Planning and evaluation of the sustainability of an agricultural farm unit: a methodological proposal

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Abstract

In this paper we propose a methodology for a farm plan that aims to reconcile the criterion of environmental sustainability with that of economic competitiveness, by employing the Multicriteria Decision Theory. Subsequently, we assess the comparative sustainability of the farm, along with that of two other farms, both of which correspond closely to the environmental and ecological conditions of northern Portugal, one of which can be thought of as a "conventional" farm and the other an "ecological" production unit. With the results obtained, we are able to conclude that an ecological production system (planned or not) results in a much more autonomous, productive, balanced, adapted and equitable management than the conventional production system considered in this study.

Keywords: sustaynability, environement, fam planning, management.

Résumé

Dans le présent travail nous proposons une méthodologie pour une planification de l'exploitation agricole qui vise à satisfaire, en même temps, aux critères de durabilité environnementale et de compétitivité économique à travers l'application de la Théorie de la Décision Multicritères. Qui plus est, nous évaluons la durabilité de l'exploitation en la comparant avec deux autres exploitations qui reproduisent de près les conditions environnementales et écologiques caractéristiques du nord du Portugal. L'une peut être qualifiée d'unité de production "conventionnelle" et l'autre d'unité de production "écologique". Les résultats obtenus indiquent que le système de production écologique (planifié ou non) permet une gestion plus autonome, productive, équilibrée, appropriée et équitable par rapport au système de production conventionnel retenu dans cette étude.

Motsclés: *durabilité, environnement, programmation, gestion.*

1. Introduction

Currently, agricultural farm units are faced with a double but contradictory challenge, in order to be successful: on the one hand the invested capital has to be profitable and the economic performance has to be maximised. On the other hand, given the socio-environmental situation, it is necessary to preserve and protect the environment and natural resources. Such a challenge requires, among others things, an appropriate consumption of inputs (such as fertilizers and crop protection products), and a readjustment of the technologies used (mainly through the adoption of energy saving measures), without jeopardising food safety standards that society expects.

Many of the existing farm units do not come close to achieving these two objectives (conventional farms), while others try to reconcile them, if not completely, at least in part (ecological farms). We should remember that it was in the context of such agro-environmental policies that many European farms received monetary support to undertake agricultural policies in accordance with the principles of ecological agriculture.

In the Portuguese context, the problem today centres on planning farms' activities in such a way to meet economic objectives (from the perspective of the private investor) as well as environmental objectives (from the perspective of the general public), in the future, and operating in accordance with the Strategy for Sustainable Development.

Given the potential conflict of the two objectives (the satisfaction of one implying an underperformance with regard to the other, and vice versa), and bearing in mind that, in the light of current economic theory, the income generated is a function of the quantity of factors used, while the main negative impact of the farm's activity on the environment derives from the very use of the same factors of production, the question then is: which is the solution to choose?

From a normative standpoint, we are convinced that farms should be planned in a way that allows them to reach a compromise between the two declared principles - economic and environmental sustainability. We intend, in this work, to formulate a plan for a farm, with the purpose of reconciling the criteria of environmental sustainability with those of economic competitiveness, using Multicriteria Decision Theory. In other words, we propose to improve to the maximum the economic performance of an ecological farm.

In fact, the underlying principle of the two above-mentioned objectives is closely related to the theme of sustainable development. On the one hand, the maintenance of agricultural activity is possible and desirable for economically viable farms as long as they are competitive. This will contribute to their survival and will prevent population loss. On the other hand, the very concept of sustainable development implies that all activities are developed on the principle that no damage be caused to the environment and that it be preserved for future generations. What is needed is the

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lowest possible environmental damage.

Taking as starting point the recent work of Marino (2002), two farms, adapted to the environmental and ecological conditions of northern Portugal, one "conventional" and the other "ecological", are used as a basis for comparison with a third farm - a hypothetical farm for which we developed a plan, via multiobjective programming.

This work constitutes the first stage in a study to be developed over the next four years and should be treated as the initial attempt to reconcile economic and environmental objectives in the planning of a farm unit.

2. The planned farm

2.1. Methodology

The preparation of a farm plan, simultaneously following economic and environmental objectives, was carried out using the paradigm of Multicriteria Decision Theory. From the standpoint of decision making in the context of multiple objectives this theory provides the basis for the methodology used in this study.

