EVOLUTION SCENARIO FOR THE AVERAGE WHEAT YIELD IN THE WEST OF ROMANIA

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Abstract

Unbalanced fertilization and insufficient use of N, P and K fertilizers are direct factors that bring variability in the quality and quantity of the wheat yield at a national level. However, taking into consideration the (upward) trend in the use of these fertilizing elements in the past few years, the aim of the present study was to estimate the evolution of the average wheat yield for the west of the country, if the same growth rate of the fertilization level is maintained. The theoretical values of the average yields were obtained with a production function that indicates the correspondence between the yield and the quantities of N and of PK used. The expression of the production function is known (Q=f(N, PK)), due to previous studies on the behavior of Alex wheat in experimental conditions at BUASVMT; these conditions are considered to be representative for the West Plain, which is the reference area. In concordance with the particular data, which are specific from a physiological point of view, as well as in what the soil conditions, climate and technology are concerned, the results of the study bring useful information on the area under research, which can be used locally and regionally as well. In addition, the model can be expanded to cover the economic efficiency of the wheat crop through fertilization and to indicate some degradation processes in the fertility of soils.

Key words: average yield, fertilization, model, prediction, wheat

Wheat is one of the main agricultural crops in our country, Romania ranking among the largest wheat producers in Europe, together with Denmark and Spain (around 5 million tons each), after France, Germany, the U.K., Poland and Italy (Vigani M. et al., 2013; Eurostat Database).

The average area covered by wheat crops in Romania is approximately 2.135 million ha, and for an average yield of approx. 3.479 kg ha⁻¹ the total yield obtained was approx. 7.428 million tons (INS, 2014).

Improving the technologies for wheat cultivation and the quality of the biological material was the main ways to increase the average wheat yields worldwide (Vigani I. V. et al, 2013) and in our country. In most agricultural exploitations in our country, the fertilization level has not raised sufficiently compared with the current fertility of soils and the productivity of the cultivars used (Dumitru M., 2002; Hera C., 2010). A number of studies have created some models to show the behaviour of wheat crops in relation to nitrogen fertilization – this type of fertilization is frequently used due to the lower costs involved (Boldea M. and Sala F., 2013; Rujescu C.I. et al, 2014a). Other studies have assessed the influence of different doses of nitrogen applied with phosphorus and potassium considered together (Sala F. and Boldea M., 2011; Sala F. et al, 2015). In addition, models have been made to simulate the optimal areas to cultivate certain crops, with applicability to wheat, with a technology based on a fixed capital (Rujescu C.I. et al, 2014b, 2015).

The average wheat yield of Timiş County in the period 2013 - 2015 was somewhere between 3900-4800 kg ha⁻¹. More exactly, the average over the three years (2013, 2014, and 2015) was approximately 4385 kg ha⁻¹ (INSSE). A simple observation of the mathematical expression of a production function regarding the Alex wheat cultivar in experimental conditions in the West Plain of Romania (Sala F. et al, 2016) highlights that the free term of the mathematical expression has a close value to the average yields recorded in this area. This fact obviously indicates low values of the average level of fertilizers applied on agricultural exploitations in Timiş County. As a matter of fact, it is known that things are not significantly different at national level in what the average yields are concerned (Dumitru M., 2002;

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Hera C., 2010), although the statistics show a slight increase in the local use of fertilizers, which indicates raised awareness about proper fertilization of agricultural lands (Vlad I.V., 2015; Eurostat 2016).

The aim of the present study was to deduce the average yield increases in Timiș County, if the evolution of the fertilization rate continues on the same upward tendency indicated at national level.

### MATERIAL AND METHOD

The statistics regarding the use of N, P and K fertilizers in Romania, according to Eurostat estimations, for utilized agricultural areas (UAA), provide the data shown in Table 1. The values are given for guidance only, but what is of interest at this point is the upward trend noticed in the past few years regarding the utilization of the three elements.

