DOI: 10.46541/978-86-7233-428-9_427

XXIX International Scientific Conference
Strategic Management
and Decision Support Systems
in Strategic Management
SM2024
Subotica (Serbia), 17-18 May, 2024

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THE INFLUENCE OF USING MINERAL FERTILIZERS ON THE OUTPUT IN CROP PRODUCTION: CASE OF THE SOUTH BAČKA DISTRICT

Abstract: In scientific research in the field of agricultural economics, in the last decade, the ecological effect of the use of chemical inputs has been increasingly in focus. Changes within the EU's Common Agricultural Policy, stimulated by the European Green Deal, contributed significantly to this trend. Following the above, the goal of this research is to determine the effect of mineral fertilizers on the output in different lines of crop production in South Bačka District. The FADN database was used in the work. The results showed that using mineral fertilizers is a significant factor in crop production. Also, a positive correlation between the use of mineral fertilizers and yield was identified in the production of corn and soybeans. In contrast, a negative correlation was present in the case of wheat and sunflower production. The negative correlation suggests that the mineral fertilizer was used suboptimally and that weather conditions significantly affected this production and prevented the absorption of nutrients. In addition, there are nitrogen surpluses, which threaten the environment. The estimated losses are 26 tons of nitrogen.

Keywords: Crop production, Fertilizers, FADN

1. INTRODUCTION

One of the key topics of contemporary European policies is the use of chemical inputs, especially the use of nitrogen fertilizers. One of the critical goals of the Farm to Fork strategy is to reduce nutrient losses by at least 50% while ensuring that there is no deterioration in soil fertility (European Commission, 2024). Also, this Strategy emphasizes the problem of the excess of nutrients (primarily nitrogen and phosphorus) in the environment, stemming from excess use and the fact that not all nutrients used in agriculture are effectively absorbed by plants, which is another primary source of air, soil and water pollution and climate impacts. In addition, this Strategy was also the basic document for the creation of the new Common Agricultural Policy 2023-2027.

In the Republic of Serbia's Strategy of Agriculture and Rural Development for the period 2014-2024, one of the priorities is achieving sustainable economic, ecological, and social development goals, in which multifunctional agriculture and rural development have a unique role (MAFWM, 2014). Although an environmental goal was prioritized, special attention was not directed to chemical inputs. As this Strategy expires in 2024, the use of chemical inputs may be the focus of the new Strategy.

The fundamental question is, how does using mineral fertilizers impact output? Two primary objectives of the research arise from this question. The first goal is to determine the effects of fertilizer use on output based on the approximation of the production function. Another goal is to find out how strong the correlation between nutrient use (nitrogen, phosphorus, and potassium) and yields in different crop productions (corn, wheat, soybean, and sunflower) is. Additionally, nitrogen losses are observed in the productions mentioned above.

Approximation of agricultural production function was a subject in a few scientific papers in previous periods. Based on data for the period 2008-2019, Đokić et al. (2024) results showed that the increase in the use of mineral fertilizers is a key source of production growth among production factors. Similar conclusions concerning the function of partial productivity were drawn from Đokić et al. (2022). The research results showed that using mineral fertilizers is a crucial source of growth in land productivity in these countries. The importance of mineral fertilizers for production growth is undeniable, and nitrogen is considered an essential nutrient. Nitrogen is responsible for feeding approximately 48% of the global population, but a large portion of the N applied to the agricultural land is lost to the environment (De Notaris et al. 2018).
This research is structured as follows: After the introduction, the research methodology and database are explained. Then, the results of the research and discussion follow. Finally, basic conclusions and guidelines for potential future research are given.

2. MATERIALS AND METHODS

This research used the FADN (Farm Accountancy Data Network) database. In last few years, this database is widely used in Serbia (e.g. Popović et al. 2020; Novaković et al. 2020; Milić et al. 2023). Only agricultural farms from the South Bačka district were analyzed, assuming they produce in similar agri-environmental and climate conditions. The sample includes 51 farms that produce arable crops, the most common of which are maize, wheat, soybeans, and sunflower. The data refers to the year 2022. The research methodology includes three segments. The first segment implies the approximation of the Cobb-Douglas production function based on the following variables:

- Total output (Y) - Total value of output of crops and crop products in RSD.
- Total labour input (X_1) - Total labour input of holding expressed in annual work units (full-time person equivalents).
- Total utilized agricultural area (X_2) - Total utilized agricultural area of farm. Does not include areas used for mushrooms, land rented for less than one year on an occasional basis, woodland and other farm areas (roads, ponds, non-farmed areas, etc.). It consists of land in owner occupation, rented land, land in sharecropping. It is expressed in hectares.
- Capital (X_3) - Capital is calculated as fixed assets less the value of land in accordance with Czubak et al. (2021).
- Fertilizers (X_4) - Purchased fertilizers and soil improvers (excluding those used for forests).