In order to arrive at the final farm plan, Multiobjective Programming, in particular NISE (NonInferior Set Estimation Method) and Compromise Programming, was used. The NISE method was selected from a variety of possible tools of analysis, due essentially to its ease of use, as well as its inherent advantage, namely the reduction in the number of solutions to a subgroup of an efficient set, which facilitates a better appreciation of the possible alternatives, though with some limitations (Romero and Rehman, 1989).

Given that this method allows us to converge on the efficient set both quickly and precisely, as long as the number of objectives under consideration does not exceed two (Romero and Rehman, 1989), we took as our objectives the maximising of the Gross Value Added (GVA) and the minimising of the energy costs.

The former was selected due to the fact that a farm's survival requires greater monetary incomes obtained via active participation in the market, i.e. the sale of products. This objective was translated, by us, into the maximisation of the GVA, as this result can easily be processed in the form of a linear equation or inequation.

With regard to the second objective, we assume here that it best reflects environmental considerations. Thus, among other possible objectives (for example, minimised water consumption, minimised consumption of production pollutants - fertilizers and crop protection products, minimised use of machines and equipment in the ground, among others) the minimum of energy costs seemed to us the most suitable given the possibility of quantifying the energy cost by the production factors used . The only factor that is not included in this objective is related to water consumption, whose energy value is imputed as nil.

This decision results from the fact that, on the one hand, it is not possible at the moment to measure the effect of the leaching caused by irrigation and, on the other, it seems to us that it is not a factor of appreciable environmental consequences, given that there is no shortage of water in the region. However, it should be noted that water consumption is implicit in the overall energy calculation, via the energy

Tab. 1. *The model formulation*

	XA_{1j} (m^2)	XA_{2j} (m^2)	MO (H)	TA (H)	MB (H)	AG (m^3)	F_N (Kg)	F_P (Kg)	F_K (Kg)	V_{ij} (Kg or Units)	GS (L)	b_i
Z1 - GVA (Euros)	$- P_{sj}s_{ij} - P_{FI}h_{ij}$	$- P_{sj}s_{ij} - P_{FI}h_{ij}$	$- P_{MO}$	$- P_{TA}$	$- P_{MB}$	$- P_{AG}$	$- P_{FN}$	$- P_{FP}$	$- P_{FK}$	P_i	$- P_{GS}$	
Z2 – Energy costs (MJ)	$VE_{sj}s_{ij} + VE_{FI}h_{ij}$	$VE_{sj}s_{ij} + VE_{FI}h_{ij}$	VE_{MO}	VE_{TA}	VE_{MB}		VE_{FN}	VE_{FP}	VE_{FK}		VE_{GS}	
Use of the green-house area (m^2)	1											= AE
Use of the outdoor area (m^2)		1										= AL
Use of labour (Hours)	a_{1j}	a_{2j}	- 1									≤ DMO
Use of tractor (Hours)	b_{1j}	b_{2j}		- 1								≤ DTA
Use of motor pump (Hours)	c_{1j}	c_{2j}			- 1							≤ DMB
Use of water (m^3)	d_{1j}	d_{2j}				-1						≤ 0
Use of N (Kg)	eN_{1j}	eN_{2j}					- 1					≤ 0
Contingent to the use of N (Kg)	eN_{1j}	eN_{2j}										≤ 0,017(AE+AL)
Use of P_2O_5 (Kg)	eP_{1j}	eP_{2j}						-1				≤ 0
Use of K_2O (Kg)	eK_{1j}	eK_{2j}							-1			≤ 0
Sale of the annual crop production (Kg or units)	$- f_{1j}$	$- f_{2j}$								1		≤ 0
Use of fuel (Liters)	g_{1j}	g_{2j}									- 1	≤ 0

used by the motor pump.

Using this approach, we propose the improvement of the economic-environmental conditions of this simulated farm, in two deliberately chosen areas: (1) competitiveness in the market with products that present greater GVA and (2) minimal energy costs.

