The Common Agricultural Policy of the European Union – the present and the future

EU Member States point of view

INSTITUTE OF AGRICULTURAL
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Contents

12. Farms and agricultural enterprises for development of sustainable and smart cooperatives: a multifactor approach using digital farm management

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Abstract

This paper presents a multi-criteria mathematical model which is capable to facilitate the formation of smart cooperatives and to collect behavioural data about small farmers. The model for smart cooperation is based on Gross Margin calculation and a multifactor approach known as the Analytic Network Process. The ANP, based on the farmer estimations, allows us to determine his behavioural risk for managing the farm. The model can also be useful for banks and insurance companies as they can be interested in estimating the risk for the farmers.

Keywords: smart cooperatives, risk profile, farm management model

JEL codes: Q12, D24, D81, Q13

12.1. Introduction

Smart cooperatives refer to the economic aspects of enforcing cooperation based on some common activities or objectives. The Third Green Revolution marks the path of digitization in otherwise traditional farming and the introduction of smart agriculture (smart farming technologies, SFTs). According to the European Innovation Partnership "Agricultural Productivity and Sustainability", 80% of the US farmers use some of these technologies in their production. The STFs are the key to precision farming, i.e. effective resource management in agriculture. Smart technologies are already incredibly diverse – from sensors to monitor the chemical composition of the soil to the use of drones to detect plant diseases, automated irrigation equipment, navigation systems for machinery, etc.

This paper presents a multi-criteria mathematical model, which is capable of facilitating the formation of smart cooperatives and collecting behavioural data about small farmers. The value of this behavioral, qualitative data is unique and can be valued in a large range of domains[17].

Two of these domains regard the banks and insurance companies. The model can be useful for them by distinguishing the risk profile of the individual farmers. One of the major problems faced by funding organizations is to assess the behavioural risk of farmers. Using the multifactor model makes it possible to assess behavioural risk of farmers and to estimate the expected outcome of their activities.

Additionally, the agricultural and food sector need to change systemically. The data that is collected can make connections between farm modernization and rural development. We see the possibilities for, and drivers and limitations of sector change in four thematic areas: the resilience of farms and rural areas; prosperity and well-being; knowledge and innovation; and, the governance of agriculture and rural areas.

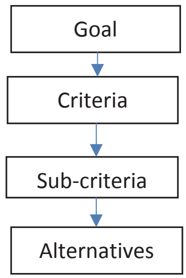
12.2. Multi-criteria approach

The Analytic Hierarchy Process and the Analytic Network Process are a part of multi-criteria approach as a decision making models constructed for synthesis of information. Their main benefits are when one have to solve problems that do not have clear quantitative measure, especially when the problem is related to social elements, subjective opinions, etc. Both the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) were introduced and their theoretical framwork was developed by T. Saaty [2001]. Historically and logically the AHP is the first model that appeared [Saaty, 1980]. The AHP can help with weighing of various alternatives according to a set of criteria, when the influences between alternatives and criteria are hieratical. At the top of the there hierarchy is the decision-making goal (Fig. 1).

The Analytic Network Process is a model that allows for considerably greater complexity. It recreates a system that allows dependences not only in the direction from a higher to a lower hierarchy toward the alternatives. When using the Analytic Network Process, it is possible that dependences are in both directions – from components to alternatives or from alternatives to the components. Additional dependences between components are possible. That creates a system that is much more complex and capable of describing in much more details the economic systems and dependences between different players on the market, etc. (Fig. 2)

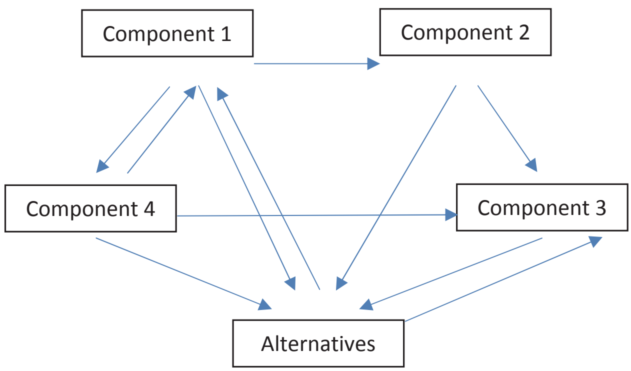
[17] For processing the information a software named GoMo (www.GoMo.bg) was created. GoMo bases on several principles ofoperation: (1) it gathers the experience and support of Bulgarian farmers; (2) it uses knowledge in the field of economy; (3) it follows the achievements of the information society for the processing of information; (4) it creates a potential for new competitive business models based on shared data.

