

MODEL FOR IMPROVING THE FERTILISATION OF AGRICULTURAL LANDS WITH NITROGEN CASE STUDY THE BACAU COUNTY

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Abstract: The paper presents the results of the first two phases of the interdisciplinary research project “Research on an ecosystem approach of sustainable development at territorial-administrative level”, a project financed by C.N.C.S.I.S. and coordinated by ASE Bucharest. The project was carried out in Bacau County between 2004 and 2006. The paper highlights the reasons that lead to losses for farmers, year after year, a model for making agriculture more efficient, the outcomes of the model, management of nitrogen in the CAP’s vision.

Keywords: sustainable agriculture, model, modelling, efficiency, management.

1. INTRODUCTION

Over the last 15 years farmers of Bacau County had lost USD 255 million, in the cereals sector only. All domains of agriculture have had losses, and according to our computation based on output, costs and prices, we evaluate them to exceed USD 650 million over the period 1989-2004 and over USD 960 million between 1989 and 2005. This decapitalization due to costs that were not covered by outputs resulted in the dramatic pauperisation of the rural population and of farmers in general. Between 1989-2004 the agricultural areas of Bacau County were diminished by 10,030 ha, i.e. by almost 670 ha/year and arable land in Bacau County was reduced by 993 ha, i.e. by 612 ha/p.a. Losses of agricultural soil in the county are by 6.6% higher than those calculated at national level for the same period. Considering the 2004 data as a starting point we find the following aspects, some of which are highly negative:

- 1) The predominance of maize, a hoeing plant which takes up 93,847 ha, respectively 51 % of the crop structure. Corn, preferred by small cultivators for fattening the pigs and rearing fowls, is cultivated on water meadows, terraces and slopes. It is a de-stabilizing factor for soils as well as for agricultural and ecological systems as a whole. Due to its cheap price the corn is difficult to sell and therefore is used for self consumption at loss;
- 2) The wheat is cultivated on a reasonable surface especially in the south of the county (21,608 ha namely 12% of the arable land). The wheat and the maize as cereals occupy together 63% of the arable land. This creates an unfavorable conjunction for achieving an acceptable scientific and technical rotation of crops (Good Practices in Agriculture – an EU requirement);
- 3) Vegetables occupy very small surfaces either as proteins for consumption (peas 78 + beans 382 ha = 460 ha), or fodder vegetables (lucerne, clover, vetch). For instance the surfaces cultivated for lucerne and clover have been reduced to a few hundreds of hectares, contributing to:

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- The dramatic reduction of the number of large cattle;
 - Reducing the possibilities to apply organic fertilizers because of the reduction of the amount of manure;
 - The disturbance of the balance of nitrogen and carbon in the soil and the stimulation of overall processes of soil degradation;
- 4) The oleaginous technical plants such as sunflower (4,100 ha), but especially the rape and the soy (105 + 106 ha) occupy non-relevant surfaces. If cultivated on large surfaces they could have reduced the financial losses of the farmers;
- 5) The average county production of cereals and maize is of 2,688 kg/ha. This implies for those who cultivate the 120,838 ha annual losses of about 170,000 tons of cereals equivalent or USD 171 million /year.

2. PRESENTATION OF THE MODEL

2.1. The objective of the model – is an integrated development of the agro-cenoses and stock raising taking into account:

- Evolution of biological processes (B);
- Reconstruction and the stabilization of the ecological systems and especially of the basic resources: water, air, soil (E) [1];
- Technological and managerial development of agriculture (TM);
- Making the system economically efficient (Ef) By optimizing subsystems B, E and TM [2].

It results that the economic efficiency is not based upon the allocation of conventional resources, that would facilitate to a large extent the elaboration of a model, but is subject to certain constraints conditioned by the good practices that should be applied to agriculture and are to be found in B, E and TM.

2.2. The description of the model

The Integrative economic efficiency (Ef_{int}) results in being a function of the usual parameters for agriculture (TM), but also an evolution of the biological (B) and ecological (E) processes. Consequently we could have two variables:

- The complex dynamic variable, in which:

$$Ef_{int} = f(TM, B, E) \quad (1)$$

and

- The subsequential variable [3]:

$$Ef_{int} = f(TM) + f(B) + f(E) \quad (2)$$

Any model needs a measurement of the indicators which describe the respective processes. For instance the biological processes can be described by indicators related to the sorts such as:

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|--|---|
| <ul style="list-style-type: none"> - Production capacity - Quality - Capacity of adaptation to the environment inscribed in the genomes and many other of the sorts | Measurable
-----→ parameters |
|--|---|

In this case the studies on structural modelling of the biological networks indicate the need of building functions composed of complex differential equations. We are not going to resort to them, one of the main reasons being that this paper is dedicated to the use of local authorities and for large agricultural audiences who need to formulate decisions and not methodologies.