To apply the model, we used information derived from an ecological farm. That is, we tried to apply a new model on this farm, having in mind the available factors of production, as well the underlying principles of ecological agriculture, in order to improve the economic result obtained. The model includes both the area covered by greenhouses and the open land. The farm uses 2040 hours of labour, a 56 horse-power tractor and one motor pump. All the remaining necessary factors of production are bought in.

We attempted to reflect the pre-existing diversity of horticultural production in our plan, namely the production of the following thirteen crops (cauliflower, broccoli, leek, onion, beetroot, carrot, potato, tomato, cucumber, maize, green beans, lettuce and strawberries).

The remaining necessary information for the application of the model was obtained from literature on the subject, namely Cary (1985), Almeida (2000) and Leach (1981).

The model can be summarised as Tab 1.

The meaning of each of the symbols used in the model is detailed in the appendix.

The model is made up of 34 decision variables and 24 constraints.

The Agriculturally-Used Area (AUA) represents two constraints and we added a constraint corresponding to the use of each of the following factors of production: labour, tractor, motor pump and fuel for the equipment. Furthermore we added a constraint for fertilizer use, thereby including in the model a reasonable use of fertilizers that does not exceed the amount per hectare specified in the European Community's Nitrate Directive[1], which has the objective of protecting underground water from extreme contamination by agricultural nitrates and, in particular, from manure. The amount specified per hectare is the amount of manure that will hold 170 kg of nitrogen (Pau Vall and Vidal, 1999). Finally, we specified the constraints relative to the sale of the crops.

As a first step in the construction of the model, we tested the real degree of conflict between the two objectives by individually optimising each of them so as to find their respective values in the optimum solution. On this basis, we constructed the Pay-off matrix found in Table 2. The elements of the main diagonal line represent the ideal point, that is, the solution in which the objectives achieve their optimum values.

Tab. 2. *Pay-off matrix obtained for the objectives under consideration*

	GVA (10^3 Euros)	Energy costs (10^3 MJ)
GVA (10^3 Euros)	67,42	178,09
Energy costs (10^3 MJ)	43,05	28,19

The interpretation of the Pay-off matrix allows us to conclude that a strong degree of conflict exists between the two considered objectives. When the GVA is maximised, the energy costs reach their highest or least ideal value, and vice versa.

Based on the steps presented below it was possible to deduce the transformation curves (trade-off) and to evaluate, at the margin, which of the objectives might be "sacrificed" so that the other could be improved.

From among the enormous number of efficient schedules generated by the multiobjective programming exercise, the most efficient solutions need to be sought. The best-compromise solutions (schedules) can usually be best determined by what is termed compromise programming, which is based on the distance to the "ideal" point, i.e. not the attained point, but that which constitutes the closest approximation to the wishes of the decision agent. This approach involves finding the solution closest to the ideal point (Romero and Rehman, 1989).

Different compromises were established in accordance with the metric used. For metric p=1, the best-compromise

$$MinL_1 = w_1 \frac{67{,}42 - Z_1(x)}{67{,}42 - 43{,}05} + w_2 \frac{Z_2(x) - 28{,}19}{178{,}09 - 28{,}19}$$

solution can be obtained, as is usually in the case of compromise programming, using the following linear programming model (Romero and Rehman, 1989):

Subject to: x €F

The decision variable x is constituted by the area covered for each crop and the set F is formed by the constraints initially imposed on the model. The coefficients w_1 and w_2 represent the preferences of the decision maker(s) to reach each one of the considered objectives.

For the metric p=α, in which the maximum individual deviation is minimised, the best-compromise solution is obtained using the following linear programming model (Romero and Rehman, 1989):

$$MinL_\infty = d$$

$$w_1 \frac{67{,}42 - Z_1(x)}{67{,}42 - 43{,}05} \le d$$

$$w_2 \frac{Z_2(x) - 28{,}19}{178{,}09 - 28{,}19} \le d$$

Subject to: x €F

Where d is the largest deviation.

[1] Council Directive 91/676/CEE, of 12 December 1991, concerning the protection of water against pollution caused by nitrates from agricultural sources, OJ L 375 of 31.12.1991.

It is well established that metrics p=1 and p=α define the two limits, L_1 and L_α, of the compromise-solutions. In other words, all the other compromise solutions fall between them (Romero and Rehman, 1989). At this point, it is sufficient to solve these two linear programming problems for each set of preferential weights, w_i.

