinery, while old ones are kept on the farm for other agricultural activities, leading to a higher increase in the number of tractors.

The importance of preparing the land for sowing is also underlined by the positive relationship between the number of ploughs and cereal production. This reiterates the fact that, despite technological advances, certain traditional farming practices remain essential for optimal yields.

As for irrigation, although it is essential for agriculture, the model suggests an inverse relationship between irrigated area and cereal production. This may indicate an urgent need to modernise and optimise existing irrigation systems.

As the demand for cereal products continues to grow and amidst climate change, it is essential that farmers and policy makers understand these dynamics and invest in technology, training and sustainable farming practices to ensure a prosperous future for Romanian agriculture.

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