<table>
<thead>
<tr>
<th>No.</th>
<th>Year</th>
<th>Average fertilizer use (active substance, kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N</td>
</tr>
<tr>
<td>1</td>
<td>2006</td>
<td>16.43</td>
</tr>
<tr>
<td>2</td>
<td>2007</td>
<td>22.09</td>
</tr>
<tr>
<td>3</td>
<td>2008</td>
<td>19.98</td>
</tr>
<tr>
<td>4</td>
<td>2009</td>
<td>23.52</td>
</tr>
<tr>
<td>5</td>
<td>2010</td>
<td>25.77</td>
</tr>
<tr>
<td>6</td>
<td>2011</td>
<td>25.64</td>
</tr>
<tr>
<td>7</td>
<td>2012</td>
<td>26.45</td>
</tr>
<tr>
<td>8</td>
<td>2013</td>
<td>33.26</td>
</tr>
<tr>
<td>9</td>
<td>2014</td>
<td>33.88</td>
</tr>
</tbody>
</table>

Source: Eurostat (July 2016)

The assessment of the status of the average wheat yield in Timiș County started from the expression of the production function communicated by Sala et al. (2016), which was based on the experimental data on Alex wheat cultivar, relation (1).

\[
Q(N, PK) = -0.0643 \cdot N^2 - 0.0237 \cdot PK^2 + 0.02362 \cdot N \cdot PK + 26.333 \cdot N + 5.361 \cdot PK + 3300.533
\]

(1)

The fertilization rate that leads to a certain average yield marked \(Q_m\) is determined by using the equations (2).

\[
\begin{align*}
Q(N, PK) &= Q_m \\
\frac{N}{PK} &= \frac{n}{1} \\
\end{align*}
\]

(2)

where \(n:1\) is the relation between the fertilization elements.

By solving only the first equation from the system we are not led to a concrete solution, but instead to the isoquant that corresponds to the average yield (Intrilligator, 2002). In order to choose, out of all the combinations of the N and PK values, only the ones that lead to the given production, we have to consider also the fertilization ratio represented by the second equation. The calculations and graphical representations of experimental data were made with the Wolfram Alpha program (www.wolframalpha.com).

### RESULTS AND DISCUSSIONS

The average fertilization rate that led to the average yield in Timiș County in the period 2013 – 2015, namely 4385 kg ha⁻¹ (INSSE), was estimated by using equation (2):

\[
Q(N, PK) = 4385
\]

Equation (2) became (2'):

\[
\begin{align*}
-0.0643 \cdot N^2 - 0.0237 \cdot PK^2 + 0.02362 \cdot N \cdot PK + 26.333 \cdot N + 5.361 \cdot PK + 3300.533 &= 4385 \\
\end{align*}
\]

(2')

From the point of view of geometry, the previous equation is an ellipse and every point on the ellipse will represent a combination of the values of N and PK that lead to the average yield \(Q = 4385\) kg ha⁻¹ (figure 1).

In other words, the solutions to the equation are situated on isoquant \(Q(N, PK) = 4385\), and in order to determine a certain solution, we admit the hypothesis that the N to PK ratio was...
5:1 in 2015.

Figure 1 Graphical representation of isoquant Q
\((N,PK)=4385\)

Thus, we consider \(PK = \frac{N}{5}\) and from equation (1) was obtained equation (3), with the graphical solution in figure 2.

\[-0.0643 N^2 - 0.0237 \left(\frac{N}{5}\right)^2 + 0.02362 N \cdot \left(\frac{N}{5}\right) +
+ 26.333 N + 5.361 \left(\frac{N}{5}\right) + 3300.533 = 4385\]

Therefore this had led us to equation (4):

\[-0.060524 N^2 + 27.4052 + 3300.53 = 4385\] (4)

Figure 2 Graphical solution to equation (3)

The solution to the quadratic equation is \(N=43.8\) kg ha\(^{-1}\); based on proportionality, it follows that \(PK=8.7\) kg ha\(^{-1}\). So we obtained the average values of \(N\) and \(PK\) quantities respectively that lead to the average yield of 4385 kg ha\(^{-1}\).