Both the previous linear programming models were solved substituting unity for the terms w_1 and w_2.

The solutions obtained delimit the space of the compromise-solutions. In order to proceed, we select as the better solution that which presented the shorter distance to the ideal point, obtained through the technique of the "Discrete approximation of the best-compromise solution" (Romero and Rehman, 1989). Of the points calculated, the solution obtained by the L_1 metric was the one that gave the shortest distance to the ideal point and was, therefore, the solution adopted for the remaining phases of the study.

2.2. Results

In accordance with the methodology adopted, the main characteristics of the farm corresponding to the economic efficiency and environmental sustainability objectives are as follows.

- The entire greenhouse area is devoted to cucumber production and in the outdoor area only broccoli is produced. These two activities are the only income sources for the farm.
- The external area of the farm requires about half an annual unit of work, as well as applications of nitrogen, phosphorus and potassium of 133, 94 and 223 kg, respectively, in the form of products that conform to annex II of the Council Regulation (EEC) n.º 2092/91, of 24 June 1991, regarding organic agricultural production.
- Given the water needs of both these crops, about 182 hours of motor pump operation are required, while the tractor available to the farm is more than enough for both the activities undertaken.
- Given the income accruing to this farm, and the costs it was to cover, an annual GVA of about 53 610 Euros is reached.
- An annual energy cost of about 46 560 MJ was attributed.

3. The Evaluation of Sustainability

3.1. Methodology used

For the final part of the study, we use the procedure described by Masera et al. (2000) and adopted by Marino (2002), but this time applied to the "planned farm".

The mythology MESMIS - "Marco para la Evaluación de Sistemas de Manejo de Recursos Naturales Mediante Indicadores de Sustentabilidad" (Masera et al., 2000) consists of a comparative evaluation of a series of translating indicators of sustainability. As related by Masera et al. (2000) sustainability cannot be evaluated per se, but only relatively or comparatively, by contrasting two systems of management or two moments in the evolution of one system.

This is an analytical methodology that tries to mitigate the lack of integration of variables and indicators of many sustainability evaluation methods, overcoming the need for non-quantifiable variables and the presence of variables of biophysical, economic and social aspects (Masera, 2000).

MESMIS draws on the following principles to evaluate sustainability (Masera et al., 2000):

- it is valid only for specific systems of production in a given social and political context and in a given space and time;
- it uses a comparative or relative approach in order to evaluate the differences in sustainability between a reference system and an alternative system, or in the same system at different times;
- it is a participative activity that involves the systems to be evaluated and promotes discussion between appraisers and the evaluated on the basis of an interdisciplinary approach;
- it is a cyclical process in which the conclusions serve to identify the critical points of sustainability and to modify the management systems, leading to the initiation of another evaluation cycle.

For the evaluation of agro-ecosystems, it is necessary to make a detailed analysis of the system to be evaluated and to determine the critical points that will serve to identify the sustainability indicators. It is also essential that these reflect the three evaluation areas (environmental, economic and social) so as to guarantee an approach evaluation that covers all sustainability aspects. Beyond the definition of indicators and evaluation areas, it is necessary to establish the attributes of the system and the diagnostic criteria (Masera et al., 2000).

The systemic attributes, diagnostic criteria and sustainability indicators selected by Marino (2002) are presented in Table 3, and coincide with the ones used in the present study. It should be noted that the five attributes can be evaluated for the three different areas: economic (E), social (S) and environmental (A).

The evaluation cycle considered by the MESMIS methodology, through the selected indicators calculation, was applied by Marino (2002) to a number of representative farms in the Asturian horticultural sector and repeated by us on two farms: one practicing conventional agriculture, called "case Con" and one that practiced ecological agriculture, called "case Eco", both situated in the North of Portugal. We also included the hypothetical farm for which we had developed our plan, via the multiobjective programming, designated "case Plan".