The created model has the following form:

$$\ln Y = \alpha + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \gamma$$

Unlike the production function model for the entire agricultural production (Swinnen & Vranken, 2010), the critical difference with this model is that it does not include livestock, as it only refers to crop production. Unlike older models that are based on the FAOSTAT database, the FADN database enables the incorporation of intermediate consumption in the model. However, as this paper aims to analyze the effect of mineral fertilizer, this variable is taken as an approximation of intermediate consumption.

The second segment involves creating a correlation matrix between nitrogen fertilizer consumption and actual yields in the production of corn, wheat, soybeans, and sunflowers to determine which production line this interdependence is most significant. The last research stage is a calculation of nitrogen losses by production lines within the given sample.

3. RESULTS AND DISCUSSION

In the model (Picture 1), the normality of the distribution of residuals was tested by the Shapiro-Wilk W test for normal data, and autocorrelation, multicollinearity and heteroskedasticity were also tested. Autocorrelation does not exist based on the distribution of residuals, while the VIF test (Mean VIF = 3.4) proved that there is no harmful multicollinearity. Heteroskedasticity was examined based on the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity and the null hypothesis of homoskedasticity was accepted ($p=0.2378$). Using the Ramsey RESET test, the null hypothesis that the model has no omitted variables was tested, which is accepted ($p=0.2607$), and it is confirmed that the specification of the model is correct. Descriptive statistics is given in Appendix.

Source	SS	df	MS	Number of obs =	51
				F(4, 46) =	131.22
Model	37.7722539	4	9.44306347	Prob > F =	0.0000
Residual	3.31042549	46	.071965772	R-squared =	0.9194
				Adj R-squared =	0.9124
Total	41.0826794	50	.821653587	Root MSE =	.26826

Y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Labour	.0456134	.0878178	0.52	0.606	-.1311547	.2223815
Land	.6359721	.1098827	5.79	0.000	.4147898	.8571544
Capital	.0195766	.0430605	0.45	0.652	-.0670997	.106253
Fertilisers	.3730315	.0838569	4.45	0.000	.2042362	.5418267
_cons	7.898242	1.115567	7.08	0.000	5.652722	10.14376

Picture 1: Estimation of the regresion model using Ordinary least square (OLS)
Source: Author's calculation based on FADN, 2024.

The model explained 91.94% of the variations of the dependent variable, which is indicated by the high coefficient of determination. What is most significant in the estimated model, from the point of view of the subject of this research, is the statistically significant positive influence of the independent variable mineral fertilizer on the dependent variable, i.e. output. The results of the analysis show that with one added unit of mineral fertilizer costs, the output increases by 0.37 with other unchanged units. This coefficient is higher than in the case of the research conducted by Đokić et al. (2024), which refers to the entire agriculture in the transitional countries of Europe and amounts to 0.10. Such a result is expected considering that livestock production is included in that model, so the influence of mineral fertilizer on output is weaker.

Table 1 shows correlation between mineral fertilizers use and yields in crop production. In the observed sample, corn was produced on 879 hectares, with an average yield of 5.93 t/ha. This yield is above the average for the entire country, 4.9 t/ha, and the Vojvodina region, 5.4 t/ha (Statistical Office of the Republic of Serbia, 2024). The use of mineral fertilizers amounted to an average of 448 kg/ha, while nutrient levels were nitrogen 125 kg/ha, phosphorus 39 kg/ha, and potassium 36 kg/ha. A positive correlation was observed between corn yield and the use of all nutrients, with nitrogen having the highest coefficient. In addition, assuming that the plant absorbs 19.3 kg of nitrogen per ton of yield, the average nitrogen loss is 27.87 kg/ha (Table 2). Nitrogen excess is not present in all areas but on 656 hectares (75% of the total sample). The total loss amounts to 18 tons of nitrogen, representing an economic loss for the farm and a potential environmental problem for society.

Table 1: Correlation between mineral fertilizers use and yields in crop production and nitrogen surpluses.

	Correlation N - Yield	Correlation P - Yield	Correlation K - Yield
Corn	0.7098	0.3579	0.5173
Wheat	-0.1304	-0.4221	-0.4221
Soybean	0.4719	0.2279	0.3432
Sunflower	-0.9336	-0.2501	-0.2663

Source: Author's calculation based on FADN, 2024.

A positive correlation is also present in the case of soybeans, although the coefficients are lower than in the case of corn. Soybean was produced on 546 hectares, with an average yield of 1.8 t/ha, slightly higher than Serbia and Vojvodina, 1.7 t/ha (Statistical Office of the Republic of Serbia, 2024). The average application of mineral fertilizer was 246 kg/ha (N-52 kg/ha; P - 31 kg/ha; K-29 kg/ha). If the plant absorbs 44 kg of nitrogen per ton of yield, the average nitrogen loss is 27.37 kg/ha, and the total loss is 3 tons. Unlike corn production, nitrogen losses occurred only on 82 hectares (15% of the total harvested area), which suggests that nitrogen fertilizers are used more efficiently in soybean production.

