APPLICATION SIMULATING CEREAL FERTILIZATION: CASE STUDY ON WHEAT

RUJESCU CIPRIAN[1], SALA FLORIN*[2]
[1] Banat`s University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara, Faculty of Management and Rural Tourism, Romania
[2] Banat`s University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara, Faculty of Agriculture, Romania
*Corresponding author's e-mail: florin_sala@usab-tm.ro

Abstract: *The creation of a spreadsheet application useful in simulating the response of cereal production to fertilization with N, P and K is presented. The inputs consist of elements that describe the fertilizing substances, estimated fixed costs, estimated sale price of cereals and production area. Using a production function, estimates of production and yield will be rendered as an image, values obtained as a result of the total quantities of fertilizer products administered.*

Key words*: fertilization simulation, N, P, K, crop production*

INTRODUCTION

Cereal crops are an important component of European Union agriculture, and wheat is representing about half of the area cultivated with cereals. Maize and barley each cover about 16% of this surface. In Romania, there are still a lot of family farms. Of the approximately 8.1 million hectares cultivated, over 5.1 are belonging to small farms. In 2019 the average wheat production in Romania was 4750 kg/ha [12,14,15].

If in medium or large-size farms the problem of optimal use of production factors is already a classic aspect, however, this requirement is not frequently implemented in small individual farms. The causes are obvious, especially due to the high costs involved in software and technical solutions, but also the difficult highlighting of a large number of production factors or even the low interest in such studies [4].

Fertilizers used in cereal crops are found in various forms when presented for sale. The practice of small farmers is to use such complex products with NPK having different active substance contents in percentage terms, followed by a supplementation of the nitrogen content, by simple nitrogen fertilizers. Urea or ammonium nitrate is often used for this purpose.

Commercial fertilizer products have various concentrations of the active substance, namely nitrogen, phosphorus or potassium. Moreover, the complex products on the market have different proportions in which the active substances are present in various commercial forms. The packs having different quantities, the various production areas are all together elements that immediately generate some difficulty in calculating the total amount of active substance administered per unit of surface.

The purpose of the paper is to present a spreadsheet application, which converts the initial data on commercial fertilizers into total quantities of active substance per unit area. Moreover, using production functions, the simulation of a fertilization scheme will be taken into consideration using this application.

MATERIALS AND METHODS

The mathematical method of calculating the production and indirect profit is based on two-dimensional production functions, which are more precisely functions of two real variables and describe parabolic surfaces, often used in the practice of optimizing the allocation of fertilizer products. Algebraic calculations that determine the amounts of active substance used, their images through the two-dimensional function, are carried out using Microsoft Excel [2,3,7,13]. In the example presented herein, a production function was used to estimate the profit by simulating a fertilization scheme. This indicates the response of wheat production to cumulative N and PK. The function was set for the Alex wheat variety at Didactic Station within BUASVM Timişoara [8,9].

RESEARCH RESULTS

The problems of optimization in agriculture is an element of study that is always challenging due to changes in the response of cultivated plants crops to various external stimuli, changes in agricultural area, plants locations, farm systems, etc. [5]. When it is required to set a balance between the quantitative and qualitative aspects of products, food safety issues [1] can also be analyzed through optimal policies of allocation chemicals.

The specialized literature indicates multiple production functions [6] that describe the links between production and the factors that determine it, also in other branches of the economy, not only in agriculture. There are also concerns of the authors for determining such functions, updated to the vegetation conditions of some varieties of wheat or corn hybrids, obtained by statistical determinations.

Complex forms of NPK, with a total N of 15%-20%, total P_2O_5 amounting to 15%-20% respectively soluble K_2O also amounting to 15%-20% are used from the multiple types of fertilizing substances. The granulated urea having 46.6% total content of N or or granulated ammonium nitrate with a total nitrogen concentration of 33.5%, are assortments often used to supplement N doses [10]. A product type very common on the market of these products is fertilizers packed in bags weighting approximately 50 kg. Nitrogen-based supplements in the form of granulated ammonium nitrate or in the form of granulated urea can also be found in similar packages. In fact, the option of purchasing fertilizers packaged in packages not exceeding 50 kg brings multiple benefits in terms of how they are handled when working small lots of agricultural land.

A common practice in small farms is to repeat every year the same fertilization scheme known as having good results locally. Even if the fertilization scheme is acceptable in terms of productivity, the economic calculations are often erroneous. Specifically, it is not enough to use exclusively the technical functions of production to fully describe the economic process studied. Frequent changes in cereal [11] and fertilizer prices lead to different needs requiring for a case-by-case approach of the problem of optimal allocation of factors influencing production.