The evaluation subject of the study is the management system of the conventional and ecological farms, consisting of the set of activities carried out by farm management, including the productive and commercial activities of the farm; training, acquisition and processing of information; resource management; decision making and the establishment and maintenance of economic and social relations of the farmers with their surroundings. Conventional agricul-

Tab. 3. *Sustainability indicators adopted by evaluation areas (E - Economic; S - Social and A – Environment), total: 56 indicators, 26 criteria and 5 attributes (Marino, 2002)*

ATTRIBUTE	DIAGNOSIS CRITERION	INDICATORS
Productivity (13)	Economic income of the farm and the resources (E)	• Gross value added (GVA)
		• Minimum income equivalent by worker
		• Annual net income of the land
		• Total annual cost by surface
		• Annual net income of the work
	Economic yield (E)	• Internal rate of yield
		• Recovery period of the investment
		• Benefit/cost relation
		• GVA/investment relation
	Productivity of the natural resources (E, A)	• Productivity by cultivated surface
		• Fertilizer application by surface
	Efficiency in the use of resources (A)	• Energy balance: produced/consumed energy
		• Energy consumption by production
Stability (18)	Economic stability (E)	• Economic income stability
		• Production stability
		• Cost stability
	Economic trustworthiness (E)	• Benefits sensitivity to the investment variation
		• Benefits sensitivity to the cost variations
		• Benefits sensitivity to the income variation
	Risk reduction strategies (E)	• Production diversification
		• Contracted insurance
	Life quality (E, S)	• Motivation in the devotion to agriculture
		• Labor and residence satisfaction in rural area
		• Economic satisfaction and economizing capacity
	Farm continuity (S)	• Generation relief in the farm
	Evolution and trend of the sector (E)	• Variation of the surface cultivated in 10 years
	Conservation of the productive natural resources (A)	• Organic substance content on the ground
		• Application of crop protection products
	Ecosystem stability (A)	• Temporal biodiversity
		• Space biodiversity
		• Treatments with crop protection products
Adaptability (8)	Information about the sector (E, S)	• Received agrarian publications
		• Information sources of the sector
	Learning capacity (E, S)	• Educational level
		• Courses in Agriculture and their duration
	Exchange and productive innovation capacity (S)	• Adoption and generation of productive techniques
		• Interest in new methods and technologies
	Availability of alternatives when faced with unexpected alterations (E, S)	• Production alternatives and commercialization availability
		• Possible exits in a crisis

tural production was the reference system for the evaluation, while an alternative system of comparison was provided by data relating to ecological production by the "Eco" and "Plan" cases, the later being more relevant for the present study, since it combines both economic efficiency and ecological objectives.

Other elements characterizing the horticultural production system, and which permitted the identification both of its critical points and the way in which key indicators were measured, can be consulted in Marino (2002). However, we should point out that the value assumed for some indicators was the inverse of that which was actually obtained. This was verified in the cases where a higher value of a given indicator meant that it was making only a minor contribution to the sustainability outcome. This is shown, for example, by the indicators relating to production costs, where the higher the value of the farm costs, the smaller its contribution to sustainability. To show clearly this phenomenon we chose to use the inverse value of the indicator obtained.

The results obtained with the remaining phases of the sustainability evaluation cycle, using the MESMIS methodology, are presented in synthesized form below.

3.2. Results

Table 4 shows the values obtained for the sustainability indicators under consideration, in the following cases: the ecological versus the conventional farm (Eco/Con); the hypothetical planned farm versus the conventional case (Plan/Con) and the planned versus the ecological farm (Plan/Eco). As previously shown, the reference system used in the first and second cases relates to conventional agricultural production, while ecological production (cases "Eco" and "Plan") constitutes the alternative system of comparison. In the third evaluation, ecological agricultural production was considered as the reference system. The reference system functions on the basis of an index of 100.

Since many of the indicators of the planned system are also common to the ecological farm there is a high degree of correspondence between the two systems.

The main conclusions to be drawn from the analysis of Table 4 would seem to be the following:

- Productivity indicators:
  - the planned system has a higher level of economic productivity than the other cases, while the ecological system has a higher value than the conventional case (in fact, three times higher). This result is, essentially, due to the fact that the highest values for both yield and economic productivity are to be found among farms following ecological agriculture, because of the substantial reduction in their production costs;
  - the three systems are similar in terms of their inefficiency in the use of energy resources, although the ecological system was less inefficient in the use of resources than the others, even though energy consumption was

Tab. 3. *Sustainability indicators adopted by evaluation areas (E - Economic; S - Social and A – Environment), total: 56 indicators, 26 criteria and 5 attributes (Marino, 2002) (continuation)*

