Application of Decision Support Methods for Sustainable Agrarian Systems

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Abstract

Currently, farms are faced with a double and often contradictory challenge, in order to be successful, in accordance with the principles of sustainable development. This work intends to formulate a production unit of bovine, in mountainous area, with the purpose of reconciling the criteria of environmental sustainability with that of economic competitiveness, using Multicriteria Decision (NonInferior Set Estimation Method complemented with Compromise Programming).

Analyses of the results allow us to confirm the possibility of planning farm activities capable of meeting economic and environmental objectives, for the diverse traced scenarios.

Key words: Agrarian sustainability; agroecosystem management; ecological-economic modelling.

Résumé

Actuellement, les exploitations agricoles sont confrontées à un double défi souvent contradictoire, pour surmonter les difficultés, conformément aux principes du développement durable. Ce travail entend formuler une unité de production de l'espèce bovine, dans une zone montagneuse, dans le but de concilier les critères de durabilité environnementale avec celui de la compétitivité économique, utilisant une Décision Multicritère (NonInferior Set Estimation method et Compromise Programming).

Les analyses des résultats nous permettent de confirmer la possibilité de planification des activités d'une exploitation agricole qui est capable de satisfaire les objectifs économiques ainsi que les objectifs environnementaux pour les divers scénarios tracés.

Mot-clé: *Développement durable agraire; gestion de l'agro-écosystème; modélisation écologique-économique.*

1. Introduction

Currently, farms are faced with a double and often 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, given the socio-environmental situation, it is necessary to preserve and to protect the environment and the natural resources. Such a challenge requires, among other things, an appropriate consumption of production factors (such as fertilizers and crop protection products), and a readjustment of the used technologies (mainly through the adoption of energy-saving measures), without jeopardising food safety standards that society expects.

Many of the existing farms do not come close to achieving these two objectives (conventional farms), while others try to reconcile them, if not completely, then at least in part (ecological farms). We should remember that it was in the context of 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 current problem centres on planning farm's activities in such a way that it is capable of meeting economic objectives (from the perspective of the private investor) as well as the environmental objectives (from the perspective of the general public), in the future, and of operating in accordance with the principles for sustainable development.

Given the potential conflict of the two aims, since the satisfaction of one implies the underperformance of the other (and viceversa), and bearing in mind that, in the light of the current economic theory, the income generated is a function of the quantity of production 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, farms should be planned in a way that allows them to reach a compromise between the two declared principles – economic sustainability and environmental sustainability. This work, based on meat production systems of the Maronesa local cattle breed, from mountainous areas of Northern Portugal, intends to design a farm plan, regarding the sustainability of the agrarian practices employed. Livestock farming is the main land use in these areas.

The systems under study were selected due to a set of economic, social and environmental reasons. Amongst these, a critical one is the contribution of these systems to fight human desertification of mountainous areas, by providing added value in economic and socio-environmental terms. These systems need revitalisation, by improving their profitability and promoting the rejuvenation of the farming population, but also by dealing with cattle breeds of high rus-

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ticity, natural transformers of intrinsic resources of the mountain zones: a significant regression of herds has been registered (to the current point, where they reached «risk of extinction» status) which can lead to the loss of genetic assets.

The research addressed a significant sample of existing farms (112) within the study area – a mountainous area, almost 30% of the total farms have five or more adult animals, their main activity being the production of bovine meat.

2. Methodology

The preparation of a farm plan, simultaneously following economic and environmental objectives, was carried out using the Multicriteria Decision Theory paradigm. 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 NonInferior Set Estimation Method (NISE) and Compromise Programming, is being used.

The NISE method is used in a first stage, to generate the trade-off curves between the different objectives, which allows a better appreciation of the possible alternatives (Cohon, 1978). Finally, the compromise technique is used as a tool to determine the set of Pareto optimal solutions nearest to the ideal point (Romero and Rehman, 1989).

Results were obtained with LINDO – Linear Interactive aNd Discrete Optimizer (LINGO 10 software), based on the operational aspects of the NISE method and of Compromise Programming, indicated in Cohon (1978); Zeleny (1982); Romero and Rehman (1989); Romero (1993); and Poeta (1994).