In view of developing the spreadsheet application, we chose to express the production function using the cumulative doses of PK starting from the hypothesis that farmers who manage small farms often choose to supplement nitrogen doses after previously crops were fertilized with complex fertilizers containing N, P and K. This will create two distinct variables, on the one hand N and on the other hand Cumulative PK. The expression f (N, PK) indicates the value of the production expressed as a function of the variables N, PK.

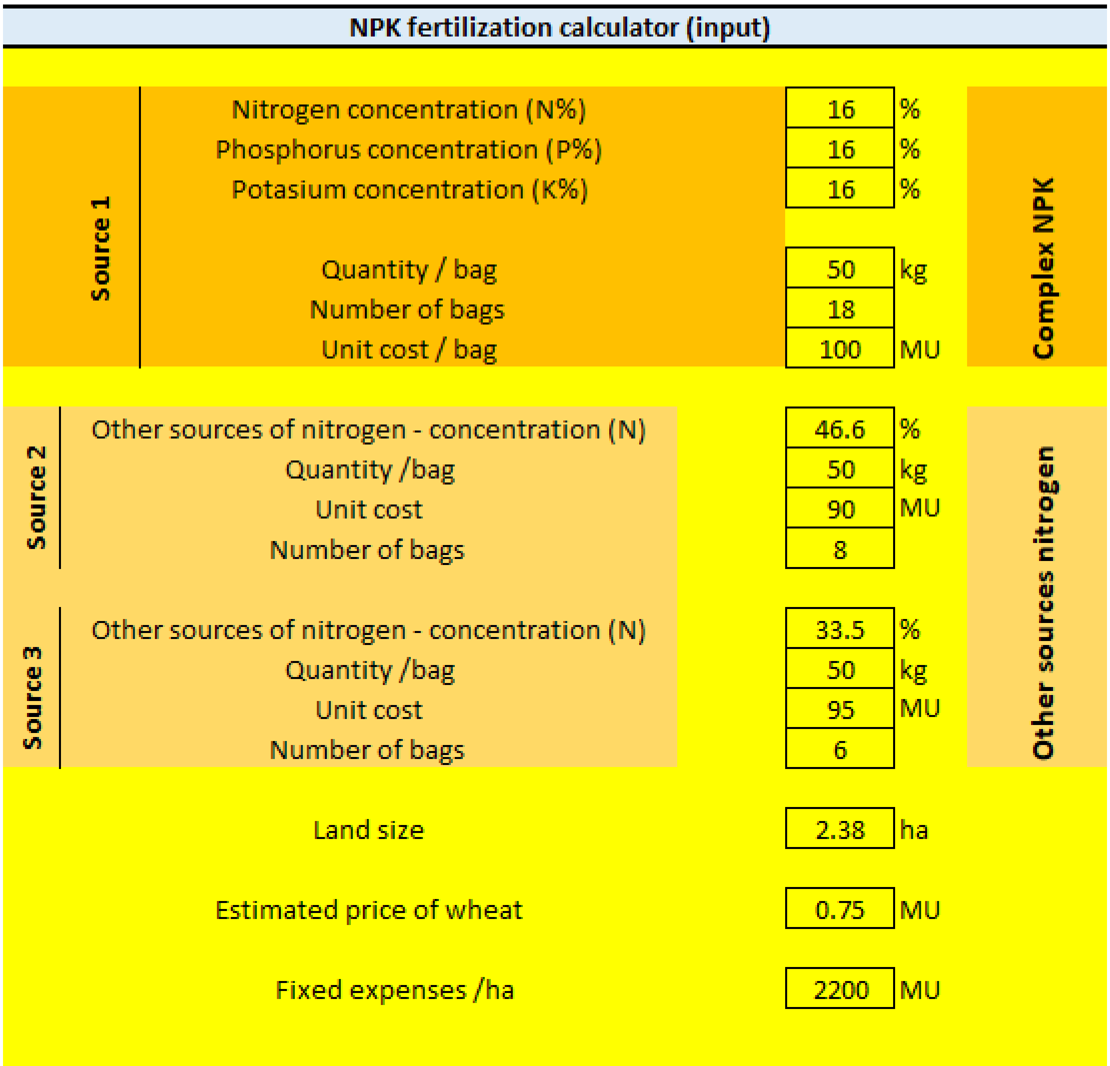
The production function used has the following formula:

$$f(N, PK) = a_1 \times N^2 + a_2 \times PK^2 + a_3 \times N \times PK + a_4 \times N + a_5 \times PK + a_6$$

where: a_i, $i=1,\ldots,6$ are coefficients of the function; N represents the amount of nitrogen expressed in kg/ha, and PK the cumulative doses of Phosphorus and Potassium in kg/ha.