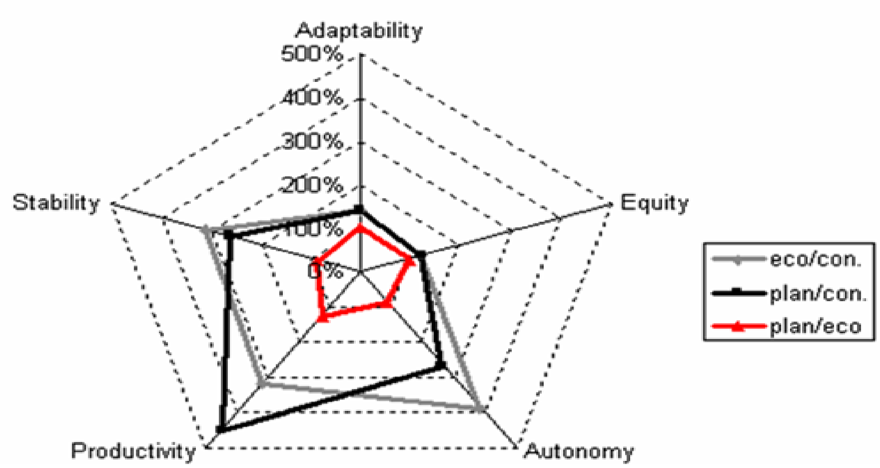
ATTRIBUTE	DIAGNOSIS CRITERION	INDICATORS
Equity (10)	Participation in the income of the commercial chain (E, S)	• Value received relative to the sale price to the public
	Supply and remuneration of the job (E, S)	• Generated jobs and demanded services • Remuneration offered relative to the minimum wage
	Work distribution and family responsibility (S)	• Work distribution within the family • Participation in the farm's decision making
	Production ethics (S)	• Existence of vegetable garden for household consumption
	Social insertion (S)	• Participation in non professional associations
	Environment protection (A)	• Residues management • Reduction measures of environmental impact
Autonomy (7)	Self-sufficiency of production (E)	• Critical factors external to the farm • Reduction strategies of production external dependence
	Control of relations with the commercial chain (S)	• Control capacity of the commercialization factors • Decision and commercial negotiation power
	Sectorial organisation (S)	• Participation in professional organizations • Feeling the sector representation
	External resources dependence (A)	• External energy consumption by surface

lowest in the planned case, followed by the conventional case (the value in question of this item was the inverse of that obtained, for the reasons previously given).

- Stability indicators:
  - the ecological system has higher values for all stability indicators, the planned case typically being found in an intermediate position and, for some indicators, below the values obtained in the conventional case. The crop diversification of each of the systems contributes to this situation: the planned case has a lower diversity, as it specialises in the cultivation of broccoli and cucumber only;
  - overall, in terms of quantitative indicators, the ecological system proves to be superior to the conventional system, as far as stability is concerned.
- Adaptability indicators:
  - the adaptability indicators are all qualitative and were obtained by means of a questionnaire. Thus, we took them as having values similar to those of the planned and ecological farms;
  - after analysing all these indicators we observed that these two systems have higher adaptability than the conventional case.
- Equity indicators:
  - the ecological case was slightly more equitable than the conventional case. This is due, as Marino (2002) has already suggested, to the greater social integration of the producers, who join in social groups; in general, those with this type of associative behaviour are more likely to adopt environmental protection measures;
  - on the other hand, the equity implicit in the conventional case is greater than that of the planned system. One of the factors that explains this situation is higher job supply of the conventional case, as well as the higher level of remuneration. For the same reasons, the ecological system is less equitable than the conventional case.
- Autonomy indicators:
  - the planned and ecological cases have greater autonomy than the conventional system, due in large part to the quantitative autonomy indicators (more objective) and, to a lesser extent, to the influence of the qualitative indicators (more subjective);
  - the greater autonomy of those systems must be due, mainly, to their lower dependence on external resources, as a result of the lower animal consumption of energy per hectare (overall, in the form of fertilizers and fuel energy) and, also, to the greater degree of cooperative organisation that characterises these systems.