3. Mathematical model

The mathematical model developed in this paper is a multiple-criteria one. Two objectives are considered – the maximisation of the Gross Value Added (GVA) and the minimisation of the energy costs.

This first objective (Z_1) was selected since a farm's survival requires greater monetary incomes obtained via active participation in the market, i.e. the sale of products. The farm profitability is an essential condition for its sustainability and, consequently, for the economic development of the region and also a strong contribution for the human fixation in the territory. This objective was translated into the maximisation of GVA, as this result can be easily processed in the form of a linear equation or inequation.

With regard to the second objective, it reflects environmental considerations. Thus, among other possible objectives (for example, minimised water consumption, minimised consumption of pollutant factors of production – fertilizers and crop protection products, minimised use of machines and equipment in the ground, among others) the minimum of energy costs seemed the most suitable given the possibility of quantification of the energy cost in terms of each factor of production used.

This objective is framed in the light of the fact that energy efficiency is an important factor to be optimised, in the global economy, being a direct indicator of sustainability. In truth, as is indicated by Lansink *et al.* (2002), in the following decades, the world faces the challenge of transitioning toward sustainable standards of energy use in such a way as to safeguard fuel for future generations and to reduce the negative impacts of fuel combustion on the environment. The authors, referencing the data of UNDO (2000), estimate that, at current consumption rates of fossil fuels, these reserves may not be sufficient for the growing demand by the year 2020. Besides this, the control of the climate change requires substantial reduction of emissions of greenhouse gases, as emphasized by the Intergovernmental Panel on Climate Change (IPCC, 2001), the massive consumption of fossil fuels having aggravated global environmental problems. The Kyoto Protocol, adopted in the context of the Forum of the United Nations relative to the Framework Convention on Climate Change, in 1997, requires the reduction of carbon dioxide emissions by a rise in energy efficiency and the use of renewable energy (EUROSTAT, 1998).

Also, investigations into aspects of energy illustrate that its use is generally related to greenhouse gas emissions and to the depletion of natural resources. In order to reduce both effects, potential ways to save energy in farming must be identified (Moerschner and Lücke, 2002), this being the main factor that induced the identification of energy saving as the second goal of farm planning.

In this regard, some documents, such as Ferreira *et al.* (2002), indicate the reduction of non-renewable energy as one of the goals that limit farm production.

The energy coefficients utilised were obtained from the reference for energy analysis adopted in the context of the «PLANETE» methodology – *Méthode Pour L'ANalyse EnergéTique de l'Exploitation»* (Établissement National d'Enseignement Supérieur Agronomique de Dijon – ENESAD and Agence de l'Environnement et de la Maitrise de l'Énergie – ADEME, 2002).

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.

Other goals, directly linked to this theme, are found in the model, not directly as in the two previous ones, but imposed under the form of restrictions.

Those observed in the farms studied were identified as principal activities, corresponding to the diverse parameters and coefficients of the functions objective to the median values found for the grouping of the farms analysed, sometimes with slight adjustments, whenever these deviated significantly from the standard median values, after, whenever possible, comparison with the specialist literature. The remaining necessary information for the application of the model was obtained from the literature on the subject, namely, Institut National de la Recherche Agronomique (INRA 1988); European Community (EC, 1991); Ministério da Agricultura, do Desenvolvimento Rural e das Pescas (MADRP, 1997 and 2003); Gabinete de Planeamento e Política Agro-Alimentar (GPPAA, 2001); Moreira *et al.* (2001); Ferreira *et al.* (2002); CONFAGRI (2003); and Domingos *et al.* (2005).

The constraints in the model are related to the Agriculturally-Used Area (AUA), crop succession and crop rotations. The labour and machinery constraints are considered on a quarterly basis. Constraints related to the fertilizers are also added, including a reasonable use of fertilizers that does not exceed the amount per hectare specified in the EC's Nitrate Directive (EC, 1991), whose objective is to protect 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). The quarterly feed requirements for the cattle are linked to forage cropping. Constraints relative to the sale of the crops and to the sale of animal products (meat, milk and manure) are also specified, bearing in mind the limits imposed by the quotas. Also considered are limits to animal stocking density of farms less than or equal to three livestock units (LU) per hectare (Ha) of AUA, in mountainous zones, according to the «Good Agricultural Practices» (MADRP, 2003), in order to guarantee cattle handling compatible with the load capacity of the natural environment. Finally, a correspondence with the assumptions initially established for the definition of the sample is imposed, in order to later validate the results obtained.