Knowing the type of NPK complex fertilizer used, the share in active substance of the three compounds, the quantities of fertilizers, the production area, we will determine the amount of N and PK per unit area using algebraic calculations made using Microsoft Excel. Specifically, the amount of nitrogen in the NPK complex determined by calculating the share of N in the total amount will be added to the amount of N as active substance in the additional nitrogen sources. The value obtained in the end will be related to the production area. We proceed similarly for PK. The estimated prices of cereals, the area, fixed costs of production per hectare are also inputs of the application that allow the estimation of profit by the production function.

The following values were used to illustrate how to use the spreadsheet. The two images presented in Figures 1 and 2 shows the input and output values that represent a pertinent practical situation. Microsoft Excel's mathematical calculation facilities provide a quick way to calculate useful items based on previously filled in fields.



NPK fertilization calculator (input)				
Source 1	Nitrogen concentration (N%)	16	%	Complex NPK
	Phosphorus concentration (P%)	16	%	
	Potasium concentration (K%)	16	%	
	Quantity / bag	50	kg	
	Number of bags	18		
	Unit cost / bag	100	MU	
Source 2	Other sources of nitrogen - concentration (N)	46.6	%	Other sources nitrogen
	Quantity /bag	50	kg	
	Unit cost	90	MU	
	Number of bags	8		
Source 3	Other sources of nitrogen - concentration (N)	33.5	%	
	Quantity /bag	50	kg	
	Unit cost	95	MU	
	Number of bags	6		
	Land size	2.38	ha	
	Estimated price of wheat	0.75	MU	
	Fixed expenses /ha	2200	MU	

Figure 1. Inputs used in the exercise simulating the wheat fertilization

The inputs are represented by the price of wheat which was estimated at 0.75 lei/kg. In fact, the price of wheat has shown significant fluctuations over the last year. If in the spring of 2021 in the western part of Romania its values were approximately 970 lei/ton, there were also several periods of time in which its value was significantly lower. For example, in the summer or autumn of 2020 these values were approximately 720 - 750 lei/ton. The evolution of prices is difficult to estimate but it should be noted that the profit function in an economic study shows very high variations when the capitalization price of the final product changes. These variations in profit as a function of grain price can be quickly determined by simulation using the application presented herein.

The price for the 16:16:16 NPK complex fertilizer packed in a 50 kg bag is 100 lei, using 18 bags in this case. The price for granulated urea with N concentration in proportion of 46.6% packed at 50 kg is 90 lei, using 8 bags. Also in this simulated situation, 6 more bags were used, each with 50 kg of ammonium nitrate and a total nitrogen concentration of 33.5%. The total crop area taken into account in this simulation is 2.38 ha.

After the here above values have been filled in the input page, the output expressions are automatically displayed in the spreadsheet.

NPK fertilization calculator (output)		
Amount of nitrogen (N)	144	kg
Amount of Phosphorus & Potassium (PK)	288	kg
Amount of nitrogen from other sources (N)	286.9	kg
Total amount of nitrogen	430.9	kg
N/ha	181.1	kg/ha
PK/ha	121	kg/ha
Total price of NPK fertilizer (source 1)	1800	MU
Total price of N fertilizer (source 2)	720	MU
Total price of N fertilizer (source 3)	570	MU
Total fixed expenses	5236	MU
Total expenses	**8326**	**MU**
Production and profit		
Estimated total production	**16103**	**kg**
Production value	**12077**	**MU**
Estimated production /ha	**6766**	**kg/ha**
Estimated total profit	**3751**	**MU**

Figure 2. Output regarding the exercise simulating the wheat fertilization

The algebraic calculations performed in Excel spreadsheets lead to a total amount of nitrogen obtained from the three different sources (NPK complex, ammonium nitrate and urea) of about 431 kg. The total amount of accumulated Phosphorus and Potassium is 287 kg. Taking into account the surface of 2.38 ha, the values obtained are: 181 kg/ha nitrogen and 121 kg/ha accumulated Phosphorus and Potassium.

The price of fertilizers in each category, the total fixed expenses as well as the sum of all costs can be found in the Output section.