Therefore, considering the subsystems that have to be integrated as optimizable variables and which pertain to a large extent to local administrative structures and to a lesser extent to farmers, we intend to present only the results of the calculations that bear a decision-making character [4].

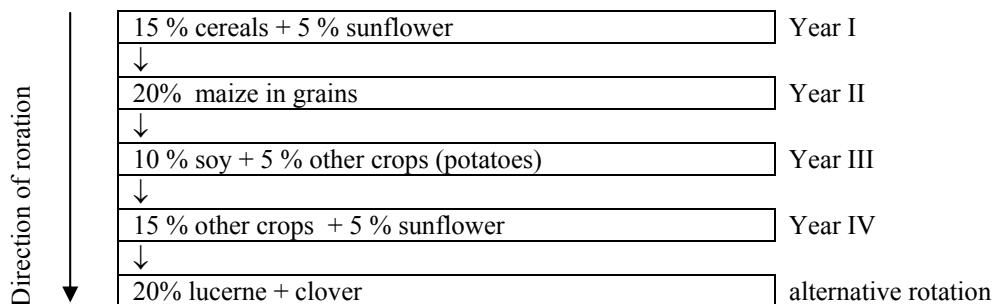
3. RESULTS OF MODELLING.

3.1. Changing the structure of crops and organizing their integrative rotation.

A. The structure of the crops in Bacău County [5] should be the following:

- 10 -15% grain cereals – sorts of Premium type;
- 15 -20% maize grains – early hybrids in the North and semi-early in South;
- 20% lucerne + clover – sorts and kinds locally adapted;
- 10% sunflower – early hybrids;
- 10% soy – early sorts;
- 5% other vegetables;
- 10 - 20% other crops cultivated on separated plots including; vegetables, medicinal plants, potatoes etc.

B. Based on this structure of the crops which is in accordance with best agricultural practices, one can organize rotations of the culture following an alternative sequence (lucerne + clover) of the following type:



The prevailing advantages of this kind of crops rotation are:

a) The adjustment of the metabolism of the plants and the increase of output of the crops by optimizing the management of nitrate and carbon contained in the soil:

- Reducing by 50% the doses of nitrate administered by organic fertilizers, reducing the overall agricultural expenditures for the county, about USD 15 million;
- Increasing by 35% the level of outputs for all cultures. Namely: +110 Euro/ha = + USD 20 mil in the farmers' pockets. At the same time reducing the pressure of diseases, pests and weeds by 30-60%.

b) Ecological effects:

- Increasing up to 50% water infiltration and filtration capacity of the soil (restriction, mechanical works in depth at 30-35 cm or using the scarifier at 65 cm once every 5 years);
- Increasing by about 40% the soil's capacity of retaining water and consequently reducing by 20-50% the erosion by water. Consequences: the reduction of the rivers' flow by 20-40% during the periods of intensive rain. Restriction of saturated soils with water on the whole surface of the soil);
- Reducing draught phenomenon and creating favourable effects which determine an increase in production and in its quality;
- Optimizing the physical phenomena, namely the biochemical ones in the soil (+60% concerning its structure + 50% of its biological quality including the heteropolicondensation of organic material);
- Adjusting the circuits of nitrate + carbon + water + other fertilizers contained in the soil. Conservation and rational use of the biotope layer.

3.2. The optimization of the subsystem (TM)

a) Selecting a set of modern, economical and performing machines which would:

- Allow work on the stubble fields after each crop after maximum 4 days;
- Eliminate on 30-40% of the land the autumn ploughing while performing the underground works of the soil;
- Eliminate completely the summer ploughing;
- Reduce to a minimum the crossings of the land (soil);

- Applying only under control and only when necessary the protective substances for the plants.

Example: Though the occurrence of weeds is very high in the Bacău county, the local studies have shown that only 6 species are predominant and produce over 85% of the losses due to weeds. As a result of this research it was established that for calculating the losses of crops due to weeds "y" and the frequency of the appearance of the weeds "x" one can use the European model $Y = 3.69 \times 10^{93}$, which is a logarithmical scale resembling a linear correlation. These results (losses DY) enabled to produce a model of managing the weeds control.

a) Optimizing the management of fertilizers and especially of nitrate.

Principle I: Mineral fertilizing must be replaced as much as possible by the organic one no matter if it is done by using manure, fermented manure, compost or green fertilizers.

Principle II: The management of the mineral nitrate is significantly modified and the basic molecules are carefully selected.