The model, made up of 129 variables and 97 constraints, is given in the appendix. Two distinct scenarios were considered: with (current scenario) and without financial support (potential scenario) to the current activities integrated in the Common Agricultural Policy.

4. Results

The algorithm begins by optimizing each objective individually subject to the same constraints set. The obtained values of each objective in the two extreme optimal solutions are shown in table 1 and 2, for without and with financial support to the current activity scenarios, respectively.

Table 1 – *Pay-off matrix in without-financial-support scenario.*

	GVA (Euros)	Energy costs (MJ)
MAX Z_1	12513.2932	239851.6379
MIN Z_2	1821.4418	56142.2851

Source: The author's findings.

Table 2 – *Pay-off matrix in with-financial-support scenario.*

	GVA (Euros)	Energy costs (MJ)
MAX Z_1	20859.6410	188844.9081
MIN Z_2	6748.9438	56142.2851

Source: The author's findings.

Table 3 – *Efficient solution obtained with the model, in without-financial-support scenario.*

Extreme points	A	B	C	D	E	F	G
Objectives							
GVA (€)	12513.2932	11753.7108	10915.3601	9301.7905	6222.2988	3193.1100	1821.4418
Energy costs (MJ)	239851.6379	157382.5187	117184.8196	100535.0583	75126.5551	58266.2151	56142.2851
Principal decision variables							
Irrigated land (Ha)							
Maize - ensilage	1.721	1.721	-	-	-	-	-
Temporary pasture	1.721	1.721	3.442	3.442	3.442	3.442	3.442
Dry land (Ha)							
Potato	0.974	0.449	0.974	0.974	0.974	-	-
Rye	-	0.262	-	-	-	-	-
Temporary pasture	-	0.262	-	-	-	0.974	0.974
Permanent and community pasture (Ha)							
Hay	2.7511	2.7511	2.7511	2.7511	2.7511	2.7511	2.7511
Pasture	5.4369	5.4369	5.4369	5.4369	5.4369	5.4369	5.4369
Community pasture	14.526	14.526	14.526	14.526	14.526	14.526	14.526
Cattle (UP)							
Maronesa breed (pure F1 – sale 9 months)	5.0208	8.4080	8.4292	6.5383	3.5336	4.3088	5
Frísio Trunk (not pure F1 – sale 0 months)	8.7401	4.4535	3.7049	2.7132	1.4664	0.6912	-
Crops and manure sale (kg)							
Potato	11239.96	5187.104	11239.96	11239.96	11239.96	-	-
Maize - ensilage	7458.696	59745.73	-	-	-	-	-
Rye	-	250.3491	-	-	-	-	-
Hay	23600.81	23600.81	30889.24	30889.24	30889.24	30889.24	30889.24
Manure	70000	70000	70000	70000	28153.47	-	-
Inputs purchase (kg)							
Man power (hours)	684.7913	137.8602	16.1064	-	-	-	-
N	347.5528	349.3785	166.6488	202.129	202.129	146.8012	146.8677
P_2O_5	351.6634	342.8313	186.0494	257.0097	257.0097	134.6661	134.7991
Maronesa concentrate	401.0847	9633.151	10679.92	8445.26	4564.278	6408.568	8086.667
Commercial concentrate	23213.94	7025.839	4141.68	2762.948	1493.247	202.9795	-

Source: The author's findings.

Observations: (1) For products of activities with different ends, only the portion sold is used, with the rest reused on the farm (cases of manure and plant products).
(2) Quantities sold were not taken into account, in cases in which the total of the products of the activity is for sale (cases of meat and milk of bovine origin).

