Sustainability study for the rearing of bovine livestock in mountainous areas

ANA ALEXANDRA MARTA-COSTA*

Jel classification: Q560, Q120

Abstract

This paper presents a comparative sustainability analysis of three different groups of farming systems ("Maronesa breed", "other cattle breeds" and "mixed cattle breeds") identified in the area under examination (the native territory of the Maronesa cattle breed) and following the MESMIS procedure – "Framework for the Evaluation of Natural Resources Management Systems via Sustainability Indicators". The aim is to establish which farming system is the most sustainable, identifying the indicators that best contribute to its sustainability together with the most unfavourable indicators where improvements can be made.

The results analysis leads to confirm an empirical trend according to which the rearing of cattle breeds different from Maronesa has greater relative sustainability. Cattle farms with a mixture of breeds came next, if the financial assistance allocated to the current activities of farms is not taken into account. Where financial assistance is included, the sustainability of the different groups becomes more similar, in accordance with breed and rearing system, despite their different scores in the various sustainability parameters. By evaluation area, the "Maronesa breed" group scores highest in terms of environmental sustainability, while the "other breeds" group is leading in terms of economic and social sustainability.

Keywords: Sustainability, Cattle farms, environment

Résumé

Ce travail présente une analyse comparative de la durabilité de trois groupes différents de systèmes agricoles (groupes «race locale Maronesa», «autres races», «races mixes») identifiés dans la zone d'étude (le territoire natif de la race bovine Maronesa) à travers l'application de la méthodologie MESMIS – "Cadre d'Évaluation des Systèmes de Gestion des Ressources Naturelles à travers les Indicateurs de Durabilité". L'objectif est de sélectionner le système d'élevage le plus durable, d'identifier les indicateurs qui contribuent davantage à sa durabilité ainsi que les indicateurs les plus défavorables qui peuvent être améliorés.

L'analyse des conclusions nous amène à confirmer une tendance empirique selon laquelle l'élevage des autres races de bovins autres que la Maronesa a une plus grande durabilité relative. Les élevages bovins avec un mélange de races viennent ensuite, si nous ne prenons pas en compte l'aide financière accordée aux activités quotidiennes des élevages. Lorsqu'une aide financière est prise en compte, la durabilité des différents groupes devient plus similaire, conformément à la race et au système d'élevage, malgré leurs différentes scores dans les différents paramètres de durabilité. Par domaine d'évaluation, le groupe de la «race Maronesa» a le score le plus élevé en termes de durabilité environnementale, tandis que le groupe «autres races» est au premier rang en ce qi concerne la durabilité économique et sociale.

***Mots clés** : Durabilité, élevages bovins, environnement.*

1. Introduction

Given the importance of agriculture as provider of food, fibre and shelter to the human population, no other sector has a larger role to play in the move towards sustainable development (Smith and McDonald, 1998).

Many authors (Food and Agriculture Organisation of the United Nations – FAO, 1993; Altieri, 1994; Hansen, 1996; Masera *et al.*, 2000b; Müller, 1996; Ikerd, 1997; Smith and McDonald, 1998; Zaham *et al.*, 2007 and others) have investigated sustainable agriculture and its requirements. The majority agree that food sufficiency, environment preservation, socio-economic viability and equity are important components of this sustainability. However, determining operating methods and definitions enabling their application in the decision-making process has proved to be a very difficult task.

This is currently one of the biggest challenges in the discussion on sustainable development, as we need to devise operating models which allow us to evaluate, in concrete terms, the sustainability of different projects, technologies and production systems. Especially, it is of utmost importance to develop evaluation methods that can explicitly demonstrate the environmental, economic and social advantages and disadvantages of the different production systems and strategies as part of a common framework of analysis (Masera *et al.*, 2000a).

This paper presents a comparative sustainability analysis of three different groups of farming systems ("Maronesa breed", "other cattle breeds", "mixed cattle breeds") identified in the area under examination (the native territory of the Maronesa cattle breed) in accordance with the proportions of breeds present and their rearing system, following the MESMIS procedure. The aim is to establish which group is the most sustainable, identifying the indicators which best contribute to its sustainability as well as the most unfavourable indicators to be improved.

The object under study was the rearing system of the Maronesa local cattle breed, due to a set of economic, social and environmental reasons. Amongst these, a critical one is the contribution of these systems to the fight against the human abandonment of mountain areas, by pro-

* University of Trás-os-Montes and Alto Douro
Department of Economy, Sociology and Management Portugal.

viding 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 being natural transformers of intrinsic resources of the mountain areas: 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.

2. Methodology

Sustainability was evaluated by the comparison of the production Maronesa systems with other cattle production systems employed in the area under study. There were two main reasons for this:

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

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

The first system was taken as reference, i.e. the standard system used in the area under study. The others were taken as alternative systems, where innovations (relative to the reference system) have been introduced – in this case, by introducing more productive cattle breeds and other production factors. The main features of the farming systems under examination are listed in the Appendix.