The use of organic fertilizers is limited due to the reduced number of animals.

The modelling requires the use on agricultural land of about 21 tons/ha of organic fertilizers once every 4 years.
 $\approx 200,000 \text{ ha} \times 21 \text{ tons/ha} = 4,200,000 \text{ tons/4 years} = 1,100,000 \text{ tons/an}$. According to the data offered by D.G.D.A.I.A. Bacău, in year 2005 720,280 t have been used, which represents 65% of the necessary amount. A situation that is not too bad, but probably is not too close to reality.

The above-mentioned rotation of crops allows to treble the number of large animals and to obtain an amount of manure of $100,000 \times 20 \times 360 = 720,000 \text{ tons/manure/year}$. It would correspond to the present amount (thus the figures offered by the Direction are not correct). The chemical fertilizers are subject to mathematical models starting with Liebing and continuing up until now. But we are interested to respect the rules of C.A.P. and especially to see what happens to the management of the nitrate in this official framework that has to be applied to Bacău too.

4. THE MANAGEMENT OF NITRATE ACCORDING TO THE C.A.P. VISION

In the framework of Good Farming Practices, [6], the production factor is diversified, is substituted, reduced etc. If "x" = "N", namely we would like to calculate a correlation between the level of production and the nitrate, we should take into consideration the fact that we are not dealing any more with a relation of the kind $q = f(x_1, x_2, \dots, x_n)$, but we are dealing with one of the kind

$$Q = f \left\{ \begin{array}{ll} x_{1.1} & x_{2.1} \\ x_{1.2} & x_{2.2} \\ x_{1.3} & x_{2.3} \\ \vdots & \vdots \\ x_{1.n} & x_{2.n} \end{array} \right. \quad (3)$$

In which if $x = N$, we can have

- N_1 = nitrate from chemical fertilizers;
- N_2 = nitrate from manure;
- N_3 = nitrate from green fertilizers;
- N_4 = nitrate from symbiotic fixation;
- N_n =etc.

This way, the calculation of the function becomes very complicated, but its obtaining is necessary because according to the process of establishing the path, N_1 , N_2 , N_3 ...etc. should be well known and quantified. The following will ensue:

- a. Not any chemical fertilizer containing nitrate will be used, but only those complying with the quality requirements;
- b. Not any manure will be used;
- c. Not any green fertilizer etc. every product will acquire a code that will imply a certain quality standard.

Especially when dealing with fertilizers as production factors it is useful to remind the following laws:

- The Liebig Law or the Law of the minimum, already formulated in 1855;
- The Wollny Law, which appeared some time later and which stresses the fact that the positive trend of the production is limited when the amount of constitutive elements exceeds a certain quantitative value and a certain price;
- Then Mitscherlich who has established in 1909 the first mathematical relationship between the production and one of its factors (Fig. 1), namely fertilizing with nitrate.

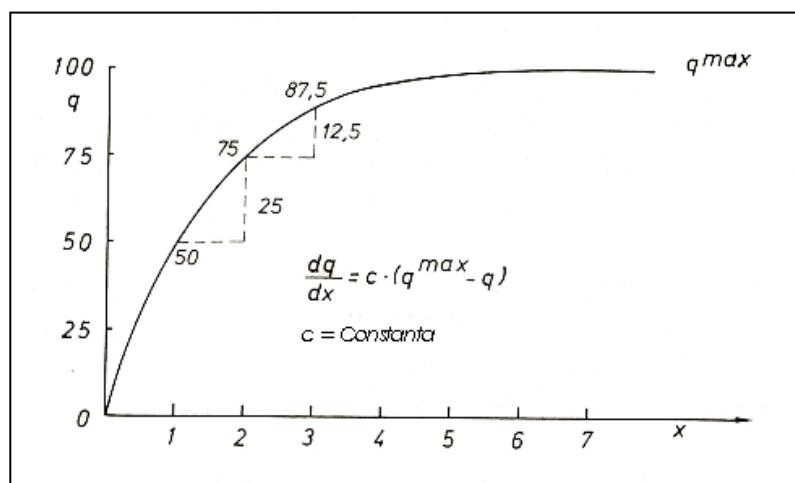


Fig. 1. The relation between a production factor (x) (nitrate fertilizer) and the level of production “ q ” (according to Mitscherlich).

The first function expressed mathematically has a logarithmic evolution. The function emphasises the fact that when there is a certain overburdening by production factors, the crop could be diminished. Therefore the function has been later modified to this effect by its author himself.

About 65 years later, Boguslawski and Schneider after remaking this function have formulated the third alternative of the production law determined by its life factors, as a classical function having an “S” shape (Fig. 2).