The values describing the quantity of N respectively PK per area unit, by replacing it in the expression of the production function, led to an estimated technical production of 6766 kg/ha.

$$f(181, 121) \approx 6766 \ \text{kg/ha}$$

The estimated production to be obtained from the entire area is also found under the output heading. This is obtained automatically by multiplying the value of the heading for production by 1 hectare by the value found under the heading of the production area. The total production is estimated at 16103 kg. The profit made for the entire area is 3751 lei and it was obtained taking into account the estimated selling price for the cereals. Thus, the value of the production was calculated, minus the fixed expenses for the entire area and also minus the expenses related to all fertilizers.

CONCLUSIONS

The number of factors influencing agricultural production always remains unknown quantity. Continuous attempts to make mathematical models using predominant factors reduce the uncertainty of describing the real phenomena.

At the level of small farms, the possibility to implement advanced solutions for optimizing production factors is often inopportune. This is due to financial expenses that exceed the budget limits of the farm.

The methods of simulating agricultural production and profit according to several factors of production, transposed into the spreadsheets of software version, provide a clearer picture of how to program production, especially in the case of small farms.

Although the example presented by the simulation indicates the wheat production, the application can be quickly transformed by inserting different production functions specific to other cereal crops.

Even if the results obtained are only estimates, the flexibility and simplicity of the application can offer real advantages.

ACKNOWLEDGEMENTS

The results obtained by simulation are based on previous experiments made within the Teaching Station of Banat`s University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara. Thank you for your kind support.

REFERENCES

[1]. ADAMOV TABITA CORNELIA, IANCU T., PIRVULESCU LUMINIȚA, POPESCU GABRIELA, CIOLAC RAMONA, 2017, Food security a problem of the XXI century. International Multidisciplinary Scientific GeoConference: SGEM, 17, pp. 409-414

[2]. BRUDIU I., 2010, Biostatistică în abordarea practică, Eurobit, pp. 165-170

[3]. BRUDIU I., 2012, Biostatistică și utilizarea calculatoarelor personale,Eurobit, pp.13-21

[4]. FLOREA A., DASCALU I., MATEOC T., MANESCU C., MATEOC-SIRB N., 2017, Evolution of agricultural farms as basic elements of rural development. International Multidisciplinary Scientific GeoConference SGEM, 17, pp. 377-384

[5]. HERA C., 2009, Cercetarea ştiinţifică şi redresarea agriculturii României, https://uefiscdi.gov.ro/userfiles/file/EVENIMENTE%20ORGANIZATE%20de%20CNCSIS/MASA%20ROTUNDA%20AGRICULTURA%20ROMANIEI%20INCOTRO/HERA.pdf

[6]. IACOB Ș.V., DUMITRU D., 2020, Production function used in microeconomic studies and analyses. Revista Română de Statistică-Supliment, 7/2020, pp. 150-163

[7]. RUJESCU C., 2015, Statistică matematică, Artpress, pp. 57-79

[8]. SALA F., RUJESCU C., FEHER A., 2016, Evolution scenario for the average wheat yield in the west of Romania, Lucrări Ştiinţifice, seria Agronomie, USAMV Iaşi, 59(1), pp. 239-244

[9]. SALA F., RUJESCU C., CONSTANTINESCU C., 2016, Causes and solutions for the remediation of the poor allocation of P and K to wheat crops in Romania, AgroLife Scientific Journal, 5(1), pp. 184-193

[10]. * AZOMUREȘ**, Produse,https://www.azomures.com/ingrasaminte/, accessed 04.03.2021

[11]. * BURSA ROMÂNĂ DE MĂRFURI**, https://www.brm.ro, accessed 19.03.2021

[12]. * EUROSTAT**, https://ec.europa.eu/info/food-farming-fisheries/plants-and-plant-products/plant-products/cereals_ro, Cereale, plante oleaginoase, culturi proteice și orez, accessed 04.03.2021

[13]. * MICROSOFT. SUPPORT,** https://support.microsoft.com/en-us/office, accessed 15.03.2021

[14]. * NATIONAL INSTITUTE OF STATISTICS, ROMANIA (INSSE)**, Productia medie la hectar, la principalele culturi, pe forme de proprietate, macroregiuni, regiuni de dezvoltare si judete, http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table, accessed 04.03.2021

[15]. * NATIONAL INSTITUTE OF STATISTICS**, **ROMANIA (INSSE)**, Suprafata cultivata cu principalele culturi, pe forme de proprietate, macroregiuni, regiuni de dezvoltare si judete, http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table, accessed 04.03.2021