However, farm sustainability can also be influenced by a number of factors, such as its headage and the level of natural resources available. 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) and spatial distribution (combined altitude and slope).

Research addressed a significant sample of farms (112) in 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.

The native territory of the Maronesa cattle breed is delimited by the Portuguese mountain ranges of Marão-Alvão-Padrela. This area entirely encompasses the district subdivisions of Alijó, Mondim de Basto, Murça, Ribeira de Pena, Sabrosa, Vila Pouca de Aguiar and Vila Real (Alves, 1993).

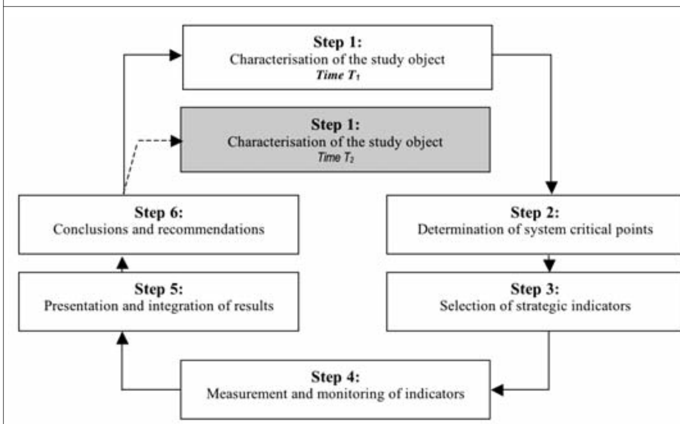
Farms with four or fewer heads of cattle generate an income lower than the national minimum wage from their cattle rearing activity. These farms are not therefore sustainable, at least in economic terms, and cannot constitute the basis for our model for sustainable farms. As a precondition, cattle's rearing was one of the main activities of the farms examined in our study.

Two distinct scenarios were considered: with (actual scenario) and without financial support (to ensure equal conditions to farms) to the current activities.

The evaluation of sustainability was conducted using the MESMIS methodology, based on the Food and Agriculture Organisation of the United Nations (FAO) Framework for the Evaluation of Sustainable Land Management (FAO, 1993), 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.

MESMIS is a cyclical process in which the conclusions serve to identify the critical points of sustainability and to modify the management systems, leading to another evaluation cycle (Figure 1).

Figure 1 – *Operative structure of the MESMIS*



In this sense, and taking into account that the degree of sustainability of natural resources systems will depend on the existence of seven attributes: a) Productivity; b) Stability; c) Trust; d) Resiliency; e) Adaptability; f) Equity; and g) Autonomy (Masera *et al.*, 2000b), we performed a detailed analysis of the systems under study, with the purpose of identifying their critical points.

This procedure allowed to make a diagnosis and define the criteria that were the basis for the 52 indicators/indexes selected, in accordance with a number of reference documents: European Economic Community (EEC, 1991; 1998; 2006); Board on Agriculture of the National Research Council (1993); Organisation for Economic Co-Operation and Development (OECD, 1993; 2004); Ministério da Agricultura, do Desenvolvimento Rural e Pescas (MADRP, 1997; 2005); Direcção Geral do Ambiente (DGA, 2000); Masera *et al.* (2000b); Commission of the European Communities (CEC, 2000; 2001; 2002; 2003; 2006); Intergovernmental Panel on Climate Change (IPCC, 2001); Altieri (2002); International Labour Organisation (ILO, 2002); Lansink *et al.* (2002); European Environment Agency (EEA, 2004; 2005; 2007); Instituto Nacional de Estatística (INE, 2005); International Atomic Energy Agency (IAEA, 2005); and European Environment and Sustainable Development Advisory Councils (EEAC, 2007). The various diagnosis criteria and their matching indexes were validated by experts on each subject, as recommended by Bockstaller and Girardin (2003).

The selected diagnosis criteria and the respective indicators/indexes per sustainability parameter are hereafter indicated.

2.1. Productivity/Profitability Indicators/Indexes

The productivity/profitability indicators/indexes selected were: energy efficiency; bovine production efficiency; work productivity; net present value; and benefit-cost relation with bovines. These indicators/indexes were designed to gauge the efficiency of each of the systems under examination. In other words, they show the relationship between the obtained results and the consumed resources. Also they reveal certain factors which are inherent to each of the systems under analysis, that can clarify the results/resources relationship, and for that reason they have influence on the productivity/profitability of the systems.

2.2. Stability/Resilience/Trust Indicators/Indexes

The selected indicators/indexes to this category address parameters relative to extensification/intensification (stocking density; animal welfare; commercially-available concentrated food per bovine livestock unit (LU); expenses with veterinarians and accessories per bovine LU); conservation of natural resources (nutrient balance per usable agricultural area (UAA); use of plant protection products per UAA; contribution for physical soil deterioration; good farming practices; and indigenous bovine LU as part of the total bovine LU), diversity (activity diversity within a holding; activity diversity external to the holding; diversity of exploited animal species) and vulnerability of systems and (de)motivation among cattle farmers (entrepreneur and family income per bovine LU; holding labour force; economic stability; activity progress and trend over the last 10 years; economic confidence; proportion of producers within a senior age group; positive/optimistic viewpoints on the farming industry; motivation regarding bovine exploitation; sustainability of bovine activity). Together they encompass the main factors which affect the status of continuous dynamic equilibrium of the systems under examination and their surroundings.