Table 4 – *Efficient solutions obtained with the model, in with-financial-support- scenario.*

Extreme points	A'	B'	C'	D'	E'
Objectives					
GVA (€)	20859.6410	20312.7177	18618.5162	11329.6504	6748.9438
Energy costs (MJ)	188844.9081	159084.4364	117403.4293	74748.1638	56142.2851
Principal decision variables					
Irrigated land (Ha)					
Maize - ensilage	1.721	1.721	-	-	-
Temporary pasture	1.721	1.721	3.442	3.442	3.442
Intercalary crop	-	0.8804	-	-	-
Dry land (Ha)					
Potato	0.974	-	0.5315	-	-
Rye	-	0.487	-	-	-
Temporary pasture	-	0.487	0.4425	0.974	0.974
Intercalary crop	0.974	-	-	-	-
Permanent and community pasture (Ha)					
Hay	2.7511	2.7511	2.7511	2.7511	2.7511
Pasture	5.4369	5.4369	5.4369	5.4369	5.4369
Community pasture	14.526	14.526	14.526	14.526	14.526
Cattle (UP)					
Maronesa breed (pure F1 – sale 9 months)	10.4397	10.6109	9.3670	6.5319	5
Frísio Trunk (not pure F1 – sale 0 months)	5.9902	4.7761	3.8883	1.0479	-
Crops and manure sale (kg)					
Potato	11239.96	-	6133.123	-	-
Maize - ensilage	49271.12	56982.5	-	-	-
Rye	-	464.8902	-	-	-
Hay	23600.81	23600.81	30889.24	30889.24	30889.24
Manure	70000	70000	70000	69364.01	-
Inputs purchase (kg)					
Man power (hours)	817.1719	373.6114	41.7157	-	-
N	358.8838	325.9456	143.649	201.8043	146.8677
P_2O_5	309.0673	254.4548	134.7394	244.6724	134.7991
Maronesa concentrate	13605.558	16216.89	13479.011	9724.147	8086.667
Commercial concentrate	8212.938	3057.3563	3231.565	324.8234	-

Source: The author's findings.

Observations: (1) For products of activities with different ends, only the portion sold is used, with the rest reused on the farm (cases of manure and plant products).
(2) Quantities sold were not taken into account, in cases in which the total of the products of the activity is for sale (cases of meat and milk of bovine origin).

The two pay-off matrices obtained indicates that there exists a strong degree of conflict between the two goals considered, in both scenarios. When the GVA is maximised, energy costs reach their highest value or anti-ideal, and vice-versa.

Next, the NISE method was applied, via the optimisation of one unique objective function, composed of the functions – GVA and energy costs – weighted by the value of incline of the line uniting the two extreme value coefficients found (ideal and anti-ideal values of the pay-off matrix).

Using NISE method, seven extreme efficient points were obtained in without-financial-support scenario (table 3) and five extreme efficient points in the other scenario (table 4).

Thus, admitting that the only goal was the maximisation of the GVA, the solution should be the one that corresponds to points A (table 3) and A' (table 4). On the contrary, at points G (table 3) and E' (table 4), the solution corresponds to the minimisation of energy costs. Solutions A and G (table 3) and A' and E' (table 4) are two extreme value coefficients, in each respective scenario, which, according to the formulation of the problem, will not be the intended solutions. Others exist (table 3: B, C, D, E, F; table 4: B', C', D') which seek to satisfy, within the limits of the possible and simultaneously, both goals. Naturally, the best solution is unattainable, because improving one of the goals always implies a loss in the other.

To reduce the set of solutions, the compromise technique was applied, giving equal weight to both objectives. At this step the continuous setting version of compromise programming was used (Romero and Rehman, 1989).

By using compromise programming, the solutions for $p = 1$ and $p = \infty$ define a subset of the efficient set called the compromise set. Other compromise solutions ($1 < p < \infty$) fall between the solutions corresponding to $p = 1$ and $p = \infty$ (Romero and Rehman, 1989).

Note, however, that given the impossibility of the existence of a non-whole number of animals on the farms, after the compromise plan was accomplished, new compromise solutions (alternate compromise solutions) were sought. To that end, the condition that each cattle activity must be equal to the whole number closest to that obtained with the first compromise solutions was imposed on the initial models. The results obtained are found in table 5.

Table 5 indicates that while GVA attains at least 78% and 77% of its ideal value, without and with financial support scenario, respectively, energy costs attain at the most 54% and 55% of the ideal value, in each situation.

