MODELING MULTIFUNCTIONALITY OF AGRICULTURE AT A FARM-LEVEL: THE CASE OF KERKINI DISTRICT, NORTHERN GREECE

Michael Vassalos[1], Carl R. Dillon[2], David Freshwater[3], Pavlos Karanikolas[4]

Abstract: Multifuncionality has become a central concern at both conceptual and empirical levels. In this study, a comparative evaluation of the economic performance of conventional and multifunctional farms (mainly organic farms) was conducted for the Lake Kerkini region (North Greece) with the use of mixed integer non-linear programming method. The economic performance of farms was evaluated in terms of farm income, resource allocation, production level and production mix. The results indicate that multifunctional farms have overall better economic performance and young farm managers are keener to adopt multifunctional farming than the older ones. Differences between the model results and the observed facts are attributed to the structural characteristics of the farms, along with the CAP measures and the existence of multiple objectives, beyond maximization of net farm returns.

Key words: Greek farming, multifunctionality of farming, farm decision making, Mixed Integer Nonlinear Programming

Introduction

An interesting strand of the literature on multifunctionality refers to the attempts that have been made from scholars to operationalise the notion of multifunctional agriculture at the farm level.

Using mathematical programming methods at the farm level, *Havlík* et al. (2005) analysed the impact of various policy instruments on the production of environmental goods, related to agricultural commodities, in view of the uncertainty in output prices and farmers' risk aversion. Additionally, *Wilson* (2008) conceptualizes the idea of multifunctional transitional processes over time and, introduces the notions of multifunctional path dependency and decision-making corridors.

Multifunctionality is integrated in the policy impact analysis from *Buysse* et al. (2007), with the use of three different, farm-level, mathematical programming models. *Moreover, Wilson* (2009), suggests that the farm level is the most important spatial scale for the implementation of multifunctional action 'on the ground'; this argument stems from the analysis of different interlinked 'layers' of multifunctional decision-making ranging from the farm level to the national and global levels. Additionally, several studies have used various types of mathematical programming methods in order to examine the differences between organic and conventional farming (i.e. *Acs* et al. (2007), *Cisilino and Madau* (2007), *Schmid and Sinabel* (2005, 2007)).

Finally, Aguglia et al. (2009), explore the adoption of diversification and multifunctionality as possible alternative strategies to the agricultural "productivist" model.

The Greek literature is quite poor with regard to studies about the economic performance of multifunctional farms and the jointness between commodity and non-commodity outputs. Recent references on various multifunctional aspects of Greek agriculture include: *Barrio and Vounouki* (2003), *Louloudis* et al. (2004), and *Karanikolas* et al. (2007). These studies illustrate that multifunctional activities are more efficient and can help family farming as well as rural communities to improve their overall performance.

Greek agriculture is a highly diversified sector. This diversification results from the high fragmentation of farm holdings, the topography and natural features of Greek landscape (83% of the agricultural area is situated in less favored areas or mountain areas), the multitude of farm holdings (860,000 holdings) and, last but not least, from the scarce resource endowments. Moreover, 36% of all farm holdings have an economic size of less than 2 European Size Units, 67% of holdings occupy less than one Annual Working Unit and 76% use less than 5 ha of agricultural area. The chief goods produced are wheat, corn, olive oil, fruits and vegetables. The age and sex distribution of farm holders

[1] Michael Vassalos, Ph.D. Candidate, Department of Agricultural Economics, University of Kentucky, 401 Woodland Avenue apt. #9 40508, USA, e-mail: vassalosmichael@uky.edu, phone: 1 859-2704716.
[2] Professor Carl R. Dillon, Ph.D., Department of Agricultural Economics, University of Kentucky, USA
[3] Professor David Freshwater, Ph.D., Department of Agricultural Economics, University of Kentucky, USA
[4] Assistant Professor Pavlos Karanikolas, Ph.D., Department of Agricultural Economics, Agricultural University of Athens, Greece

is another important aspect of Greek agriculture; 25% of the holders are women, 55% are aged 55 or more (37% are aged 65 or more), and only 7% are younger than 35 years. Finally, only 15% of farm holders are full-time farmers.

The purpose of this study is to evaluate the economic performance of multifunctional and conventional farming, by using a mathematical programming method at the farm level.