Observing the values in table 1 on the dynamics of fertilization at national level in years 2006-2014, we can determine the average annual growth for \(p_N\) and \(p_{PK}\). So we have:

\[p_N = \frac{33.88 - 16.43}{8} = 2.18\) kg N/ha/year\]
\[p_{PK} = \frac{6.72 - 3.13}{8} = 0.44\) kg PK/ha/year.\]

In this way we obtained the estimated values for \(N_{TM}\) and \(PK_{TM}\) respectively, representing the average fertilization rates in Timiș County, considering that kept growth dynamics at the nationwide in recent years, in concordance with the average growth determined previously. The data are presented in table 2.

### Estimated values of the average fertilization rate in Timiș County

<table>
<thead>
<tr>
<th>No.</th>
<th>Year</th>
<th>Estimated average fertilizer consumption (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(\text{N}_{TM})</td>
</tr>
<tr>
<td>1</td>
<td>2015</td>
<td>43.8</td>
</tr>
<tr>
<td>2</td>
<td>2016</td>
<td>45.9</td>
</tr>
<tr>
<td>3</td>
<td>2017</td>
<td>48.1</td>
</tr>
<tr>
<td>4</td>
<td>2018</td>
<td>50.3</td>
</tr>
<tr>
<td>5</td>
<td>2019</td>
<td>52.5</td>
</tr>
<tr>
<td>6</td>
<td>2020</td>
<td>54.7</td>
</tr>
<tr>
<td>7</td>
<td>2021</td>
<td>56.8</td>
</tr>
<tr>
<td>8</td>
<td>2022</td>
<td>59.0</td>
</tr>
<tr>
<td>9</td>
<td>2023</td>
<td>61.2</td>
</tr>
<tr>
<td>10</td>
<td>2024</td>
<td>63.4</td>
</tr>
<tr>
<td>11</td>
<td>2025</td>
<td>65.6</td>
</tr>
</tbody>
</table>

* Source: our own calculations
Going back to expression (1) of the production function, the estimation of the average wheat yield in Timiș County until the year 2025 was made by replacing in (1) the estimated values \( N_{TM} \) and \( PK_{TM} \).

\[
Q^*_{\text{estimated}} = Q(N_{TM}, PK_{TM}).
\]

After solving function (1) with the estimated values \( N_{TM} \) and \( PK_{TM} \) for the period under study, we obtained the average wheat yields that are presented in table 3, with the graphical distribution in figure 3.

\[
\begin{align*}
Q^*_{2016} &= Q(45.9; 9.1) = 4432 \text{ kg ha}^{-1} \\
Q^*_{2017} &= Q(48.1; 9.5) = 4479 \text{ kg ha}^{-1} \\
&\vdots \\
Q^*_{2025} &= Q(65.6; 13.1) = 4837 \text{ kg ha}^{-1}
\end{align*}
\]

The data obtained are presented in table 3.

**Table 3**

<table>
<thead>
<tr>
<th>No.</th>
<th>Year</th>
<th>Estimated ( Q^* ) (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2015</td>
<td>4384.4</td>
</tr>
<tr>
<td>2</td>
<td>2016</td>
<td>4432.3</td>
</tr>
<tr>
<td>3</td>
<td>2017</td>
<td>4479.6</td>
</tr>
<tr>
<td>4</td>
<td>2018</td>
<td>4526.4</td>
</tr>
<tr>
<td>5</td>
<td>2019</td>
<td>4572.6</td>
</tr>
<tr>
<td>6</td>
<td>2020</td>
<td>4618.2</td>
</tr>
<tr>
<td>7</td>
<td>2021</td>
<td>4663.3</td>
</tr>
<tr>
<td>8</td>
<td>2022</td>
<td>4707.7</td>
</tr>
<tr>
<td>9</td>
<td>2023</td>
<td>4751.6</td>
</tr>
<tr>
<td>10</td>
<td>2024</td>
<td>4794.9</td>
</tr>
<tr>
<td>11</td>
<td>2025</td>
<td>4837.7</td>
</tr>
</tbody>
</table>

* Source: our own calculations

The model thus obtained can be expanded to estimate the average wheat yield in any other county or interest area, for local or regional planning of cultivated areas, for technologies or for macroeconomic studies. Moreover, the approach can be adapted to various other agricultural crops.