Figures 1 and 2 show the trade-off curve between GVA and energy costs, in both scenarios, with the decisive agent being able to choose between the various productive combinations which best correspond to his preferences.

Analysing figure 1, we can observe that between points A and B the incline is, at this part of the *trade-off* curve, 108.5717. This means that the opportunity cost of each GVA Euro can be measured as the sacrifice of 108.5717 MJ of energy cost.

On the other hand, we can also observe in both figures that between the possible solutions the energy cost grows at an increasing rate (the incline keeps rising), and is accompanied by the rise in opportunity cost of the VAB. If, hypothetically, the choice were to be point B instead of point A (figure 1), then a decrease of 759.5824 euros in G-VA compensates for the 82469.1192 MJ reduction of energy costs.

In the compromise solution, a gain of one Euro in GVA leads to an increase of 10.6254 MJ and 6.1923 MJ in energy costs, in the scenarios without and with subsidies at the current farm, respectively, which signifies a more than proportional rise in energy costs.

The analyses of the solutions allow us to enumerate the following comments:

- When the financial supports are contemplated, for the same energy cost level, greater levels of GVA are reached. Besides the incomes of the supports, this situation results from bigger allowed heading mainly for the Maronesa breed, which is associated to lower energy costs;
- The analysis of the activities of the selected models shows an accentuated use of the areas by crops connected to the cattle activity, mainly the irrigated land;
- The meat and milk cattle activities are included in every solution obtained, being certain that the milk activity is always present when the GVA tendency is greater. Also, it is sure that the meat activity is always present when the tendency is for the minimum energy costs;

Table 5 – *Obtained compromise solutions to the developed models.*

	Without financial support		With financial support	
Extreme points	L_1	L_∞	L_1'	L_∞'
Objectives				
GVA (€)	10915.3601	9707.7997	18672.2209	16035.5943
Energy costs (MJ)	117184.8196	104353.9879	119351.9899	101515.5431
Principal decision variables				
Irrigated land (Ha)				
Maize - ensilage	0.012	-	-	-
Temporary pasture	3.430	3.442	3.442	3.442
Dry land (Ha)				
Potato	0.9354	0.9019	0.5689	0.1918
Maize - ensilage	-	0.0154	0.0455	-
Temporary pasture	0.0386	0.0567	0.3596	0.7822
Permanent and community pasture (Ha)				
Hay	2.7511	2.7511	2.7511	2.7511
Pasture	5.4369	5.4369	5.4369	5.4369
Community pasture	14.526	14.526	14.526	14.526
Cattle (UP)				
Maronesa breed (pure F1 – sale 9 months)	8	7	9	8
Frísio Trunk (not pure F1 – sale 0 months)	4	3	4	3
Crops and manure sale (kg)				
Potato	10794.84	10407.77	6564.9	2213.115
Hay	30838.3	30889.24	30889.24	30889.24
Manure	70000	70000	70000	70000
Inputs purchase (kg)				
Man power (hours)	13.0616	-	33.6083	-
N	168.8733	191.5864	148.0853	164.4066
P_2O_5	188.6641	234.5038	142.4224	172.1782
Maronesa concentrate	9430.373	8965.372	11827.1594	10569.786
Commercial concentrate	5816.1298	3188.5391	4201.135	2891.965
Others feeds to the cattle (kg)	79.3008	-	82.1625	-

Source: The author's findings.

Observations: (1) For products of activities with different ends, only the portion sold is used, with the rest reused on the farm (cases of manure and plant products).
(2) Quantities sold were not taken into account, in cases in which the total of the products of the activity is for sale (cases of meat and milk of bovine origin).