Figure 1. Analytic Hierarchy Process



Source: own study.

Figure 2. Analytic Network Process



Source: own study.

In addition, the components may be constituted by elements. When evaluating the influence of components and elements on the alternatives, it is necessary to make pairwise comparisons between the individual elements. These comparisons are made on a scale from 1/9 to 9, where 1 means that both elements have equal influence on the alternatives, 9 means that the factor in the row has very strong influence and the factor in the column has no influence, 1/9 means that the factor in the column has very strong influence and the factor on the row has no influence. Table 1 summarizes possible scores and their explanation for the estimation of the elements.

Possible applications of the ANP can be very wide. It can be successfully used for solving decision problems in private corporations, public issues, military and conflict decisions, forecasting, market share estimation [Saaty and Vargas, 2006].

Table 1. The scale for estimation

Numerical	*Intensity of importance*	*Definition explanation*
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation

Source: Saaty and Vargas [2006].

12.3. Construction of Farm Management Model

The design of targeted, well-tailored policies in the agriculture, articulated with the CAP, is flawed by the particularities of small farms, their main concern being the amount of the allocated subsidies. Inability to form associative structures like, for example, agricultural cooperatives, based on common activities is usually blamed on the historical past when such solutions were enforced against the will of the proprietors. Nowadays, general discussions about the optimal functioning of the cooperatives in agriculture are carried out, with the scope to improve efficiency and achieve economies of scale.

Scopes and reasoning of the small farmers differ from behavioural perspective from those of large farms. In the process of production, substitutability between factors of production depends on many issues. We can stress the following behavioural patterns:

– The vulnerability to the weather conditions and farmers reaction to it;

- The simple ignorance about specific solutions;
- The ignorance of the official recommendations about specific conditions.

Risks and expectations mutually reinforce in the attempt to improve the farm operational management. In predicting and planning production, price and income for agricultural farms, both *a priori* and *a posteriori* Gross Margin's (GM) computation operates as proxy for the profit's dynamics. The correct estimation of the gross margin can act as a proxy for the dynamics of future profits.

This is why, the existence of a reliable, real data base concerning behavioural data presenting the process of formation of expectations regarding the current and future gross margin, stay at the base of the success of any action on the small farms. The model proposed is built on an innovatory mathematical model, following a multi-criteria approach.

The model constructed using this technique is entirely original and it was tailored to the specific needs of the Bulgarian agriculture. Several focus groups helped to construct, confirm and estimate this prototype and specific derivations, like the estimation of the cash flow, break-even point or the risk profile of the users.

The software allows farmers to be more and more conscious about:

- the structure of the variable costs,
- the errors in the estimation of gross margin,
- better adjusting their expectations and also the options they have about costs,
- the degree of substitution between factors of production.

Perhaps one of the most important other achievements is the possibility to aggregate these behavioural data on reports to be used as meaningful references of performance comparisons and to assist in the design of optimal agricultural policies.

The model is build using the Analytic Network Process (ANP) theory to incorporate behavioural decisions at the level of small farms regarding the substitution in between factors of production with the aim of determining the expected gross margin (GM).

- It is anchored on a standard calculation of the GM;
- The calculation of the GM follows the next theoretical idea:
- Consider there is a farmer's production function:

(1) Y=Y(Labour, Nutrition, Chemicals, Canopy , Machinery, Irrigation…),

where:

Y is the yield and Labour, Nutrition, Chemicals, Canopy, Machinery, Irrigation are all factors of production.

Gross Margin (GM) can be regarded as a proxy for the dynamics of the profits, being calculated as:

(2) GM=Y* Average Gross price-Variable Costs,

where:

(3) Variable Costs=wL*Labour*+wN*Nutrition*+…..WI*Irrigation* +….