In Figure 1 the global value of comparative sustainability in each of the considered cases is presented. It is clear that when the conventional farm is used as the reference, all of

FIGURE 1. *Synthesis of the sustainability evaluation average value for Ecological versus Conventional management (Eco/Con), for Planned versus Conventional management (Plan/Con) and for lanned versus Ecological management (Plan/Eco) (Case reference = Index 100)*



Tab. 4. *Synthesis of the average value ranking for the diverse sustainability criteria in Ecological versus Conventional management (Eco/Con), Planned versus Conventional (Plan/Con) and Planned versus Ecological (Plan/Eco)*

ATTRIBUTE	DIAGNOSIS CRITERION	RANKING Eco/Con relation	Plan/Con Relation	Plan/Eco Relation
Productivity (13)	Economic income of the farm and the resources (E)	320%	422%	131%
	Economic yield (E)	609%	1063%	171%
	Productivity of the natural resources (E, A)	200%	200%	100%
	Efficiency in the use of resources (A)	139%	118%	95%
	Total	**317%**	**451%**	**124%**
Stability (18)	Economic stability (E)	166%	166%	100%
	Economic trustworthiness (E)	757%	757%	100%
	Risk reduction strategies (E)	150%	50%	60%
	Felt life quality (E,S)	133%	133%	100%
	Farm continuity (S)	100%	100%	100%
	Evolution and trend of the sector (E)	480%	480%	100%
	Conservation of productive natural resources (A)	300%	300%	100%
	Ecosystem stability (A)	396%	127%	38%
	Total	**310%**	**264%**	**87%**
Adaptability (8)	Information about the sector (E, S)	133%	133%	100%
	Learning capacity (E, S)	150%	150%	100%
	Exchange and productive innovation capacity (S)	133%	133%	100%
	Availability of alternatives when faced with unexpected alterations (E, S)	150%	150%	100%
	Total	**142%**	**142%**	**100%**
Equity (10)	Participation in the income of the commercial chain (E, S)	134%	134%	100%
	Supply and remuneration of the job (E, S)	59%	49%	75%
	Work distribution and family responsibility (S)	100%	100%	100%
	Production ethics (S)	100%	100%	100%
	Social insertion (S)	200%	200%	100%
	Environment protection (A)	150%	150%	100%
	Total	**124%**	**122%**	**96%**
Autonomy (7)	Self-sufficiency of production (E)	150%	150%	100%
	Control of relations with the commercial chain (S)	150%	150%	100%
	Sectorial organization (S)	200%	200%	100%
	External resources dependence (A)	1064%	559%	52%
	Total	**390%**	**265%**	**88%**
SUSTAINABILITY TOTAL		**257%**	**249%**	**99%**

the other types of farms exceed the index of 100 by a substantial margin. The values of the adaptability and equity attributes are similar for all of the three systems considered, whereas there is a wide disparity for the productivity, stability and autonomy attributes, since in the planned and ecological cases these are three times higher than in the conventional.

These two systems, aside from the afore-mentioned similarities, have very comparable sustainability scores. Nevertheless, the ecological farm exhibits a slightly higher level of sustainability (ecological versus planned - 99%), despite its lower productivity. The factors that contributed to this phenomenon are:

- the lower level of crop diversity, implying a less stable planned system;
- the lower level of job creation and the lower labour remuneration, justifying a less equitable planned system;
- a higher annual energy consumption, justifying a lower level of autonomy of the planned system.

Finally, the productivity of the planned system is higher compared to the other cases considered. This is due, essentially, to the fact that it exhibits the highest yield and economic productivity.

4. Final considerations

One of the main conclusions of this investigation is that it is still impossible, in absolute terms, to affirm which of the solutions is unquestionably the best and, therefore, which seems the most suitable in a given moment or circumstances but not under different conditions. Moreover, having used data from only three farms, our conclusions cannot be generalized.

It should be noted that the only objectives considered in the multiobjective programming of the performance of the planned farm were the GVA and energy costs. That is, we were able to obtain a figure for the increase in financial efficiency of the planned farm, relative to the other systems considered (conventional and ecological). However, when the situation is examined with a view to reconciling the two objectives under consideration, we found that the planned farm had the highest energy consumption per area unit.

