Stages for the More Sustainable Farm

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Abstract— **Currently, agricultural farm units are faced with a double and most times 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 to protect the environment and natural resources. Given the potential conflict of the two aims, since the satisfaction of one implies the underperformance of the other (and vice versa), the question then is: which is the solution to choose?**

We intend, in this work, to formulate a farm plan with the purpose of reconciling the criteria of environmental sustainability with that of economic competitiveness.

For this achievement we proceed to the comparative study of sustainability of different groups of farms identified in the study area (first evaluation cycle) through MESMIS (*"Marco para la Evaluación de Sistemas de Manejo de Recursos Naturales Mediante Indicadores de Sustentabilidad"* - Framework for Evaluation of Natural-Resource Systems Handling through Sustainability Indicators) methodology, that allowed to select the more sustainable group of farms.

Based on the found potentialities and weakness on these production systems, we stepped to the planning of a production unit of bovine meat, which obeys simultaneously to economic and environmental objectives, using Multicriteria Decision.

We finished the work with the sustainability evaluation between groups of farms identified previously and the planned farms (second evaluation cycle), based, again, in the MESMIS methodology, to confirm (or not) the greatest sustainability of the last ones. Analyses of the results allow us to confirm the greatest relative sustainability of the planned farm, for the diverse traced scenarios.

Keywords— **Decision taking, planning, sustainability.**

I. INTRODUCTION

Currently, agricultural farm units are faced with a double and most times 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 to protect the environment and natural resources. Such a challenge requires, among others 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 farm units 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 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 current problem centres on planning a 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 operating in accordance with the Strategy for Sustainable Development.

Given the potential conflict of the two aims, since the satisfaction of one implies the underperformance of 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 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, we are convinced that 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, intends to design a farm plan, regarding the sustainability of the agrarian practices employed.

The systems under study were selected due to set of economic, social, and environmental reasons. Amongst these, a critical one is the contribution of these systems to fight human desertification of mountain 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 rusticity, 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 loss of genetic assets.

II. DEVELOPED METHODOLOGY

This work contemplates three phases:

Phase I:

Comparative study of sustainability of diverse groups of farms identified in the study area (first evaluation cycle – "Maronesa local breed"; "other cattle breeds" and "mixed cattle breeds" groups), through MESMIS methodology. This phase allowed to select the more sustainable farm group.

The sustainability was evaluated by comparison of the production system of Maronesa cattle with other cattle production systems adopted in the area under study. Two main reasons allowed us to proceed this way:

1. The production system of Maronesa cattle has been replaced, in many situations, by systems with more productive breed cattle.
2. The goal of the study was to evaluate the sustainability in economic, social and environmental terms, by performing comparisons between production systems of Maronesa cattle and other cattle production systems in the study area.

The identified production systems, sorted by cattle breed, were: "Maronesa breed" - farms exclusively devoted to Maronesa cattle; "Other cattle breeds" - farms exclusively with cattle of non-Maronesa breed; "Mixed cattle breeds" - farms which combine Maronesa cattle and other breeds.

However, farm sustainability can also be influenced by a number of factors, such as its headage. We tried to measure this influence, by comparing the sustainability of these three groups of farms, in terms of headage (5-9 cows and more than 10 cows).

The research took place on a significant sample (112) of existing farms within the study area (mountainous), having five or more adult animals, whose main activity is the production of bovine.

Phase II:

Based on the found potentialities and weakness on these production systems, we proceed to the planning of a production unit of bovine meat, which simultaneously obey to economic and environmental objectives, using Multicriteria Decision.

Phase III:

We finished the work with the sustainability evaluation between groups of farms identified previously and the planned farms (second evaluation cycle), based, again, in the MESMIS methodology, to confirm (or not) the greatest sustainability of the last ones.

III. THE EVALUATION OF SUSTAINABILITY: 1ST CYCLE

A. Methodology used

The evaluation of sustainability was made using the MESMIS methodology, based on FAO's Framework for the Evaluation of Sustainable Land Management [1], whose proposal for assessment of sustainability is based on a strategy of full analysis of production systems, including economic, social and environmental aspects. MESMIS 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. It consists of a comparative evaluation of a series of indicators of sustainability. 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.

In this sense, and having in account that the degree of sustainability of natural-resources systems will depend on the satisfaction of seven attributes - (a) Productivity; (b) Stability; (c) Trust; (d) Resiliency; (e) Adaptability; (f) Equity; (g) Autonomy, [2], we performed a detailed analysis of the systems under study, with the purpose of identifying their critical points. This procedure allowed us to elaborate a diagnosis and define criteria that were the basis for the 54 indicators selected.

B. Results

The results obtained with the sustainability evaluation, using the MESMIS methodology, are summarised below (table 1).