2.3. Adaptability Indicators/Indexes

The adaptability indicators/indexes are designed to express the ability of the system under examination to strike a new equilibrium in its attempts to improve its own situation. Indicators are here included and address agro-ecological restrictions (concentration index; land structure; and landscape physiographic quality index), capacity for alteration and innovation (competition ability; available/willing to change; new technology adoption), capacity for learning (proportion of bovine producers with education higher than primary school; and courses and training participation) and information on the sector (number of publications received; and information sources).

2.4. Equity Indicators/Indexes

These indicators/indexes are designed to evaluate the ability of the system to distribute, in an equitable manner, the costs and benefits related to the management of natural resources. This must be verified among the same generation and from one generation to another, between the farmer and the society. The respect for the environment must be mandatory together with the satisfaction of the farmer's requirements on different levels. These are essential factors for the system to endure over time. Satisfaction is an essential criterion if people have to enter and remain in the activity. The distribution of costs and/or benefits (type of tenure; living standard; professional satisfaction of the bovine producer and family; living location satisfaction of the bovine producer and family; price proportion received by the bovine producer regarding the market price of bovine meat; financial support received to maintain the system per LU; and greenhouse effect per LU) and social participation (created jobs; and wages compared to the national minimum wage) are the criteria identified for the equity category.

2.5. Autonomy Indicators/Indexes

Autonomy is the ability of a system to control and regulate its interaction with the external world. The identified criteria for the diagnosis of autonomy are self-sufficiency (degree of dependence on external production factors; and debt level); organization (bovine producers' participation in organisational issues; organisation of distribution channels; and existence of accounting/records); and access to resources (self-financing ability; and alternative activities).

3. Results and discussion

The global findings of the comparative study of the three types of farm, with and without the subsidies allocated to the current farm activities, are given in table 1 and figure 2.

The given values were obtained by the following procedure:

The selected indicators/indexes were individually measured by farm. The value for each group was the average of all the values obtained for the farms belonging to each group;

All indicators show the relationship between two systems, where the reference system is the Maronesa breed

Table 1. *Relationship between sustainability attributes of the three groups, in relative scales (M – Maronesa breed group = index 100; Mx/M – relationship between mixed breeds group and Maronesa breed group; O/M – relationship between other breeds groups and Maronesa breed group)*

ATTRIBUTE	DIAGNOSIS CRITERION	WITHOUT FINANCIAL SUPPORT		WITH FINANCIAL SUPPORT	
		Mx/M	O/M	Mx/M	O/M
A - PRODUCTIVITY/ PROFITABILITY	I – Efficiency	241	439	124	169
	Productivity/Profitability	**241**	**439**	**124**	**169**
B - STABILITY/ RESILIENCE/ TRUST	II - Extensification / Intensification	56	53	61	56
	III - Natural resources preservation	72	20	72	20
	IV - Diversity	106	104	106	104
	V - System vulnerability: motivation of cattle farmers	109	186	84	118
	Stability/Resilience/Trust	**86**	**91**	**81**	**75**
C - ADAPTABILITY	VI - Agro-ecological and socio-economic restrictions	83	140	83	140
	VII - Ability to change and innovate	133	114	133	114
	VIII - Ability to learn	135	144	135	144
	IX - Industry information	115	118	115	118
	Adaptability	**116**	**129**	**116**	**129**
D - EQUITY	X - Distribution of costs and/or benefits	94	90	94	90
	XI - Social participation (employment status)	106	323	85	136
	Equity	**100**	**206**	**89**	**113**
E - AUTONOMY	XII - Self-sufficiency	95	86	95	86
	XIII – Organisation	35	98	35	98
	XIV - Access to resources	113	112	113	112
	Autonomy	**81**	**99**	**81**	**99**
SUSTAINABILITY		***125***	***193***	***98***	***117***

Source: The authors' findings.

(M), which assumes the index 100. For some indicators an inverse relationship was considered.

This is the case where a value greater than the indicator signifies a smaller contribution to the evaluation of sustainability. This is what is observed, for instance, with indicators on production costs. Where a higher value for the costs supported by the farm (i.e. higher value for the indicator) means that the same will represent a smaller contribution to sustainability;

Each diagnosis criterion corresponds to the average of the obtained relations for the indicators/indexes included in the criterion. The average of these corresponds to the respective attribute, with the average of the attributes giving the relative sustainability value.

3.1. Sustainability evaluation of the attribute set

Table 1 and figure 2 present a global score of the sustainability attributes for the three groups.