All the authors of these functions have worked on establishing the parameters of the equations with nitrate fertilizers, because they have shown the most important reaction of the plants to this factor. At the same time, all authors have taken into consideration the quantitative elements of the studied production factors and by no means the qualitative ones.

After Boguslawski and Schneider there were numerous other researchers who have sought functions that would express in the best way the relationship between the production and its conventional component factors.

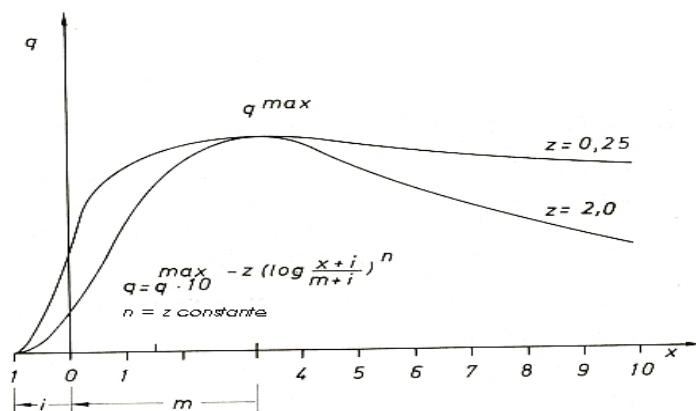


Fig. 2. The production function determined by its life factors according to the vision of Boguslawski and Schneider, applicable also to Bacău county.

An analysis of the specialized literature that we also adhere to, shows as being the most suitable a quadratic, which in the case of the nitrate has the form shown in Figure 3.

$$q = a + b \cdot x \cdot N - cN^2 \quad (4)$$

a function very frequent in Romania and applicable also to the agriculture of the Bacău county.

$$q = a + b \cdot x \cdot N - cN^2$$

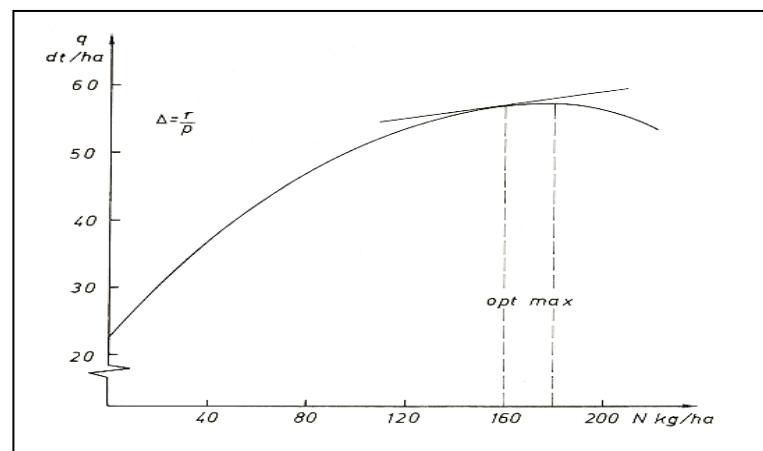


Fig. 3. The quadratic of the relationship between the production “ q ” (q/ha) and the nitrate factor (N)/kg/ha.

This last equation takes into consideration not only the maximal level of crop as a biological consequence of its activity. If one takes into account the “costs”, then we are dealing with an economical optimal value, which corresponds to a lesser level of nitrate doses but also of crops, as formulated in the relation

$$\Delta p = \frac{r}{p} \quad r = \text{yield} \quad p = \text{price} \quad (5)$$

We specify once more that especially this last function was formulated during the development of intensive agriculture, when great attention has been given to the quantitative elements and by no means to the concepts of quality or saving procedures.

The above-mentioned function does not take into account the following:

- a) the possibility of applying nitrate in fractioned doses;
- b) the possibility of substituting conventional sources of nitrate by nitrate generated from organic fertilizers, by ribozomial nitrate or nitrate generated by other sources.

If one takes into account the good practices, then the above-mentioned function is composed of several sub-functions created by the parameters determined by various forms and methods of applying the nitrate obtained from conventional or natural alternative sources (Fig. 4).