Table 1 Relationship of sustainability attributes for the three groups in relative units ("Maronesa breed" = index 100)

Attribute	"Mixed cattle breeds" vs. "Maronesa breed"				"Other cattle breeds" vs. "Maronesa breed"			
	Without financial support		With financial support		Without financial support		With financial support	
	Total	≥ 10 Heads	Total	≥ 10 Heads	Total	≥ 10 Heads	Total	≥ 10 Heads
Productivity/Profitability	241	577	125	126	440	964	171	142
Stability, Resiliency and Trust	98	94	93	93	95	72	79	62
Adaptability	116	87	116	87	129	102	129	102
Equity	100	84	89	79	206	144	113	99
Autonomy	81	69	81	69	99	78	99	78
Sustainability	127	183	101	91	194	272	118	97

The analyses of the table 1 allow us to enumerate the following comments:

- The main results achieved supports the empirical belief that farms with other cattle breeds besides Maronesa present a greater relative sustainability. Observing farms with mixture of cattle breeds, we find them in intermediate position.
- The "productivity/profitability" dimension was identified as the one with clearer disparity amongst the studied groups. The remaining attributes are not as distinct between the three groups under analysis, and one can emphasize the biggest "autonomy" and "stability/resiliency /trust" of the "Maronesa breed" group.
- When one takes into account the financial support provided to the current activity of the farms, the groups of farms under analysis become more similar.
- A comparison of the three groups of farms by headage classes does not provide any significant change to these results. It only strengthens the "productivity/ profitability" of the "Mixed cattle breeds" and "Other cattle breeds" groups in headage classes over ten normal heads. And this effect is diluted when one takes into account the financial support provided to the current activity of the farms.

IV. THE PLANNED FARM

A. 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 NISE (NonInferior Set Estimation Method) and Compromise Programming, is being used. The NISE method was selected from a variety of possible tools of analysis, due to its capacity to adapt to the means available to us

and essentially for its inherent advantage, namely the reduction of the number of solutions to a subgroup of an efficient set, which allows a better appreciation of the possible alternatives, eventhough we are aware that it may present some limitations [3].

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 do not exceed two [3], we took as our objectives the maximising of the Gross Value Added (GVA) and the minimising of the energy costs.

This first objective was selected since 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, it was our intention that 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 to us the most suitable given the possibility of quantification of the energy cost in terms of each factor of production used.

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 the farms evaluated previously. The remaining necessary information for the application of the model was obtained from literature on the subject, namely, [4]; [5]; [6]; [7]; [8]; [9]; [10]; [11]; and [12].

The defined model, constituted by 129 variables and 98 constraints, in the scenarios without and with financial support to the activity, was resolved with the LINGO 10 software.

The Agriculturally-Used Area (AUA) represents twelve constraints and we added constraints corresponding to the use of each of the following factors of production: labour, tractor and fertilizers. 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 [6], which was 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 [13]. Finally, we specified the constraints relative to the feedstuffs of the cattle and to sale of the crops and to the sale of animal products (meat, milk and manure), being in mine, also, the limits imposed by the quotes.

B. Results

The obtained compromise solutions in this phase, and to use in the next stage of the work, are exposed in the table 2.

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

- When the financial supports are contemplated, for the same energy costs level, it is reached greater levels of GVA, in each one of the considered models. This situation results, besides the incomes of the supports, from bigger allowed heading, mainly for the Maronesa breed, which is associated to lesser energetic costs;
  Analysing the selected models activities is evidenced 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 obtained solution, being certain that the milk activity is always present when the GVA tendency is greater. Also, is sure that the meat activity is always present when the tendency is for the minimum cost;
- The following binomial appears to be the key for the future of the farming sector, in mountainous areas, in the direction of quality development in equilibrium with environment, social promotion and, simultaneous, 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

- All the obtained solutions for the both considered models have Maronês cattle greater than 25% of the total, imposed limitation on the models, with more remarked values on the situation with financial supports.

Table 2 Obtained compromise solutions to the developed models (PL1, PL∞, PL1', PL∞')

	Without financial support		With financial support	
Extreme points	PL1	PL∞	PL1'	PL∞'
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	0,01203004	-	-	-
Temporary pasture	3,42997	3,442	3,442	3,442
Dry land (Ha)				
Potato	0,9354278	0,9018869	0,5688822	0,1917777
Maize - ensilage	-	0,01542594	0,04551565	-
Temporary pasture	0,03857222	0,05668715	0,3596022	0,7822223
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)	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)	13,06156	-	33,6083	-
N	168,8733	191,5864	148,0853	164,4066
P_2O_5	188,6641	234,5038	142,4224	172,1782
Maronês feed	9430,373	8965,372	11827,1594	10569,786
Commercial feed	5816,1298	3188,53914	4201,135	2891,965
Others feeds to the cattle (kg)	79,3008	-	82,1625	-

V. THE EVALUATION OF SUSTAINABILITY: 2ND CYCLE

A. Methodology

In this phase, the MESMIS methodology was used again, with the same earlier defined indicators, to evaluate the sustainability of the planned farm, relatively to the others farms groups identified in the study sample.