Figure 1 – *Trade-off curves between GVA and energetic costs for without financial support scenario (The author's findings).*

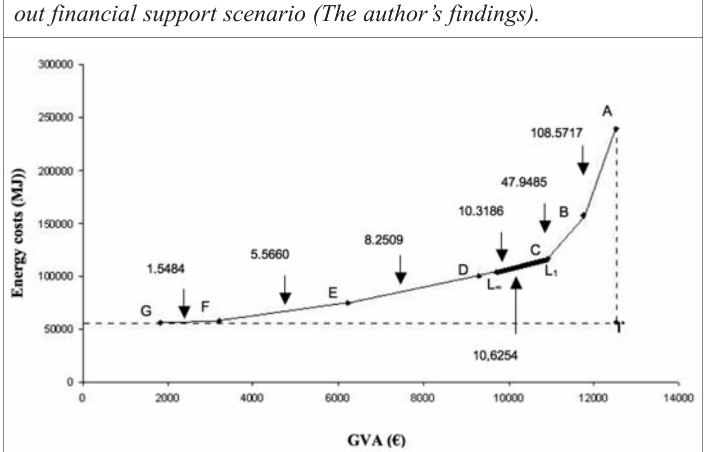

Figure 2 – *Trade-off curves between GVA and energetic costs for with financial support scenario (The author's findings).*

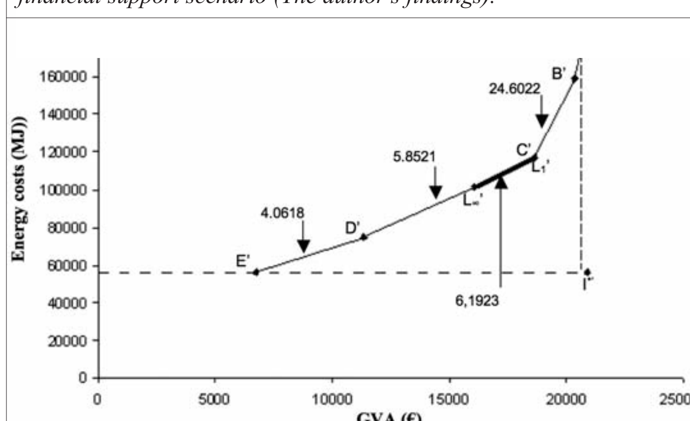

Table 6 – *Comparison of average LU observed with the LU of the models.*

Solutions		Average LU observed	LU of the models	Absolute deviation	Relative deviations (%)
Without financial support scenario	A	17.2798	17.3946	0.1148	0.6600
	B	17.2798	16.7179	-0.5619	-3.3611
	C	17.2798	15.8338	-1.4460	-9.1324
	D	17.2798	12.0861	-5.1937	-42.9725
	E	17.2798	6.532	-10.7478	-164.5407
	F	17.2798	6.6279	-10.6519	-160.7130
	G	17.2798	6.7135	-10.5663	-157.3888
	L_1	17.2798	15.8338	-1.4460	-9.1324
	$L_{\bullet}$	17.2798	12.5867	-4.6931	-37.2862
With financial support scenario	A'	17.2798	21.3188	4.0390	18.9457
	B'	17.2798	20.0689	2.7891	13.8976
	C'	17.2798	17.3205	0.0407	0.2350
	D'	17.2798	10.0476	-7.2322	-71.9794
	E'	17.2798	6.7135	-10.5663	-157.3888
	L_1'	17.2798	17.3205	0.0407	0.2350
	$L_{\bullet}$'	17.2798	14.6429	-2.6369	-18.0080

Source: The author's findings.

- All the solutions obtained for both models have greater Maronês cattle, with more remarked values on the situation with financial supports.

Finally, table 6 presents the comparison of the average number of livestock units (LU) observed on the farms studied with the LU obtained in the models.

The analysis reveals that, in the scenario that coincides with the reality, that is, the subsidies scenario, the least deviation is obtained with a compromise solution (L_1'), which may allow us to identify the «compromise» that the farmer, directly or indirectly, and intentionally or not, strikes between economic and environmental goals.

However, if one considers the hypothesis of the real farms adopting on average 17.2798 LU also for the situation in which subsidies were not conceded to the current farm, the deviations calculated under analysis would be lower for solution A (0.66%), this being the extreme coefficient obtained when the GVA is maximised. This may be due to the fact that, in the absence of subsidies, the farmer seems to make the decisions most likely to maximise economic results.

5. Conclusion

A model of decision-making support for problems of multiobjective formulation, in the context of sustainability, for two distinct scenarios (with and without subsidies at current activity), is presented. Two objectives are considered – the maximization of GVA and the minimisation of the energy costs.