The paper is organized as follows. In the next section, the mathematical model and the data used in the study are described. In section 3, the results of the model are discussed and then are compared with the actual behavior in order to draw some conclusions about farmer behavior in the Lake Kerkini region, Greece.

Materials and Methods

In order to achieve the objective of this study, a field survey was conducted in 2007 in the Lake Kerkini area (Northern Greece). A sample of 70 farms was drawn, consisting of 45 representative conventional farms, along with 25 multifunctional (MF) farms (see below). Two specific kinds of activities have been used as an indication of the concept of multifunctionality. The first is, organic farming and the second is the provision of eco-touristic activities, a major form of on-farm diversification in the Greek countryside.

After the compilation of a detailed dataset through face to face interviews with the heads of those farms, a mixed integer non-linear programming (MINLP) method was implemented. MINLP is selected as an approach in this paper because it was necessary to be able to simultaneously optimize the system structure (discrete) and the parameters (continuous). The mathematical model is as follows:

(1) Max: $\sum_j R_j X_j - \sum_j C_j X_j + (HSAMT \times HS) + (LSAMT \times LS)$

Subject to:

(2) $\sum_j A_j X_j \leq CP$

(3) $\sum_j D_j X_j \leq DRLND$

(4) $\sum_j F_j X_j \leq IRLND$

(5) $\sum_j T_j X_j \leq PST$

(6) $\sum_j H_j X_j \leq L$

(7) $\sum_j N_{jm} X_j \leq MCN, \forall m$

(8) $HS + LS \leq 1$

(9) $DI = \dfrac{X_{\text{'cows'}} \times [10 + (6 \times \gamma)] + X_{\text{'sheep'}} \times 1.5}{PST}$

(10) $HSAMT = (200 \times X_{\text{"cow"}}) + (25 \times X_{\text{"sheep"}})$

(11) $LSAMT = (25 \times X_{\text{"cow"}}) + (6.25 \times X_{\text{"sheep"}})$

(12) $DI - 1.8HS - M \times LS \leq 0$

Where j represents the possible enterprises of: apple, pear, sheep, cow, trefoil, olive, cherry, corn, tare, pig, tomato, and barley for organic producers and cow, sheep, pig, soft wheat, hard wheat, trefoil, olives, tare, cotton and tobacco for conventional producers. Regarding the objective function coefficients, R_j represents the gross revenue (in €) calculated at the prevailing market price of the j^{th} enterprise. C_j represents the production cost (including variable costs) of one unit (stremma or head) of the j^{th} enterprise. The decision variable includes X_j which represents the stremmas or head produced of the j^{th} enterprise. Finally, HSAMT represents the high subsidy amount (€) and LSAMT represents the low subsidy amount (€) of livestock subsidies. Binary variables (HS, LS) were created in order to choose between high subsidy and low subsidy payments.

There are six resource constraints in the model for capital availability (€), three types of land availability (stremmas), labor (available working hours) and machinery availability (available operating hours). Land includes irrigated land, dry land and pasture (stremmas). Operating hours of machines are potentially limiting and are represented in individual constraints by machine type (m). Resource endowments include available area of irrigated land (IRLND), pasture land (PST) and dry land (DRLND) in stremmas, capital availability (CP) in Euros, labor (L) and machinery (MCN) availability in working hours.

Regarding technical coefficients, A_j represents the amount of capital (in €) used when producing one unit of the j^{th} enterprise, similarly, D_j and F_j represent the amount of dry and irrigated land used to produce one unit of the j^{th} enterprise (in stremmas). T_j represents the amount of pasture land required for the production of one unit of the j^{th} enterprise. Finally, H_j and N_{jm} represent the hours of labor and machine operation required for the production of one unit of the j^{th} enterprise. Regarding accounting constraints, DI represents the density index of livestock productivity, γ is the weighted average of the number of cows between six and twenty-four months age and is calculated based on life expectancy and livestock replacement assumptions[5] (for this study $\gamma = 0.8$).The need to incorporate an either/or condition on subsidy amount is enabled with binary variables. Equation (12) establishes the density index dependent requirements of receiving either a high subsidy (HS) or a low subsidy (LS) but not both, as mentioned previously. Thus, if HS=1 and LS=0 then DI must be less than 1.8. Otherwise, the DI is not restricted as M theoretically represents pasture infinity but practically is a very large number (e.g. 1,000,000,000). This formulation therefore depicts an empirical application of introducing Boolean logic not often used in mathematical programming demonstrating a potentially powerful technique.