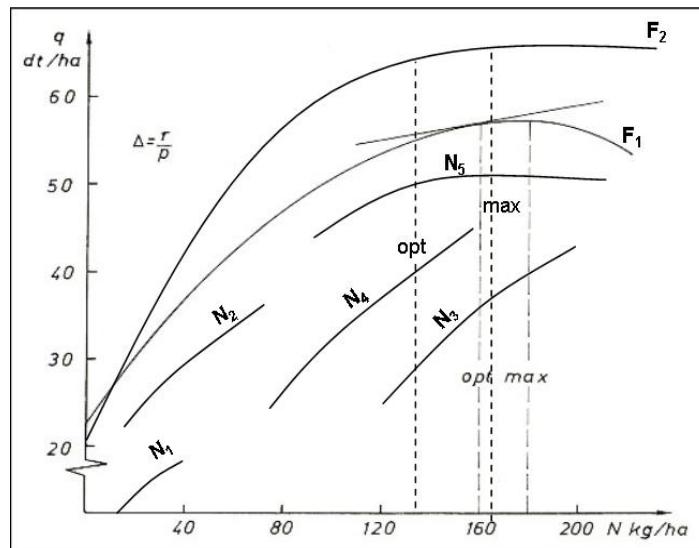


Fig. 4. The quadratic function and its component sub-functions determined by the nature of the applied nitrate:

- N_1 = residual nitrate in the soil obtained by summer burning;
- N_2 = nitrate obtained from manure;
- N_3 = ribosomal nitrate;
- N_4 = nitrate obtained from mulci;
- N_5 = nitrate applied by foils.

The new management of nitrate does not consist any more of a unique dose. That is what we are advising the Bacău farmers to do. If we calculate the optimal dose of "N" it is a resultant of summing up several forms of nitrate, which are included in the nutrition of plants. The calculations show that it amounts to over 160 kg/ha. As the E.U. does not allow us to apply more than 150 kg and since the danger of polluting becomes high and the efficiency low it becomes necessary to fraction it (Fig. 5).

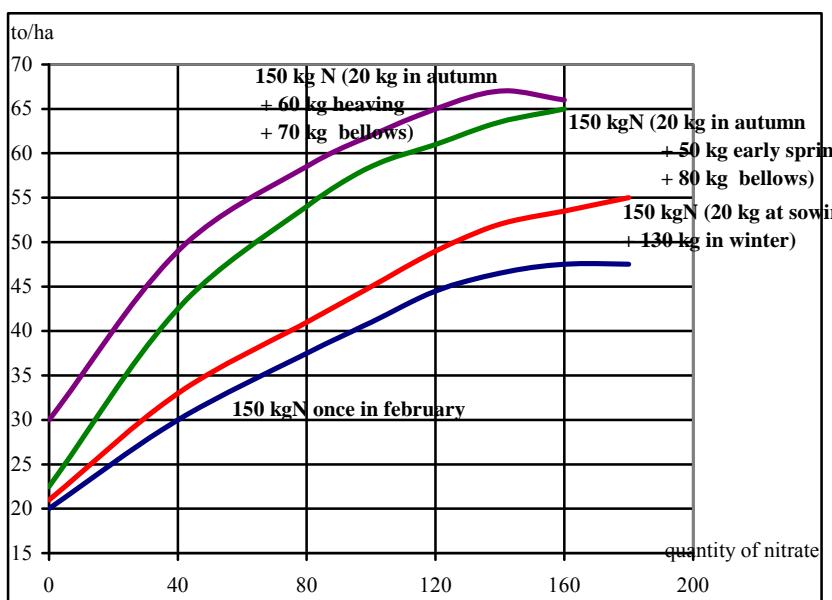


Fig. 5. The evolution of wheat output in Bacău County by fractioning the doses (Data obtained by modulation).

The fractioning of nitrate doses has the following advantages:

1. It practically doubles the wheat output;
2. It avoids the washing out produced at the soil surface or in depths, especially when the applications are made in winter, avoiding thus nitrate pollution;
3. The quantity and the quality of the crop output are increased especially when the application are made when the wheat is coming into ear. Therefore from the managerial point of view it is necessary to couple the applied treatment with that of maintenance.

CONCLUSIONS

- THE FARMER administers not only a farm but a whole agricultural eco- system being part of the natural environment. For this purpose he needs education and support in the same way it happens in the E.U.
- THE FARMER must know (or learn) to use multiple information about all aspects and levels of agricultural ecosystems, including social, economic, pedologic, agrochemical etc. aspects.
- The sustainable development of agriculture is achieved by THE FARMER. He establishes the techniques and the technology that are to be applied, combining the output factors and achieving an activity compatible with what is now called “THE GOOD PRACTICE CODE”. For this purpose he must be trained and helped by the state institutions.
- In order to promote a sustainable agriculture and the management of “GOOD PRACTICES” (agricultural, of soil cultivation, of protection of agricultural cultures, of plants’ nutrition, of the environment etc.) the farmer is required to possess a very high level of qualification, as he is supposed to adopt strategies or their component elements related to the specified situations, motivation and training, in Bacău County inclusively.

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