From the figure we can conclude the following:

– "Productivity/Profitability" and "equity" exhibit the most noticeable differences across the studied groups. This is particularly due to economic indicators/indexes, which indicate higher profitability, in decreasing order, for the "other breeds groups" and the "mixed breeds group". This is essentially due to the existence of a bovine product – milk – that is only sold in the "other breeds group";

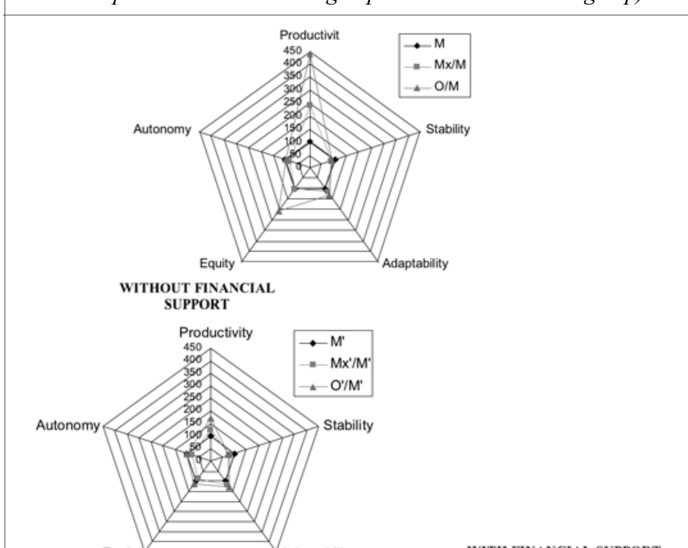
– The different groups broadly exhibit similar results when we include the financial support provided to the current activities of the farms. Regardless of the permanent trend for higher "productivity/profitability" in the "mixed breeds" and "other breeds" groups, the difference in values is smaller: instead of 2.4 and 4.4 times higher, they become 1.2 and 1.7 times higher, respectively;

– The remaining attributes taken into account in the methodology exhibit very similar results for the three groups under analysis. Note especially the greater "autonomy" and "stability/resilience/trust" figures for the Maronesa breed group.

This is due not only to the use of farming practices that are more environmentally friendly, but also to a weaker dependence on external production factors, to the participation of bovine producers in organisational matters and to the organisation of the marketing circuit for "Carne Maronesa DOP" (Maronesa protected designation of origin beef – PDO);

– Confirmation of the theoretical trend that farms with other cattle breeds (besides Maronesa) have higher relative sustainability, i.e. above

Figure 2. *Relationship between sustainability attributes of the three groups, in relative scales (M – Maronesa breed group = index 100; Mx/M – relationship between mixed breeds group and Maronesa breed group; O/M – relationship between other breeds groups and Maronesa breed group).*



index 100 as established for the Maronesa breed group. The "other breeds" group records values of 193 and 117 for conditions with and without subsidies respectively. Farms with a mixture of breeds find themselves in the middle ranking, with a value of 125 (without subsidies), and below the Maronesa breed group (with subsidies) with 98.

3.2. Sustainability evaluation by physiographic level

Although the area delimited by the Marão-Alvão-Padrela Mountains is generally homogenous in its edaphoclimatic characteristics, some variations are to be found in cultivation practices and farming systems, essentially deriving from the conditions inherent to the different physiographic levels found within the area under examination. This area includes mountain zones, with altitudes above 700 metres and steep gradients (15-20% or more); submontane valley, with altitudes below 700 metres; and a plateau zone with altitudes over 700 metres but with little or no gradient. This information was obtained from informal conversations with experts and specialists with a good knowledge of the area under examination, field visits, and consultation of the literature (Alves, 1993 and Colaço-do-Rosário, 1998).

Table 2 shows the results obtained from the sustainability evaluation of the "mixed breeds" and "other breeds" relative to the Maronesa breed by physiographic level.

The analysis of the figures given in table 2 allows us to enumerate the following conclusions:

– The attributes relative to "productivity/profitability" and "adaptability" remain poor for the Maronesa breed, with and without subsidies and at all physiographic levels, with the exception of the latter attribute in the plateau environment and with subsidies, relative to the "mixed breeds" group. This is essentially due to the fact that at this physiographic level the "ability to learn" of farms belonging to the mixed breeds group is very low, since all the cattle farmers in this group are of lower than primary-level schooling and do not attend any kind of training course;

– "Stability/resilience/trust" and "autonomy", on the other hand, are more favourable to the Maronesa breed in mountain areas, compared with other physiographic levels;

– Conditions are more favourable for the other breeds group at lower altitudes and in the no-subsidies scenario, due essentially to the "productivity/profitability" attribute. This situation may be due to the milder conditions in the valley, which are therefore more propitious to the greater productivity, profitability and adaptability of the systems. It is on the plateau, however, that the best situations for this group are to be found across all attributes, not only productivity/profitability, in both subsidy and non-subsidy scenarios;

– General sustainability is only greater for the Maronesa breed in a mountain context when subsidies are included, and on the plateau relative to the mixed breeds group.