While modeling the constraints, a difficulty has arisen, concerning the specification of the right hand side for pasture land availability. Specifically, pasture land has the characteristics of free good (zero opportunity cost) in the

[6] KM = Convertible Marks. 1 KM = 0.511292 Euro.

Table 1. Characteristics of the "Average Farms" By Farm Size

Size	Type	Irrigated land	Dry Land Stremmas	Pasture	Capital €	Labor Hours	Tractor Hours
Small	MF	40	0	10	900	1200	150
	Conventional	18	20	15	850	800	120
Medium	MF	70	0	15	1200	2000	300
	Conventional	33	27.5	20	1600	1400	180
Large	MF	95	0	15	2000	2600	400
	Conventional	45	45	30	3000	3000	400

Source: Questionnaire results

examined area; as a result farmers may be able to have an "infinitely high" amount of pasture land and, because of the high price of dairy products, they could use all their available labor, capital and machine for cattle production instead of crops. What stops farmers from having infinitely high amount of pasture are the quotas form the Common Agricultural Policy regarding milk productivity for each country. Based on these limits each farmer has some productivity rights regarding the number of animals and his/her milk production. So the right hand side regarding pasture availability constraint was defined as the historic average of the pasture land farmers had based on their productivity rights.

Finally, regarding the units of the different sets of constraints the following should be taken into account: a) land was measured in stremmas (5 stremmas = 1.25 acres) b) labor was measured in hours per stremma or in hours per head for livestock productivity c) gross revenue, variable costs, capital and wage rates are in Euros (1 € = 1.2 U.S. dollars for the examined period). The model was solved with the use of General Algebraic Modeling System (GAMS), which provides a flexible framework for formulating and solving MINLP problems.

The samples used for this study consist of 25 MF (organic) farms, 10 of which engage in eco-tourist activities, and 45 conventional farms respectively. All the organic farms of the area of interest are included in the sample. The choice of the conventional operations was made with the method of stratified random sampling. Specifically, the population of the conventional farmers in the examined area was divided in groups with main criterion land availability and type of enterprises in order to create comparable groups of MF and conventional farms. Afterwards, with a random number generator farmers from each category were selected. Finally, MF and conventional farms were divided into three groups with main criterion the land availability for agricultural activities: Firstly, *small farms*, consisting of 10 MF and 18 conventional farms respectively with less than 50 stremmas available. Secondly, *medium farms*, comprising 9 MF and 16 conventional farms respectively, which have between 50 and 100 stremmas available. The third group, *large farms* consists of 6 MF and 11 conventional farms which have more than 100 stremmas available for agricultural activities.

For each one of these groups an "average" conventional and MF farm operation was estimated based on the data coming from the questionnaire. The characteristics of the "mean farms" are presented in Table 1. Descriptive statistics regarding important characteristics of decision makers are presented in Tables 2 through 5.

Table 2 shows that the leaders of MF farms are quite often between 30-39 years old. The age of the manager turns out to be an important factor for decision making. This is so because, younger decision makers are less risk averse and have a longer planning horizon.

Table 2. Age of Primary Decision Makers

	Small farms		Medium Farms		Large Farms	
	MF	Conventional	MF	Conventional	MF	Conventional
30-39	70.0%	33.3%	47.5%	30.7%	30.0%	53.8%
40-49	20.0%	26.4%	22.5%	38.4%	50.0%	23.0%
50-59	10.0%	32.4%	30.0%	23.0%	20.0%	15.6%
60+	0.0%	7.8%	0.0%	7.6%	0.0%	7.6%
Mean	40	47.7	43.6	40	42	41.4

Source: Questionnaire results

From *Table 3* it can be seen that, as the size of the farm expands the percentage of the farm managers with off farm activities is declining. Additionally, it can be seen that the percentage of farm managers with off farm activities is higher in conventional enterprises. This is not unexpected because MF enterprises are more labor intensive.

Table 3. Percentage of Primary Decision Makers With Off Farm Activities

Small farms		Medium Farms		Large Farms	
MF	Conventional	MF	Conventional	MF	Conventional
60.0%	70.0%	23.0%	30.0%	15.0%	23.0%

Source: Questionnaire results

Another important point is related to the education level of farm managers *(Table 4)*. Specifically, as the farm size gets bigger, the education level of managers in both MF and conventional operations increases. This improvement can be attributed to the complexity of problems that have to be answered by the managers of bigger farms.