Where Labour*, Nutrition*, Irrigation* and so on represent the optimal demand functions for the correspondent input factors of production after minimizing the cost of producing an arbitrary level of output Y.

It is customary to place the issue of determining the gross margin under the theoretical assumption of separability of the factors of production, yet this hypothesis is mostly contradicted for small farms.

This fact leads to significant discrepancies between the theoretical-standard estimations of the GM and the actual ones, these discrepancies being further interpreted as departures from some efficiency and optimal and standard values. These departures impede further derivations like a correct determination of future cash flows, break-even point and future profits and through that, conduce to an improper estimation of the farmers risk profile and management efficiency and, thus, to an inadequate financing of the specific agricultural activities.

To sum up, the main two theoretical assumptions in the neo-clasicall theory of production function are:

- the separability of the factors of production; and
- the dependence between the output and the selling price in the context of market characterization are addressed by this model and replaced by the next two assumptions.

The interdependence (substitutability) of the factors of production in case of small farms, is inversely proportional with the size of the farm.

The construction of the cluster matrix assessing the comparative importance of all the variables participating in the formation of the GM address exactly the two theoretical drawbacks previously mentioned.

12.4. Digital smart cooperation in agriculture

The core of the model for smart cooperation is the Gross Margin. It can be used as a proxy for profits, break-even analysis, cash flow, trends in development and investment. Many influence factors and dependences can be built around the Gross Margin, including input factors in agriculture, trading platform for nutrients, chemicals, machinery, financing instruments, consumers, reports, databases created from various dates (Table 2).

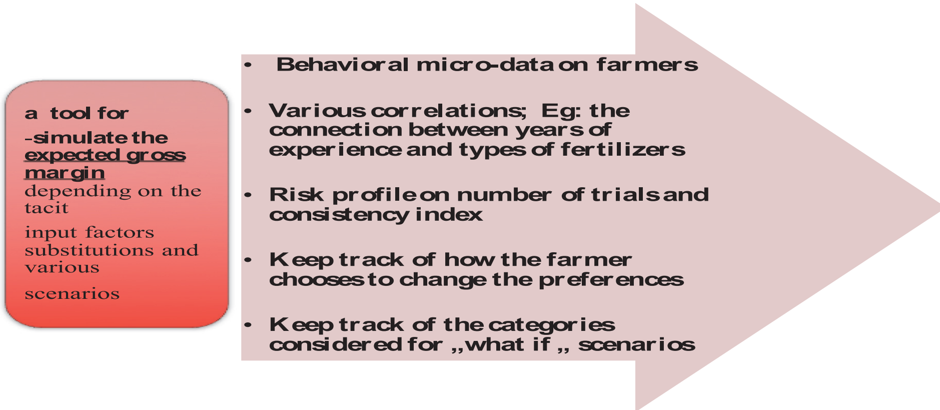
Table 2. Digital Smart Cooperation in Agriculture: Gross Margin and area of dependences.

External users	Digital solution	Internal benefits
Input factors in agriculture	**A platform for comercialization of various nutrients, chemicals, machinery**	**Behavioural database**
Producers of fertilizers, chemicals, nutrients, seeds, machinery	To be used as a the starting point in the future diversification and refinment in the production process	About expectation formation in the production and distribution for small and medium farm producers
Financing instruments	**Gross Margin for smalll and medium farms**	**A bold database**
Banks, insurance companies, credit cooperatives	As a proxy for profits, break-even point, cash flow, trends in development and investment	About assets, input factors demand and nominal production – leading to a more accurate assesment of financial reliabaility of individual farmers
Consumers	**A platform for traiding of production inputs and outputs**	**Reports on agregated performances**
Individuals, processing and/or storage	To be used as a starting point in the future for smart cooperation and other trding businesses	For a correct distinction in between categories of farmers, crops, regions etc.

Source: own study.

Once the data is digitalized it can be used in many different ways. One of the most valuable application can be simulating different scenarios based on assumptions and alternatives. These simulations can be loaded with different behavioural data for farmers. The software can show various correlations on individual level or at the level of the market as a whole. It will be possible to create risk profile on a number of trials and consistency index. "What if" scenarios will be easily accessible for the farmers and they will be able to study different options (Figure 3).