Similar studies have been made for the prediction of wheat yields (and for other cereal crops, as well) in relation to fertilization rates (especially with nitrogen), to herbicide application rates, to climate changes and rainfall regime (Lobell D.B. and Burke M.B., 2010; Raun W.R. et al, 2011; Dumont B. et al, 2014), to edaphic factors, technological and economic factors (del Carmen Vera-Diaz M. et al, 2008) and to the vulnerability level of some crops and agricultural systems (Luers A.L. et al, 2003).

Imaging methods based on the analysis of satellite images, whether aerial or terrestrial, are very useful for the real-time assessment of crop dynamics and the nutrition state of plants, and for recommending fertilization corrections in order to reach the estimated yields (Shou L. et al, 2007; Herbei M. and Sala F., 2015) or for predicting the production of biomass (Serrano L. et al, 2000; Herbei M. and Sala F., 2016).

Based on the average growth rate of the quantities of fertilizers used (N, PK) and on a mathematical model obtained in experimental conditions, the present study predicted the average wheat yields in the conditions characteristic for Timiș County, West Plain, Romania. The model can be expanded to cover other regions and agricultural areas, thus facilitating the decision-making process on the optimization of the wheat yield by improving the fertilization system, the crop technologies as a whole, or by the dynamics of the cultivated areas.

The present study designed an evolution scenario for the wheat yield in the West of Romania based only on the growth rate of the fertilization levels and on the average ratio of N:PK. The impact of fertilizers on the wheat yield also depends largely on the degree of assurance and on other technological and climatic factors (e.g. rainfall).

In the context of the crop technologies specific for the reference years (the period when the data were collected), which, together with the soil and climate conditions in the area under study, presumably appeared in the values of the output, our model predicted on real bases the evolution of the wheat yield only in relation to one factor, i.e. fertilization, whose dynamics was deduced through calculations.

At the same time, various other studies obtained more complex models for predicting...
wheat yields, taking into consideration a larger number of parameters specific for certain areas. Thus, Wagner N.C. et al., (2007) used 5 variables (wheat crop, density of wild oat species, nitrogen rate, herbicide rate and rainfall during the growth season) in order to develop a complex model for predicting the wheat yield. Similar studies that used traditional or unconventional methods and techniques were made by Kastens T.L. et al. (2001), Lukina E.V. et al (2001), and Mullen R.W. et al. (2003).

Mann M. and Warner J. (2015) have made an extensive study on wheat crop productivity, taking into consideration the climate conditions, the quality classes of the cultivated lands, the fertilization rate, social and economic conditions, etc. The study resulted in a GAP methodology for estimating the wheat yields under the given conditions.

CONCLUSIONS

Although fertilization has seen an upward trend in recent years, the annual growth rhythm is slow, as the fertilization level is still too low. The production increase is also low, at approximately 45 kg/year. In these conditions, the average wheat yield in the year 2025 would be approximately 4840 kg ha⁻¹, which are still very small values when compared with the values in other European countries.

Therefore it is necessary to adopt policies that stimulate fertilization on agricultural exploitations, because the speed at which the fertilization rate increases must become higher than it has been in recent years.

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REFERENCES


Borlan Z., Hera, Cr., 1982 – Tabele si nomograme agronomiche, Editura Ceres, Bucuresti.


Rujescu C.I., Mateia A. N., Martin S., Ciocac R., 2015 – Determination of the optimum productions surface (monofactorial model) having an initial
fixed capital, Quaestus Multidisciplinary Research Journal, 149.


http://statistici.insse.ro (07.2015)
ec.europa.eu/eurostat (07.2015)
http://www.wolframalpha.com/