Reorganization of Agricultural Holdings in the Region of Central Macedonia Using Multi-Criteria Decision Analysis

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Abstract

The aim of this paper is to reorganize the production plan of agricultural holdings in the region of Central Macedonia in Greece using a Multi Criteria Decision Model. For this reason, a Multicriteria Decision Model was developed. The Multi Criteria Decision Model (MCDM) calculates a utility function for farmers, taking into account various conflicting criteria, which explain the decisions of farmers (e.g. maximization of gross margin, minimization of risk, minimizing labor, etc.). The model managed to achieve the goals set by farmers. The increase of the gross margin was the initial goal of the farmers. At the same time, the model succeeded to reduce the other two goals which were the use of fertilizers and the use of labor. As regards the production plan the models suggested the abandonment of three main cultivation in the region.

Keywords

Agricultural holdings, farm management, mutlicriteria analysis, quantitative methods, agricultural policy

1. Introduction

The complexity of decision systems, as well as the competitiveness conditions under which decisions are made, led to the development of the multiple criteria decision theory [1].

The application of multi-criteria decision analysis in agriculture does not have as its sole goal the maximization of gross margin, as in Linear Programming, but uses more than one goals to find the optimal production plan for farmers. The Multi Criteria Decision Model (MCDM) calculates a utility function for farmers, taking into account various conflicting criteria, which, however, explain the decisions of farmers (e.g. maximization of gross margin, minimization of risk, minimizing labor, etc.) [2].

There are many studies in Greece and Europe [3–6] where multi criteria decision making models were used for the reorganization of the production plan of agricultural holdings. In their studies Bournaris et al. [7] and Manos et al. [8] used multi-criteria mathematical programming to assess the impacts for the measure of "setting up young farmers" in Greece. Also in Georgilas et al. [9] a multi-criteria decision model was applied to study the socioeconomic impacts of climate change in rural areas of Greece. Moulogianni et al. [10] assessed the impacts of rural development plan using a multicriteria model. Manos, et al. [11] used MCDM to simulate the impact of different policies based on water prices on agricultural production and analyzed the economic, social and environmental impacts of alternative policies for irrigation water. Bournaris et al. [12] present a fuzzy multi-criteria model of mathematical programming, applied in an area of northern Greece with irrigated agriculture, where the optimal production plan is achieved. They compare the results of this model with those of a multi-criteria mathematical programming model (MCDM model), as well as those of a linear programming model (LP model). Manos et al., [13] in their study used a multi-criteria mathematical programming model to

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evaluate the utility function of the farmer and to simulate various scenarios and policies, as well as to compile alternative production plans. Finally, Chatzinikolaou et al [14–16] used multicriteria analysis for grouping and ranking the European Union rural areas based on social sustainability indicators. In their work Manos et al., [17] presented a decision support system (DSS) for the sustainable development and environmental protection of rural areas. DSS is based on a multi-criteria optimization model. Its aim was to optimize the production plan of the rural area taking into account the available resources, the environmental parameters, and the vulnerability map of the area.

The aim of this paper is to reorganize the production plan of agricultural holdings in the region of Central Macedonia in Greece using a Multi Criteria Decision Model. The data for the model development was collected from a sample of agricultural holdings participating in the "Setting young up farmers" measure of the Greek Rural Development Plan of the second pillar of Common Agricultural Policy [18].

2. Methodology

Sumpsi et al. [19] and Amador et al. [20] proposed the weighted goal programming methodology for the analysis and simulation of agricultural production systems based on multi-criteria techniques. The weighted goal programming methodology is used to analyze the farmers' decision-making process [21].

In this study the methodology of multi-criteria analysis is applied using the method of weighted goal programming to calculate the utility function of farmers, and to simulate their decision-making process.

The weighted goal programming methodology can be summarized in three steps:

1. Initially, a number of goals are set, which are considered as the most important for farmers.
2. The pay-off matrix of the selected objectives is then determined.
3. Finally, the pay-off matrix is used to calculate a set of weights that it is believed that reflect farmers' preferences.

Thus, the first step in our analysis consists of defining the set of goals $f_1(X) \ldots f_i(X) \ldots f_n(X)$ that represents the goals of farmers (e.g., gross margin maximization, fertilizers use minimization, labour hours minimization).