Figure 3. Smart cooperation in agriculture – possible outcome and benefits



Source: own study.

12.5. Application of the ANP Farm Management Model

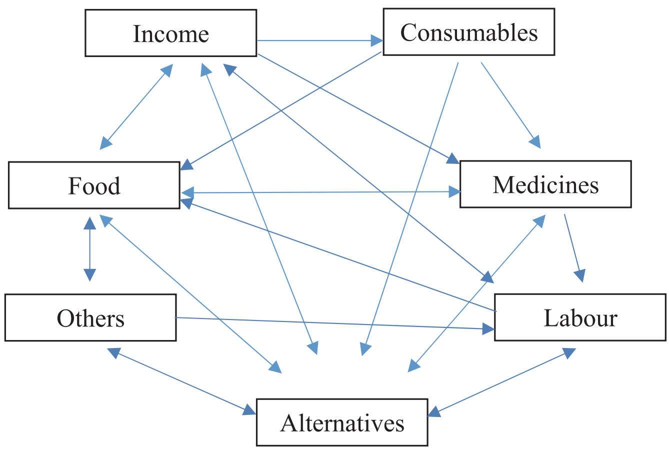
The ANP can be used as a management tool on farms. To demonstrate how it can be useful we are going to use a honeybee farm as an example. The first that is important is the farmer to decide what are the alternatives. Our proposal is that alternatives can be:

- Nominal Gross Margin – that is the GM calculated form the farmer based on his real results;
- Pessimistic Gross Margin – that is the GM calculated from nominal GM – certain % of the GM (the % is defined by the farmer);
- Optimistic GM – that is the GM calculated from nominal GM + certain % of the GM.

The second step is to arrange the components (sometimes called clusters) of dependencies and the elements of the components. After a consultation with honeybee farmers we have defined the following components: income, food, consumables, medicines, work, others. The clusters and their dependences are shown in Figure 4. As it is shown, the alternatives depends on all clusters but also the clusters depend on the alternatives. One can observe that from the arrows. If the arrow points in both directions that means that cluster influences the alternatives and the alternative influences the cluster too. In our particular case if we take for example the food cluster. It is obvious that the quality and quantity of food can influence the alternatives (i.e. Gross Margin). From other point of view, if the farmer requires higher Gross Margin he should be aware of the quantity and quality of food needed and he should distribute enough food to the bees. That is how the influence can go from clusters to the alternatives and back.

Moreover, the observations clearly showedthat there are not only dependences between alternatives and clusters but also between clusters too. In Figure 4, they are shown as arrows between clusters. The direction of the arrows shows the direction of dependence. If it is in one direction the dependence goes form one cluster to the other. If the arrow is in both directions then the dependence goes form one cluster to the other but the other influences the first too.

Figure 4. Clusters and dependences of a honeybee farm



Source: own study.

The next step is to define the elements of clusters. They are summarized in Table 3.

Table 3. Elements of the components (clusters)

Income	**Food**	**Consumables**	**Medicines**	**Labour**	**Others**
Direct sales	Sugar	Wax bases	Regular	Farmer	Transport
Retailers	Honey	Frames	Not regular	Family	Certification
Subsidies	Prepared food			Seasonal work	

Source: own study.

Every element in any cluster can influence any other element in all clusters. The influence of the elements over the other elements of the network can be represented by a matrix, which is known as a supermatrix. The supermatrix of a honeybee farm is represented in Table 4. Not all cells of the supermatrix have to be filled in with estimations. We have to create only the matrixes of dependences between clusters and elements that we find an influence. These are the same influences that we have outlined in Figure 4.

There is a problem of a practical nature here. Each arrow, which is seen in Figure 4, must be evaluated with a series of matrixes. If the arrow is in both directions – the number of matrices is doubled. The number of matrixes depends on the number of elements in the clusters. Additionally each matrix consists of multiple estimations. For example if we evaluate the matrix of the dependences between income and food clusters we will have 6 different matrixes to evaluate. Each matrix consist of 3 independent estimations. As you can imagine the number of evaluations grows exponentially with the numbers of clusters and dependences between them. In our case this means that 55 matrixes should be created, every matrix with a number of estimations (Table 4). Our opinion is that in practice the farmers will not make so much estimations or will make estimation automatically which can make the estimation invalid.