3.3. Sustainability evaluation by headage level

The bovine headage level, directly associated with available UAA, is also an important factor for the sustainability of the farming systems. Table 3 shows the results obtained from the sustainability evaluation of the "mixed breeds" and "other breeds" relative to the Maronesa breed, by headage (five to nine and more than nine LU). The classes are based on the median partitioning method defined by Hill and Hill (2002).

Comparison of the three groups by headage class allows us to enumerate the following general conclusions:

– The "productivity/profitability" and "adaptability" attributes continue to be more favourable to the mixed breeds and other breeds groups; for the latter, "equity" too scores higher than the Maronesa group. However, while in general we can observe markedly higher productivity/profitability for headage under ten LU, for a higher headage class adaptability and equity in the same category are lower, with the lowest ratings for these attributes found in the mixed breeds group in both the subsidy (with the exception of equity) and non-subsidy scenarios. Once again we can observe that the discrepancy of values for "productivity/profitability" is significantly lower when subsidies are included;

– For each of the different headage levels, "stability/resilience/trust" and "autonomy" are most favourable for the

Table 2. *Relationship between sustainability attributes of the three groups, in each physiographic level, in relative scales (M – Maronesa breed group = index 100; Mx/M – relationship between mixed breeds group and Maronesa breed group; O/M – relationship between other breeds groups and Maronesa breed group).*

ATTRIBUTE	WITHOUT FINANCIAL SUPPORT						WITH FINANCIAL SUPPORT					
	Mountain		Valley		Plateau		Mountain		Valley		Plateau	
	Mx/M	O/M	Mx/M	O/M	Mx/M	O/M	Mx/M	O/M	Mx/M	O/M	Mx/M	O/M
Productivity/Profitability	137	266	397	756	182	381	123	118	137	146	95	178
Stability/Resilience/Trust	82	57	100	93	102	93	79	47	88	73	100	82
Adaptability	121	127	188	147	84	191	121	127	188	147	84	191
Equity	82	141	94	142	142	348	84	92	89	101	109	163
Autonomy	77	92	95	110	99	128	77	92	95	110	99	128
SUSTAINABILITY	**100**	**137**	**175**	**250**	**122**	**228**	**97**	**95**	**119**	**116**	**97**	**148**

Source: The authors' findings.

Table 3. *Relationship between sustainability attributes of the three groups, by headage level, in relative scales (M – Maronesa breed group = index 100; Mx/M – relationship between mixed breeds group and Maronesa breed group; O/M – relationship between other breeds groups and Maronesa breed group).*

ATTRIBUTE	WITHOUT FINANCIAL SUPPORT				WITH FINANCIAL SUPPORT			
	5 - 9 LU		> 9 LU		5 - 9 LU		> 9 LU	
	Mx/M	O/M	Mx/M	O/M	Mx/M	O/M	Mx/M	O/M
Productivity/Profitability	154	280	578	963	115	148	127	140
Stability/Resilience/Trust	89	97	81	67	82	79	80	57
Adaptability	147	128	87	102	147	128	87	102
Equity	108	164	84	144	95	101	79	99
Autonomy	95	87	69	78	95	87	69	78
SUSTAINABILITY	**118**	**151**	**180**	**271**	**107**	**109**	**88**	**95**

Source: The authors' findings.

Maronesa breed, and all the more so when headage increases;

– Generally speaking, relations for the different headage levels reveal improvements only in "productivity/profitability" when the headage levels increase, with deterioration in the other sustainability attributes for mixed breeds and other breeds. In the non-subsidy scenario, however, increases in "productivity/profitability" are more than proportional to the decreases in the other attributes, with more favourable sustainability values for these groups.

3.4. Sustainability evaluation by evaluation area

Finally, we present the average relationships between indicators/indexes for environmental, economic and social areas, in an attempt to assess the contribution of each dimension to the resulting sustainability (table 4).

The area analysis by "environmental, economic and social" indicators/indexes allows us to corroborate the previous observations:

– Superior environmental parameters for the Maronesa breed group, even though it scores lower in economic indicators/indexes, as seen earlier;

– More favourable environmental impact for the Maronesa breed group, essentially resulting from lower stocking density; lower per-animal input of commercially-available concentrated food and also fertilizers and plant protection products (which produce more favourable nutrient balances and lower contributions to the greenhouse effect); and also from lower physical deterioration (in terms of traction hours per surface unit); predominant use of indigenous bovine breeds (Maronesa); and greater diversity in rearing animal species.

However, though more beneficial from an environmental standpoint, the animal welfare condition and energy efficiency of these farms run against their sustainability;

– In terms of economic indicators/indexes, the results show the superiority of the other breeds group for the selected indicators.

This is essentially due to the fact that this group includes cattle breeds which are fit for providing an additional product – milk.