Table 4. Educational Level of the Decision Makers

Education	Small farms		Medium Farms		Large Farms	
	MF	Conventional	MF	Conventional	MF	Conventional
Illiterate	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Primary School	50.0%	57.8%	37.8%	53.8%	50.0%	23.0%
Secondary School	40.0%	26.5%	12.5%	30.7%	30.0%	38.4%
High School	10.0%	15.7%	37.5%	7.7%	0.0%	38.4%
University	0.0%	0.0%	12.5%	7.7%	20.0%	0.0%

Source: Questionnaire results

From *Table 5*, it can be seen that MF producers prefer direct selling of their products while the conventional producers in their majority prefer selling their products to vendors. This difference can be attributed to some of the factors mentioned above (younger decision makers, higher education level) and to the fact that marketing channels regarding MF products in Greece have not been fully developed yet. In addition to that, producers said that by direct selling they can avoid the middle-men thus increasing their profits.

Table 5. How Products Are Sold

Size	Type	Sold to vendor	Direct sales	Consumed by the family	Used in the ecotourism activities of the farm
Small	MF	20.0%	60.0%	10.0%	10.0%
	Conventional	57.8%	21.1%	21.1%	0.0%
Medium	MF	30.0%	70.0%	0.0%	0.0%
	Conventional	76.9%	23.0%	0.0%	0.0%
Large	MF	69.0%	20.0%	0.0%	11.0%
	Conventional	90.0%	10.0%	0.0%	11.0%

Source: Questionnaire results

Results and Discussion

The results regarding income, shadow prices, slacks and decision variables, for all the types of farms examined in this study are shown in *Tables 6 and 7*.

From *Table 6* it can be seen that, the level of maximum income for all farm sizes (small, medium, large) is greater for MF farms. Thus, the results of the present paper are in agreement with similar conclusions found in literature, confirming that MF farming can be more profitable and attractive to farmers compared to conventional methods (among other references: *Acs* et al. (2007), *Cisilino and Madau* (2007), *Schmid and Sinabel* (2005, 2007), *Pacini* et al. (2003), *Parra-Lopez and Calatrava-Requena* (2006)).

The incomes estimated from the model are higher than the average income estimated from the questionnaires. This difference can be attributed to several possibilities: 1) the model does not depict the fragmentation of the farm holdings, 2) farm managers may have multiple objectives besides maximizing farm income (for example reducing risk and volatility of income), and 3) the model is static and does not take into account the loss of income from the transition periods. Despite these differences, the model results are not unreasonable and they can act as a good indicator for the difference in economic performance between MF and traditional enterprises.

Another important point is the high shadow prices of pasture land (which has the characteristics of a free good in the examined area) for conventional farms. Since shadow prices indicate the marginal value product of pasture, why do producers not use more pasture to increase their income? The answer to this question comes from the milk quotas imposed by the Common Agricultural Policy of Europe (CAP). If the operation has more animals or more production than the limit placed by CAP then the monetary amount of subsidies will decrease drastically. Greek farmers prefer to have a stable monetary amount of subsidies than to take the risk of increasing production and lowering subsidies without knowing if the extra production can cover the loss of subsidies. Consequently, shadow prices of pasture land likely reflect the subsidies given to cattle producers. In contrast to conventional farms, MF farms do not use all their available pasture land. This is so because MF products have higher returns than the conventional ones so the model allocates the limited amount of labor to crops or to trees instead of cattle.

Furthermore, from *Table 6*, it can be seen that irrigated land for small conventional farms has a high shadow price. But, the high cost of asset fixity (i.e. irrigation systems) and the extra labor needed substantially reduce this value. Additionally, medium and large conventional farms have higher slack of irrigated land compared to dry land *(Table 6)*. This is due to the more labor intensive nature of farming in irrigated land, which, in conjunction with the limiter amount of available labor leads the model to allocate more labor to dry land.

Moreover, it can be seen *(Table 6)* that there is a slack of capital and operating machine hours for all the types of enterprises examined. The former, is a result of self-insure methods adopted by the farmers, while, the latter, can be contributed to “lumpy-assets”. Specifically, if farmers can not find the machine that exactly fits with their needs they prefer to buy a bigger one, which, may be useful if they decide to expand their operation in the future.