Table 4. Visualization of cluster matrix

	Clusters	1			2			3		4		5			6		7		
Clusters	Elements	1A	1B	1C	2A	2B	2C	3A	3B	4A	4B	5A	5B	5C	6A	6B	7A	7B	7C
1	1A																		
	1B																		
	1C																		
2	2A																		
	2B																		
	2C																		
3	3A																		
	3B																		
4	4A																		
	4B																		
5	5A																		
	5B																		
	5C																		
6	6A																		
	6B																		
7	7A																		
	7B																		
	7C																		

* The colored leading rows and columns represent different clusters and elements. The gray area inside are the matrixes that have to be estimated.

Source: own study.

Cluster numbers are: 1 – Income; 2 – Food; 3 – Consumables; 4 – Medicines; 5 – Work; 6 – Others; 7 – Alternatives. Element numbers are: 1A - Direct sales; 1B – Retailers; 1C – Subsidies; 2A – Sugar; 2B – Honey; 2C – Prepared food; 3A – Wax bases; 3B – Frames; 4A – Regular; 4B – Not regular; 5A – Farmer; 5B – Family; 5C – Seasonal work; 6A – Transport; 6B – Certification; 7A – GM -10%; 7B – GM; 7C – GM +10%.

In order to solve this problem, we decided to further assess the dependencies between clusters and classify them as strong and weak dependencies. Subsequently, we removed the weak dependencies from the supermatrix and thus reduced the number of matrices to 15 (Table 5).

Table 5. The reduced number of dependences between clusters and elements.

	Clusters	1			2			3		4		5			6		7		
Clusters	Elements	1A	1B	1C	2A	2B	2C	3A	3B	4A	4B	5A	5B	5C	6A	6B	7A	7B	7C
1	1A																		
	1B																		
	1C																		
2	2A																		
	2B																		
	2C																		
3	3A																		
	3B																		
4	4A																		
	4B																		
5	5A																		
	5B																		
	5C																		
6	6A																		
	6B																		
7	7A																		
	7B																		
	7C																		

Source: own study.

If the supermatrix is solved in this way, that means all clusters have an equal weight. It is logical to assume that clusters have a different weight in the final evaluation of alternatives. Therefore, a cluster matrix is created that assesses the degree of impact of individual clusters. The cluster matrix is assessed by experts and is not set by the farmers. The cluster matrix for honeybee farm is shown on table 6.

Table 6. Cluster matrix of a honeybee farm.

	Income	Food	Consumables	Medicines	Work	Others	Alternatives
Income	25%	23%	22%	18%	30%	23%	33%
Food	16%	21%	28%	28%	16%	12%	27%
Consumables	3%	4%	8%	7%	4%	7%	5%
Medicines	7%	9%	4%	10%	5%	9%	5%
Work	22%	7%	12%	5%	23%	16%	19%
Others	2%	4%	4%	6%	3%	7%	3%
Alternatives	24%	31%	22%	26%	19%	26%	8%

Source: own study.

After calculating the cluster matrix, the initial supermatrix is weighted with the farmer's estimates and the final weights of the alternatives are calculated.

12.6. Summary and conclusions

The result of the analysis shows comparatively equalized probabilities for each of the alternatives ranging around 30% (have in mind that the result is from the answers of our experts, which is why we find it as expected). A slightly higher probability is for the pessimistic option – 39%.

Table 7. Weights of the alternatives according the ANP

Pessimistic GM -10%	39%
Nominal GM	27%
Optimistic GM +10%	34%

Source: own study.

As a summary of the results it can be said that if moderate results are shown, as in the example shown, this indicates that the behavioural risk of the farmer is minimal. It can be assumed that he follows a coherent technology tailored to the specifics of production. Large percentages for one of the variants would be indicative of a specific behavioural risk and could alert the interested party. The application of the ANP to a large group of farmers can achieve even better results by comparing them on a regional basis or over different periods of time.

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