B. Results

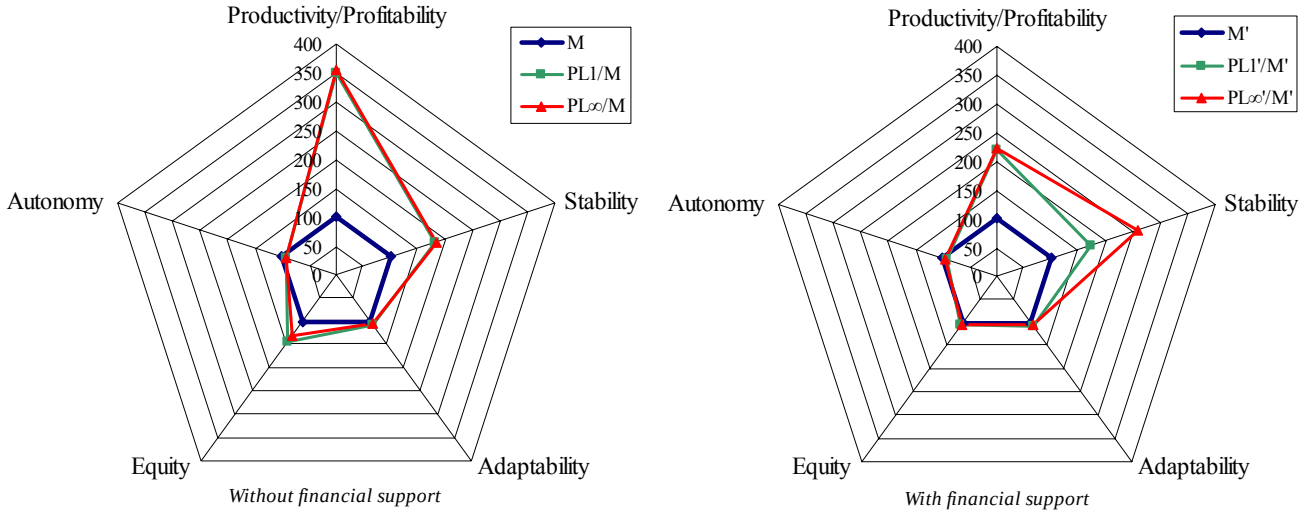

Fig. 1 Relationship between the sustainability attributes on the planned farms (PL1, PL∞, PL1', PL∞') comparatively to the "Maronesa breed" (M, M'), in related units ("Maronesa breed" = index 100)

Figure 1 shows the obtained results. Its analysis allows us to bring out the following observations:

- the planned cases presents greater scores to the sustainability attributes, relatively to the studied farms, when the financial supports are ignored or included, being the only exception the 'autonomy', on the comparison with the "Maronesa breed group";
- generally, 'productivity' and 'stability' are the improved attributes with the planned cases. The first is more related with the economic indicators and the second is closely to the environmental indicators, having been these objectives the ones that were tried to be improved in the planned farms;
- the total values of sustainability relations are the closest on the situation with financial supports than when those values are excluded.

VI. CONCLUSIONS

The sustainability evaluation of the studied farms, according MESMIS methodology, allows us to conclude that farms with others breeds besides Maronesa presents a greater relatively sustainability, mainly when the financial supports aren't considered. The 'autonomy' and the 'stability/resilience/trust' are the strongest points for farms sustainability that adopt Maronesa local breed, having as weak points, essentially, its economic 'productivity'. That means, regardless the minor evolved production costs, the obtained incomes stay away from the ones achieved with the other more productive breeds. Nevertheless, the financial supports to the activity allow mitigating this effect.

Recurring to the operational research techniques and based on the sustainability concept, the main goal of this work was achieved, having, for that, planned a production system that obeys to the compromise between the dimensions where is observed more accentuated differences – economic and environmental sustainability.

The analysis of compromise solutions chosen by the models allow to identify an accentuated cultivation of the land with crops linked to the cattle activity, mainly the irrigated land. Every solution included the meat and milk cattle activities, being sure that milk activity is always present when the tendency is for a greater GVA. Also is sure that meat activity is always present, when the tendency is for the minimum cost.

Using, only, the obtained compromise solutions with multiobjective programming, regarding to economic and environmental objectives, in the scenarios without or with financial supports to the activity, was possible to confirm the greater sustainability relatively to the planned farms, having been the indicators related with that themes that more contributed to the favorable results to sustainability.

The obtained results allowed to conclude, essentially, two main aspects:

- it is possible to conjugate a factors series to obtain a farm that can heavily obey to the sustainability requirements on its multiple dimensions, through a compromise between them;
- the integrated use of the methodological proposal in this work is valid for the decision making, on a multiple objectives context, in the sense of economic and environmental sustainability equilibrium. Its verified that to the individual use of the methodologies used in this work, already testes in other studied themes and in various places, regions and countries, is added now the possibility of their conjugated use in integral way as confirmed by the realization on this study.

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