Furthermore, these are not the only factors that will influence the sustainability attained by a given production system. For example, crop diversification and employment creation were far from the levels expected or hoped for in the case of the planned farm. We should not forget that biodiversity is an inherent condition for genuinely ecological agriculture. However, these factors could easily be over-come by modifying the initial farm plan, or by combining them with other objectives to be achieved in the planned farm, or even by grouping the objectives that have sustainability implications.

It should be noted that, as the title of this paper suggests, this was a first attempt to address the problem discussed here and the intention is to study further the most relevant aspects and difficulties of the problem. In fact, the important point emphasized in this paper is that it is possible to bring together a series of factors in a model of farm management that are conducive to a large extent to the achievement of multiple sustainability requirements.

Other considerations derived from this study are related to the MESMIS methodology. In fact, as stated earlier, we have followed the same sustainability evaluation cycle as that used by Marino (2002). However, and after further literature review, we must conclude that the key aspect of this methodology lies in the choice of the indicators and in the integration of results through a qualitative valuation. Clearly, the criteria adopted in choosing the indicators and the procedure used to attain the results can have a significant effect on the final value attributed to sustainability, given that the basis for this exercise is relative rather than absolute. However, considering the data used and the results obtained, we can conclude that ecological production systems (planned or otherwise) allow much more autonomous, productive, stable, well-adapted and equitable management than the conventional production systems analysed in this study.

Appendix

	VARIABLES:
XA_{ij} =	Annual crops (m^2),
	i = 1, greenhouse area
	i = 2, outdoor area
	j – type of crop
MO =	Hired labour (Hours)
TA =	Tractor rental (Hours)
MB =	Rent of motor pump (Hours)
AG =	Water utilization (m^3)
F_N =	Purchase of N fertilizer (Kg of N)
F_P =	Purchase of P_2O_5 fertilizer (Kg of P_2O_5)
F_K =	Purchase of K_2O fertilizer (Kg of K_2O)
V_{ij} =	Sales correspondng to annual crop production (Kg or Units)
GS =	Purchase of fuel (Litres)
	PARAMETERS:
AE =	Availability of total area under greenhouse (m^2)
AL =	Availability of total outdoors area(m^2)
DMO =	Labour availability (Hours)
a_{ij} =	Labour needs by crop (Hours/m^2)
DTA =	Tractor availability (Hours)
b_{ij} =	Tractor needs by crop (Hours/m^2)
DMB =	Motor pump availability (Hours)
c_{ij} =	Motor pump needsby crop (Hours/m^2)
d_{ij} =	Water needs by crop (m^3/m^2)
eN_{ij} =	N fertilizer needs by crop (Kg/m^2)
eP_{ij} =	P_2O_5 fertilizer needs by crop (Kg/m^2)
eK_{ij} =	K_2O fertilizer needs by crop (Kg/m^2)
f_{ij} =	Sales correspondng to annual crop production (Kg or units/m^2)
g_{ij} =	Fuel needs by crop (Litres/m^2)
h_{ij} =	Crop protection products needs by crop (Kg or litres/m^2)
s_{ij} =	Seedneedsby crop (Kg or units/m^2)
VEs_j =	Energy value of seed (MJ/Kg or units)
VE_{FN} =	Energy value of N fertilizer (MJ/Kg)
VE_{FP} =	Energy value of P_2O_5 fertilizer (MJ/Kg)
VE_{PK} =	Energy value of K_2O fertilizer (MJ/Kg)
VE_{FT} =	Energy value of the crop protection products (MJ/Kg)
VE_{MO} =	Energy value of labour (MJ/Hour)
VE_{TA} =	Energy value of tractor (MJ/Hour)
VE_{MB} =	Energy value of motor pump (MJ/Hour)
VE_{GS} =	Energy value of the fuel (MJ/Litre)
	PRICES:
P_j =	Price of the product supplied by crop (Euros/Kg or units)
P_{MO} =	Labour cost unit (Euros/Hour)
P_{TA} =	Tractor rental unit(Euros/Hour)
P_{MB} =	Motor pump rental unit (Euros/Hour)
P_{AG} =	Water price unit (Euros/m^3)
P_{FN} =	N fertilizer price unit (Euros/Kg)
P_{FP} =	P_2O_5 fertilizer price unit (Euros/Kg)

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