The application of the framework is demonstrated through a case study from Northern Portugal where local bovine rearing appears as an important contribution to fight human desertification in the mountain areas, by providing added value in economic and socio-environmental terms; these systems also contribute to the nature conservation.

The techniques utilised allowed us to find various solutions and, to this extent, the system can be considered open. This means that all of the solutions present advantages and inconveniences, when the results are analysed within possible alternative scenarios with diverse socio-economic circumstances and where goals can have more or less importance.

However, when seeking the satisfaction of both goals, with equal importance, via a compromise between them, we see that the solutions found seem to answer current problems, in the context of sustainability, in which it is necessary to attain, simultaneously, diverse and conflicting goals.

The solutions reached in the case study show that the following binomial appears to be the key to the future of the farming sector, in mountainous areas, in the direction of quality development in equilibrium with environment, social promotion and, simultaneously, generator of incomes for agents that depend on it:

Meat cattle/local breed/lesser
energy cost/lesser GVA
Milk cattle/exotic breeds/greater
energy cost/greater GVA

Or, considering available resources, the most inhospitable areas, such as community pastures and uncultivated land, must take advantage from the local native breeds (Maronesa), natural transformers of the intrinsic resources of the mountain zones, resulting in an environmental capital gain (from the public perspective), with lower energy as well as economic cost (the private perspective), in spite of presenting profitability inferior to cattle of exotic breeds. For these situations, the size of the indigenous cattle herd may still be strengthened, with economic consequences, if monetary aid is attributed to breeding.

The most productive areas, on the other hand, must be used for more lucrative activities, such as the breeding of dairy cattle, for which the sale of the calf must happen at birth, due not only to the greater economic yield resulting thereof, but also to the absence of food resources available to raise them. This situation is associated, comparatively to the raising of local breeds, with a greater energy cost but also with a superior profitability.

It can be concluded therefore that it is possible to plan agricultural activities in order to reconcile some essential objectives in the context of policies to promote sustainable agriculture and fighting human desertification in mountain areas. On the one hand it is possible to obey to the environmental conditions by maintaining genetic biodiversity (animal and plant) and the territory without environmental degradation, through the raise of local breeds, with high rusticity and promoters of some economic benefits, despite their low productivity. Moreover, the raising of exotic breeds, although some cause negative environmental consequences, strengthens the total economic benefits of the farm, providing a higher quality of life, essential to keep the population and for the region development.

Appendix – Mathematical model

1. Objective functions

The objective function Z_1 represents the economic objective, in this case the maximisation of the GVA, in Euro. This economic result is calculated by the difference between the value of the sold productions and the consumption of the variable production factors acquired to the exterior. For the situation that subsidies are considered, its value was included in the objective function (Z_1').

The objective function Z_2 represents the environmental objective, the energy costs minimisation, expressed in Megajoules, that correspond to the goods and services purchased on the Z_1 function.

2. Constraints

The constraint system of the identified model was grouped into fifteen main categories, which are enumerated later. Its concept is based on the expression of what a farm unit can do, that is, its field of choice and how it relates to the technological characteristics, the available resources, the satisfaction of demand and the limits of the market, having environmental conditions and the farm autonomy as base.

- Restrictions on use of land (Ha);
- Restrictions on use of manual labour (H);
- Restrictions on use of traction (H);
- Restrictions on use of fertilizers (Kg);
- Restrictions on nutritional balance of livestock and on the sale of products supplied by agriculture (Kg);
- Restrictions on nutrition of livestock (Fodder unit – UF);
- Restrictions on nutrition of livestock (Kg of digestible protein in the intestine – PDI);
- Restriction on the maximum food ingestion capacity of livestock (Kg of dry matter – DM);
- Restriction on the minimum ingestion of food produced on farm (Kg DM);
- Restriction on the sale of meat (Kg);
- Restriction on the sale of milk (Kg);
- Restriction on the sale of manure (Kg);
- Restriction on animal stocking density (LU);
- Restriction on the cattle herd (LU).

References

ENESAD, ADEME, 2002. Analyse Énergétique d'Exploitations Agricoles et Pouvoir de Réchauffement global, Méthode et Résultats sur 140 Fermes Française, Document du Groupe Planète, France.