Table 2: Nitrogen surpluses in crop production.

	Average N loss per hectare (kg/ha)	Total N surplus (kg)	Area (ha)[1]
Corn	27.87	18,290	656
Wheat	39.45	3,266	82
Soybean	27.37	1,683	61
Sunflower	35.06	2,804	80
All	29.57	26,044	880

Source: Author's calculation based on FADN, 2024.

On the other hand, in the case of sunflowers, there is a negative correlation. This situation is most likely the result of bad weather conditions that did not allow adequate absorption of nutrients, but also bad management, as evidenced by nitrogen losses of 35 kg/ha. The average use of mineral fertilizer was 298 kg/ha (N-57 kg/ha; P-36 kg/ha; K-36 kg/ha). Sunflower was produced on 192 hectares, of which 80 hectares (42% of total harvested area) showed excessive nitrogen use. The average yield was 2.5 t/ha, corresponding to the average yields at the level of the state and Vojvodina (Statistical Office of the Republic of Serbia, 2024).

In the case of wheat, there is a negative correlation between yield and the use of mineral fertilizers. In addition, the highest nitrogen loss per hectare was recorded at 39 kg/ha. The average yield of wheat was 6.8 t/ha, significantly above the national average (4.9 t/ha) and the average in Vojvodina (5.4 t/ha). The use of mineral fertilizer amounted to 460 kg/ha, which testifies to extremely intensive production in this area. This sample includes 196 hectares under wheat, of which excessive nitrogen fertilizer use is noticeable on 82 hectares (41% of total area).

If the complete sample is observed, excessive nitrogen use occurred in 50% of the areas, creating surpluses of around 26 tons. This suggests that there is a space for improving nitrogen management to reduce economic losses and environmental consequences. Also, this signals the creators of agricultural policy in Serbia to devote special attention to solving this problem in the coming period.

4. CONCLUSIONS

Based on the research results, it is possible to conclude the following:

- Mineral fertilizer is a crucial factor in crop production, as evidenced by the approximation of the Cobb-Douglas production function. In this case, most output variations are determined by changes in mineral fertilizers and land use. These results are consistent with previous research.
- In the case of corn and soybean production, there is a positive correlation between the yield and the use of mineral fertilizer for each nutrient separately, while the correlation coefficient is negative in the case of wheat and sunflower. The absorption of the active substance from the mineral fertilizer is conditioned by weather, so it is possible that these crops' climate conditions were inadequate. This conclusion follows the critical limitation of this research, which is that the analysis was done only for one production year.
- Excessive use of nitrogen fertilizer is noticeable in all production lines. Nitrogen surpluses appeared in as much as 50% of the observed area. In addition to harmful effects on the farm's economic results, such surpluses also create a negative ecological effect.
- Following the results and achievements of modern agricultural policy, the creators of agricultural policy should pay special attention to the problem of using nitrogen fertilizers in Serbia when creating a new strategy.

Future research can go in several directions. First, it is necessary to extend the analysis to the regional or national level and increase the sample. Second, to better understand the effect of weather conditions, it is necessary to extend the analysis to a longer period, and it is recommended that at least three years be covered. Also, based on the available data within the FADN, it is essential to investigate the factors on the farm that influence excessive use of nitrogen fertilizers.

[1] It refers to the area where excess nitrogen use has appeared.

5. APPENDIX

Variable	Obs	Mean	Std. Dev.	Min	Max
Y	51	15.42597	.9064511	13.57484	17.24055
Labour	51	-.1575216	.6057271	-1.272966	1.064711
Land	51	3.367554	.8117444	1.526056	4.919981
Capital	51	14.92305	1.214902	12.44312	17.45612
Fertilisers	51	13.67472	.9277441	11.36326	15.61687

Picture A1: Descriptive statistics of variables
Source: Author's calculation based on FADN, 2024.

	Y	Labour	Land	Capital	Fertil~s
Y	1.0000				
Labour	0.6786	1.0000			
Land	0.9391	0.6817	1.0000		
Capital	0.6318	0.5410	0.6716	1.0000	
Fertilisers	0.9097	0.6436	0.8675	0.5411	1.0000

Picture A2: Correlation analysis of variables
Source: Author's calculation based on FADN, 2024.

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ACKNOWLEDGEMENT:
This paper presents a part of the research from the Erasmus + project: Jean Monnet Centre of Excellence: Sustainable Agriculture for Greener Future - AgriGREEN (101085183).