The edata of the table must be computed by optimizing one goal in each row. Thus, f_{ij} is the value of the *i-th* attribute when the *j-th* goal is optimized. When the pay-off matrix is complete, we solve the following system of q (number of goals) equations:

$$\sum_{j=1}^{q} w_j f_{ij} = f_i, i = 1,2,...q; and \sum_{j=1}^{q} w_j = 1, \quad (1)$$

where w_j are the weights adjusted to each goal that reproduces the actual farmer's behavior, f_{ij} is the pay-off matrix data and f_i is the value achieved for the *i-th* goal, according to the existing production plan.

The above system does not result in a set of weights w_j, so it is necessary to look for the optimal possible solution, minimizing the sum of the deviational variables found by the nearest set of weights. For this purpose, a problem of weighted goal programming with percentage variables-deviations is created [22]. This solution is found in the following linear programming model:

$$Min \sum_{i=1}^{q} \frac{n_i + p_i}{f_i} \quad (2)$$

Subject to:

$$\sum_{j=1}^{q} w_j f_{ij} + n_i - p_i = f_i, i = 1,2,..., q and \sum_{j=1}^{q} w_j = 1 \quad (3)$$

where *pi* represents the positive deviation from the goal *i* and
n_i represents the negative deviation from it.

3. Results

The sample of the study was 219 farmers from the region of Central Macedonia in Greece. From their production plans the average production plan of the region was calculated. The production plan of the average agricultural holding of the sample is presented below in Figure 1. The following figure shows the percentage share of each crop in the average production plan.