Cohon J. L., 1978. *Multiobjective Programming and Planning,* Mathematics in Science and Engineering Vol. 140, Academic Press, San Diego, California, 333 pp.

CONFAGRI, 2003. *O Exemplo Holandês*. In Proceedings of «Efluentes Pecuários e seus Efeitos no Ambiente» Seminar, CONFAGRI Ed., Esposende, Portugal.

Domingos T., Rodrigues O., Avelar T., Brito A., Piçarra A., Sendim A., Ferreira F., Dias N., Crespo D., Crespo J., Lopes A., Belo C., Alcazar R., Sarmento N., Sequeira E., 2005. *Sustentabilidade Garantida – Norma para Carne Bovino,* Extensity Project – Sistemas de Gestão Ambiental e de Sustentabilidade na Agricultura Extensiva LIFE ENV/P/505 Ed., Portugal, 27 pp.

EC, 1991. *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, 1-8.

EUROSTAT, 1998. *Environnement*, Statistiques en Bref 2, Luxemburg, 8 pp.

Ferreira J., Strecht A., Ribeiro J., Soeiro A., Cotrim G., 2002. *Manual de Agricultura Biológica. Fertilização e Protecção das Plantas para uma Agricultura Sustentável*, AGROBIO – Associação Portuguesa de Agricultura Biológica Ed., Lisbon, Portugal, 435 pp.

GPPAA, 2001. *Contas de Culturas das Actividades Vegetais – Modelo de Base Microeconómica*. GPPAA Ed., Lisbon, Portugal.

INRA, 1988. *Alimentation des Bovins, Ovins & Caprins*. INRA, Paris, 471 pp.

IPCC, 2001. *Climate Change 2001: Mitigation*, Contribution of Working Group III to the third assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, 752 pp.

Lansink, A., van Ierland, E., Best, G., 2002. *Sustainable Energy in Agriculture: Issues and Scope*. In E. van Ierland and A. Lansink, eds., Economics of Sustainable Energy in Agriculture. Kluwer Academic Publishers, Netherlands, pp.1-7.

MADRP, 1997. *Código de Boas Práticas Agrícolas para a Protecção da Água contra a Poluição com Nitratos de Origem Agrícola,* MADRP Ed., Lisbon, 52 pp.

MADRP, 2003. *Portaria Nº 1212/2003, aprova o Regulamento de Aplicação da Intervenção «Medidas Agro-Ambientais», do Plano de Desenvolvimento Rural (RURIS)*, Diário da República N.º 240, I-B Série de 16 de Outubro de 2003, 6894-6931.

Moerschner J., Lücke W., 2002. *Energy Investigations of Different Intensive Rape Seed Rotations – A German Case Study*. In Van Ierland, E. and Lansink, A. éds., Economics of Sustainable Energy in Agriculture. Kluwer Academic Publishers, Netherlands, 27-40.

Moreira N., Aguiar C., Pires J., 2001. *Medidas Agro-Ambientais: 3.3 Lameiros e outros prados e pastagens de elevado valor florístico – Pastagens de Montanha*, Direcção Geral de Desenvolvimento Rural Ed., Lisbon, Portugal, 47pp.

Pau Vall M., Vidal C., 1999. *Nitrogen in Agriculture*. In Agriculture, Environment, Rural Development: Facts and Figures – A Challenge for Agriculture. European Comission.

Poeta A. D., 1994. *A Tomada de Decisão no Planeamento da Exploração Agrícola num Contexto de Objectivos Múltiplos*, PhD Dissertation, University of Trás-os-Montes and Alto Douro, Vila Real, Portugal, 182 pp.

Romero C., 1993. *Teoria de la Decisión Multicriterio: Conceptos, Técnicas y Aplicaciones,* Alianza Editorial, Madrid, 195 pp.

Romero C., Rehman T., 1989. *Multiple Criteria Analysis for Agricultural Decisions*, Developments in Agricultural Economics 5, Elsevier, Amsterdam, 257 pp.

Zeleny M., 1982. *Multiple Criteria Decision Making*, McGraw-Hill Series in Quantitative Methods for Management, McGraw-Hill, USA, 563 pp.