However, certain bovine productivity efficiency indicators are not included, such as mortality rate; veterinary expenses, economic stability and confidence (highly dependent on the price of milk), the lower proportion of price received by the cattle breeder with regard to the market price of beef, lower subsidies, greater dependency on external production factors, including capital, and poorer organisation of market circuits, with the product usually sold to cattle dealers or directly to butchers and end consumers;

– The analysis by evaluation area leads to the conclusion that social indicators/indexes are the only ones with similar values across the three systems examined, a situation which was also observed in comparable research (Colomer, 2003);

– Comparative social sustainability is greater, however, for the other breeds group and even more for the Maronesa group, a result of the heterogeneity of values recorded for the social indicators;

– From a social point of

Table 4. *Relationship between the sustainability dimensions of the three groups, in relative units (M – Maronesa breed group = index 100; Mx/M – relationship between mixed breeds group and Maronesa breed group; O/M – relationship between other breeds groups and Maronesa breed group).*

EVALUATION AREA	WITHOUT FINANCIAL SUPPORT		WITH FINANCIAL SUPPORT	
	Mx/M	O/M	Mx/M	O/M
Environmental	82	66	83	67
Economy	136	234	91	111
Social	98	122	98	122
SUSTAINABILITY	**105**	**141**	**91**	**100**

Source: The authors' findings.

view, note the future continuity of the activity faced with an adversity of situations, as also confirmed by trends in recent years. Willingness to change and adopt new technology, as well as levels of education and vocational training and quality of life, are some of the negative social aspects associated with the Maronesa breed.

4. Conclusions

Tables 5 and 6 show the conclusions drawn from the findings analysis.

These should be taken into consideration in the alteration/correction of the production systems under examination towards sustainable development.

The tables show which group has the best (+) and worst (-) relative position across the various scenarios examined and relative to each sustainability attribute and area of evaluation.

The bottom line of each table shows the global sustainability rating, with unit weightings across the different parameters.

The conclusions (tables 5 and 6) confirm: Greater relative sustainability of the other breeds group, followed by mixed breeds and with the Maronesa group in the last position. In the subsidy scenario, the second and third positions are reversed;

The 'stability/resilience/trust' and the 'autonomy', as the environmental factors are the strongest points for sustainability on farms with the Maronesa local breed.

The weak point for this group is essentially the economic productivity;

Higher headage and plateau conditions are, in general, more propitious to sustainability, although there are situations where a higher number of animals is unfavourable, with the opposite applying to mountain environments and low headages.

The results obtained and the conclusions lead us to consider that a combination, in suitable proportions, of various cattle breeds (including local breeds) could attain sustainability.

With the Maronesa breed the environmental aspect comes to the fore, while with the other breeds group the emphasis would be on the economic dimension, with social issues being broadly the same for both systems.

Table 5. *Best (+) and worst (-) group per sustainability attribute and area of evaluation, in the non-subsidy scenario.*

FARM GROUP	Maronesa local breed						Mixed cattle breeds						Other cattle breeds					
	Mountain		Valley		Plateau		Mountain		Valley		Plateau		Mountain		Valley		Plateau	
	5-9 LU	>9 LU	5-9 LU	>9 LU	5-9 LU	>9 LU	5-9 LU	>9 LU	5-9 LU	>9 LU	5-9 LU	>9 LU	5-9 LU	>9 LU	5-9 LU	>9 LU	5-9 LU	>9 LU
Sustainability Attribute																		
Productivity/Profitability	-																	+
Stability/Resilience/Trust						+										-		
Adaptability			-															+
Equity							-											+
Autonomy						+		-										
Evaluation Area																		
Economy	-																	+
Social		+														-		
Environmental							-											+
Total																		
SUSTAINABILITY	-																	+

Source: The authors' findings.

Table 6. *Best (+) and worst (-) group per sustainability attribute and area of evaluation, in the subsidy scenario*

FARM GROUP	Maronesa local breed						Mixed cattle breeds						Other cattle breeds					
	Mountain		Valley		Plateau		Mountain		Valley		Plateau		Mountain		Valley		Plateau	
	5-9 LU	>9 LU	5-9 LU	>9 LU	5-9 LU	>9 LU	5-9 LU	>9 LU	5-9 LU	>9 LU	5-9 LU	>9 LU	5-9 LU	>9 LU	5-9 LU	>9 LU	5-9 LU	>9 LU
Sustainability Attribute																		
Productivity/Profitability	-																	+
Stability/Resilience/Trust						+										-		
Adaptability			-															+
Equity							-											+
Autonomy						+		-										
Evaluation Area																		
Economy							-											+
Social		+														-		
Environmental							-											+
Total																		
SUSTAINABILITY							-											+

Source: The authors' findings.