Fourthly, regarding labor, the average wage of an unskilled worker in the examined area (7 € per hour) in conjunction with the shadow prices of labor for conventional and MF farms (7 and 11 € per hour respectively) justifies why there is a substantial big number of MF farms with hired workers, while, conventional enterprises, despite the slack of agricultural area, do not hire off farm workers.

The model results suggest that small and medium producers should have three enterprises and large producers optimally should have two types of enterprises if they are

Table 6. Economic Results and Slack Levels By Farm Type and Size

		Small		Medium		Large	
		MF	Conv	MF	Conv	MF	Conv
Net Returns-Model (Survey Results) – €		30,786 (26,530)	24,435 (20,802)	53,403 (44,200)	32,660 (27,700)	60,945 (50,638)	50,803 (45,655)
Irrigated Land	Slack – str*	4.7	(-)	3.4	9	5	13
	Shadow Price	(-)	482	(-)	(-)	(-)	(-)
Dryland	Slack – str	(-)	2	(-)	3.5	(-)	13
	Shadow Price	(-)	(-)	(-)	(-)	(-)	(-)
Pasture	Slack	0.815	(-)	4.08	(-)	2.5	(-)
	Shadow Price	(-)	237.74	(-)	196	(-)	270
Labor	Shadow Price	11.5	7	11.47	7.48	11.36	6.69
Tractor	Slack – hrs	18	16	79.26	68	115	228
Capital	Slack -€	505	358	696	821	332	1683

Source: Model results
*str stands for stremmas

Table 7. Production Level Results By Farm Type and Size

		Tare-Dry	Tare-Irr	Trefoil	Olives	Cows	Sheep
Size	Type	Stremmas				Head	
Small	MF	(-)	26.67	(-)	6.67	3	(-)
	Conventional	14.2	(-)	3.7		(-)	8
Medium	MF	(-)	28.33	(-)	8.6	1	(-)
	Conventional	24	21	(-)		4	6
Large	MF		33.3	(-)	33.3	4	(-)
	Conventional	20	21	(-)	11	8	(-)

Source: Model results

conventional and three types if they are MF *(Table 7)*. But, the questionnaire results show that small producers (MF and conventional) have on average five enterprises while large and medium producers have three. Two reasons justify this difference. Firstly, small producers have multiple goals beyond the maximization of net farm returns (i.e. equal distribution of the available family labor through the year, cultivation of some products to cover family needs, diversification of enterprises in order to have income even if some type of crops fail etc.). Secondly, farm holdings are highly fragmented (in average every farm has 4 different land parcels). Each parcel of land has different characteristics (e.g., different slope, different yield) that affect the decisions of farm managers, but, the model does not consider these spatial characteristics and differences.

Regarding production levels, *Table 7* shows that MF farms should keep the same enterprises as their size gets larger and increase the number of stremmas or the number of head. Meanwhile, the model selects different type of enterprises for the different size of conventional farms.

Another difference between the model results and the questionnaire is the production mix, especially for medium and large conventional operations. Specifically, cotton and tobacco, which are two of the main types of enterprises according to the questionnaire, are not chosen from the model. Three reasons justify this difference: a) The reduction in cotton and tobacco subsidies made these crops less profitable, b) the vast majority of farmers who continue to cultivate those crops are more than 60 years old. A main goal of this group of farmers is to decrease the volatility of their farm income. This objective in conjunction with the high level of risk aversion of elderly farmers and their short planning horizon prevent them from changing their set of enterprises, c) a change of enterprises would require new investments in capital and machinery which is a costly procedure that farm managers especially on smaller farms want to avoid.

Finally, the reduced cost ranking estimated from the model for each of the possible enterprises is consistent with actual enterprise choices made by the managers.

In conclusion, the results of this study indicate that, for every farm type, multifunctional farms have better economic performance than the conventional ones. Moreover, the results illustrate that young farm managers are keener to adopt multifunctional farming compared to older ones. This difference can be attributed to the longer planning horizon of the former and to the fact that older managers have learned to operate under a different environment.

Finally, the structural characteristics of the farms, along with the CAP measures and the existence of multiple objectives, beyond maximization of net farm returns, justify the differences between the model results and the observed facts.

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