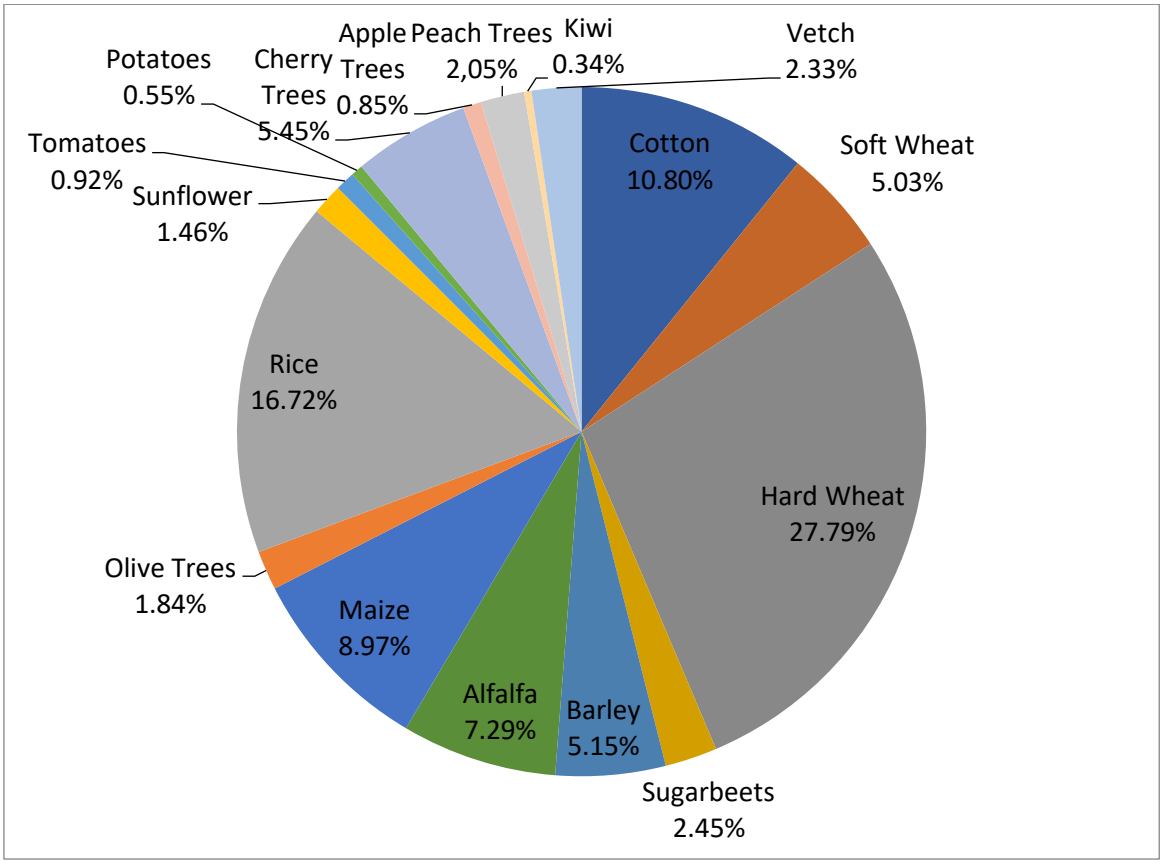

Figure 1: Average production plan for the region of Central Macedonia in Greece

From this figure we can conclude that the largest cultivation is hard wheat with a percentage of 27.79%. The following are the cultivations of rice and cotton with 16.72% and 10.80% respectively. Maize participates in the production plan by 8.97% and alfalfa by 7.29%. Cherry trees (5.45%), barley (5.15%) and soft wheat (5.03%) have similar participation rates. The participation of sugar beet (2.45%), vetch (2.33%), peach (2.05%), olive trees (1.84%) and sunflower (1.46%) is also important. A percentage of less than 1% in the production plan present the cultivations of tomatoes (0.92%), apple trees (0.85%), potatoes (0.55%) and kiwi (0.34%).

The following table presents the changes made to the production plan of the average agricultural holding after the application of the of multi-criteria decision model. The main objectives of the multi-criteria analysis were to increase gross margin, reduce fertilizer use and labor use. As shown in Table 1, all goals have been achieved. In fact, gross profit increased by 5.2%, fertilizer use decreased by 1.3% and labor use decreased by 2.7%. More specifically, the gross profit from €15,699 increased to €16,511, when the fertilizers use decreased from 6,791 kg to 6,706 kg and the labor use from 2,715 hours decreased to 2,642 hours.

As regards the production plan the multi-criteria decision model suggests the abandonment of three cultivations (cotton, common wheat and sugar beet). All the other cultivations are shown an increase.

More specifically, the cultivation of hard wheat shows an increase of 29.5% (from 27.79 acres to 35.98 acres). The cultivation of barley increases by 30%, (from 5.15 acres to 6.70 acres). Alfalfa also shows an increase (from 7.29 acres to 8.74 acres) by 20%. Maize increases by 19.9% (from 8.97 acres to 10.76 acres). Olive cultivation shows an increase of 4.7% (from 1.84 acres to 1.93 acres). The cultivation of rice increases from 16.72 acres to 20.07 acres, by 20%. The sunflower increases from 1.46 acres to 1.89 acres, by 29.9%. The cultivation of tomatoes increases by 19.8%, from 0.92 acres to 1.10 acres. The potatoes increase from 0.55 acres to 0.67 acres, by 20.8%. The cherry trees show an increase of 4.9%, from 5.45 acres to 5.72 acres. The apple trees show an increase of 5.4%, from 0.85 acres to 0.90 acres. Respectively, the cultivation of peach increases, from 2.05 acres to 2.15 acres, by 4.8%. Kiwis show an increase of 4.9%, from 0.34 acres to 0.36 acres. Finally, the vetch increases from 2.33 acres to 3.03 acres, by 30.2%.

Table 1
Results from the MCDM model

	Real	MCDM model	
		Values	%
Gross Margin (€)	15.699	16.511	5,2
Fertilizers Use (kg)	6.791	6.706	-1,3
Labor Use (hours)	2.715	2.642	-2,7
Cotton	10,80	0,00	-100,0
Soft Wheat	5,03	0,00	-100,0
Hard Wheat	27,79	35,98	29,5
Sugar beets	2,45	0,00	-100,0
Barley	5,15	6,70	30,0
Alfalfa	7,29	8,74	20,0
Maize	8,97	10,76	19,9
Olive Trees	1,84	1,93	4,7
Rice	16,72	20,07	20,0
Sunflower	1,46	1,89	29,9
Tomatoes	0,92	1,10	19,8
Potatoes	0,55	0,67	20,8
Cherry Trees	5,45	5,72	4,9
Apple Trees	0,85	0,90	5,4
Peach Trees	2,05	2,15	4,8
Kiwi	0,34	0,36	4,9
Vetch	2,33	3,03	30,2
Total	100,0	100,0	

4. Conclusions

In this study a try to reorganize the production plan of the agricultural holdings in the region of Central Macedonia was made. For this reason, a Multicriteria Decision Model was developed. The model managed to achieve the goals set by farmers. The increase of the gross margin was the initial goal of the farmers. At the same time, the model succeeded to reduce the other two goals which were the use of fertilizers and the use of labor. As regards the production plan the models suggested the abandonment of three main cultivation in the region.

The Multi-Criteria Decision models can be used:

- in cases where we are interested in achieving more than one goals, since it achieves the integration of separate conflicting goals into a unique utility function.
- although this model is considered to be basically static, it can be converted to potential by using longitudinal data mainly for the integration of risk into the utility function, as well as for the simulation of various scenarios.

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