APPENDIX

Elements of the cattle production systems under study (reference and alternatives)

SYSTEM ELEMENTS			MARONESA CATTLE	MIXED BREEDS	OTHER BREEDS
BIOPHYSICAL			Sub-continental climate. Physiography composed of plateaux and mountain ranges, interspersed with submontane valleys. Granite-based soil, associated with shales and greywacke. Hydrography based on high river basins with a network of little density and frequency. Dominant wild vegetation of the subcontinental variety, with an emphasis on Pyrenean oaks and chestnut trees. Wild fauna with an emphasis, amongst mammals, on wild rabbits, wild boars, roe deers, and genets.		
TECHNOLOGY AND REARING FEATURES	Main species and varieties	Agricultural subsystem	Rye; potatoes; chestnut tree groves; pome fruits; stone fruits; horticulture; maize.		
		Animal rearing subsystem	Rainfed pasture; irrigated permanent grassland/wetland; permanent wasteland meadow; Maronesa cattle; wild goats.	Maize silage; rainfed pasture; irrigated permanent grassland/wetland; permanent wasteland meadow; Maronesa cattle; mixed-breed cattle and Friesian trunk cattle.	Maize silage; rainfed pasture; irrigated permanent grassland/wetland; permanent wasteland meadow; Friesian trunk and mixed-breed cattle.
		Silvicultural subsystem	Pyrenean and English oaks; maritime pines.		
	Exploitation/Cultivation system	Agricultural subsystem	Biennial or triennial rye, with successive rainfed pastures. On the most fertile soils, crop rotation between rye and potatoes. Pure groves of chestnut trees or associated with annual crops. Intensive pure orchards. Horticulture: mixed cultivation of vegetables on small patches of the most fertile soils. Annual maize and pastures.		
		Animal rearing subsystem	Pastures: rainfed pastures, permanent grassland. Cows and goats: pasturing and semi-stabled.	Maize silage and annual pastures. Pastures: rainfed pastures, permanent grassland. Cows and goats: pasturing and semi-stabled.	Maize and annual pasture. Pastures: rainfed pastures, permanent grassland. Dairy cows: semi-stabled and stabled.
		Silvicultural subsystem	Pyrenean oak: scattered trees plus small groves on lower areas, usually uncultivated areas, resisting the expansion of maritime pine, preserved from cattle pasturing. Maritime pine: sowing, planting, and regenerating, in pure occupations, on large wooded areas in uncultivated areas, or small areas in private forestries, in both cases without planning.		
TECH. AND REARING FEATURES	Technology		Labour-intensive technology, employing mechanical traction for the most physically-demanding operations.		
	Labour force		Predominantly working families, supported by employees on larger farms.		
	Soil management		Ploughing: use of various soil tillage systems, as a preparation for seeding and planting, and to fight weeds, although the latter being replaced by the use of herbicides. Fertilisation: mainly organic manuring, with some cases of chemical manuring.		
	Pest, disease, and weed management		Use of synthetic agrochemicals.		
SOCIO-ECONOMIC AND CULTURAL FEATURES	Producers		Mainly family unit producers, typically old and with low education.		
	Production units		Production goal: bovine meat. Average area: 10 hectares per farm, with 19 blocks; average uncultivated area reported as 17.4 hectares; and 20 livestock units (LU).	Production goal: bovine meat. Average area: 9 hectares per farm, with 20 blocks; average uncultivated area reported as 7.5 hectares; and 11 LU.	Production goal: milk and bovine meat. Average area: 16 hectares per farm, with 25 blocks; average uncultivated area reported as 15.6 hectares; and 25 LU.
	Production organisation		Predominantly individual systems, resorting to specific producers associations (ACM and APCM), and for product certification.	Predominantly individual systems.	Predominantly individual systems, resorting to some organisations for supplies, and product transformation and distribution (milk).

Source: The authors and adapted from Colaço-do-Rosário (1998).

References

Altieri M.A., 1994. *Bases Agroecologicas para una Produccion Agrícola Sustentable*, Agricultura Técnica, 54(4), 371-386.

Altieri M.A., 2002. *Agroecology: the Science of Natural Resource Management for Poor Farmers in Marginal Environments*, Agric. Ecosyst. Environ., 93, 1-24.

Alves V.C., 1993. *Estudo sobre a "Raça Bovina Maronesa" – Situação Actual e Perspectivas Zootécnicas*, PhD Thesis, University of Trás-os-Montes and Alto Douro, Vila Real, Portugal, 172 pp.

Board on Agriculture of the National Research Council, 1993. *Soil and Water Quality: An Agenda for Agriculture*, National Academy Press, Washington, 519 pp.

Bockstaller C. and Girardin P., 2003. *How to Validate Environmental Indicators*, Agricultural Systems, 76, 639-653.

CEC, 2000. *Indicators for the Integration of Environmental Concerns into the Common Agricultural Policy*, Communication from the Commission to the Council and the European Parliament, COM (2000) 20 final, Brussels, 29 pp.

CEC, 2001. *On the sixth environment action programme of the European Community 'Environment 2010: Our future, Our choice' – The Sixth Environment Action Programme*, Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the regions, COM (2001) 31 final, Brussels, 89 pp.

CEC, 2002. *Towards a thematic strategy for soil protection*, Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, COM (2002) 179 final, Brussels, 38 pp.

CEC, 2003. *Report on the situation in Portuguese agriculture*, Communication from the Commission to the Council and the European Parliament, COM (2003) 359 final, Brussels, 12 pp.

CEC, 2006. *Halting the loss of biodiversity by 2010 – and beyond – Sustaining ecosystem services for human well–being*, Communication from the Commission, COM (2006) 216 final, Brussels, 15 pp.

Colaço-do-Rosário M.F., 1998. *Ensaio de Caracterização Agrária Integrada do Norte de Portugal no Contexto do Continente – Estudo com vista à Orientação do Agros na Perspectiva da Modernidade no Equilíbrio*, PhD Thesis, University of Trás-os-Montes and Alto Douro, Vila Real, Portugal, 638 pp.

Colomer N.A., 2003. *Estúdios de Caso Aplicando el Marco MESMIS – Recopilación, Sistematización y Análisis*, Tesis de licenciatura em Ingeniería Agrónoma. Escola Técnica Superior d'Enginyeria Agraria – CIECO, UNAM, 48 pp.

DGA, 2000. *Proposta para um Sistema de Indicadores de Desenvolvimento Sustentável*. DGA, Amadora, Portugal, 224 pp.

EEA, 2004. *Greenhouse Gas Emission Trends and Projections in Europe 2004*, EEA Report N.º 5/2004, EEA, Copenhagen, 40 p.

EEA, 2005. *EEA Core Set of Indicators Guide*, EEA Technical Report N.º 1/2005, EEA, Luxembourg, 38 pp.

EEA, 2007. *Europe's Environment – The Fourth Assessment*, EEA, Copenhagen, 452 pp.

EEAC, 2007. *Energy Efficiency – Key Pillar for a Competitive, Secure and Environmentally Friendly European Energy Policy*, EEAC, Brussels, 7 pp.

EEC, 1991. *Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources*, Official Journal L 375, 31/12/1991, pp. 1-8.

EEC, 1998. *Council Directive 98/58/EEC of 20 July 1998 concerning the protection of animals kept for farming purposes,* Official Journal L 221, 08/08/1998, pp. 23-27.

EEC, 2006. *Regions: Statistical Yearbook 2006*, EUROSTAT, Luxemburg, 165 pp.

FAO, 1993. *FESLM: An International Framework for Evaluating Sustainable Land Management*, World Soil Resources Reports n.º 73, FAO, Roma, 85 pp.

Hansen J.W., 1996. *Is Agricultural Sustainability a Useful Concept?* Agricultural Systems, 50, 117-143.

Hill M.M. and Hill A, 2002. *Investigação por Questionário*, 2ª ed., Edições Sílabo Lda, Lisbon, 376 pp.

IAEA, 2005. *Energy Indicators for Sustainable Development: Guidelines and Methodologies*, IAEA, Viena, 161 pp.

Ikerd J., 1997. *Understanding and Managing the Multi-Dimensions of Sustainable Agriculture.* In Southern Region Sustainable Agriculture Professional Development Program Workshop, 15 Janeiro 1997, SARE Regional Training Consortium, Gainesville, FL, 12 p.

ILO, 2002. *Key Indicators of the Labour Market (KILM): 2001-2002*, ILO, Geneva, 621 pp.

INE, 2005. *Estatísticas Agrícolas 2004*, INE, Lisbon.

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. and 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, Lisbon, 52 pp.

MADRP, 2005. *Decreto-Lei N.º 202/2005, estabelece o regime jurídico do licenciamento das explorações de bovinos*, Diário da República N.º 226, I-A Série, de 24 de Novembro de 2005, pp. 6690-6697.

Masera Ó., Astier M. and López-Ridaura S., 2000a. *El Marco de Evaluación MESMIS*. In O. Masera, and S. López-Ridaura (eds), Sustentabilidad y Sistemas Campesinos, GIRA A. C. – Mundi Prensa – PUMA, México, pp. 13-44.

Masera Ó., Astier M. and López-Ridaura S., 2000b. *Sustentabilidad y Manejo de Recursos Naturales. El Marco de Evaluación MESMIS*, GIRA – Mundi-Prensa, México, 109 pp.

Müller S., 1996. *Como Medir la Sostenibilidad? Una Propuesta para el Area de la Agricultura y de los Recursos Naturales*, Serie Documentos de Discusión sobre Agricultura Sostenible y Recursos Naturales Nº 1, Costa Rica: I-ICA/BMZ/GTZ, 55 pp.

OECD, 1993. *OECD Core Set of Indicators for Environment Performance Reviews, A Synthesis Report by the Group on the State of the Environment*, OCDE/GD (93) 179, Environment Monographs N.º 83, OECD, Paris, 39 pp.

OECD, 2004. *OECD Key Environmental Indicators 2004*, OECD, France, 36 pp.

Smith C. and McDonald G., 1998. *Assessing the Sustainability of Agriculture at the Planning Stage*, Journal of Environment Management, 52, 15-37.

Zaham F., Girardin P., Mouchet C., Viaux P., Vilain L., 2005. *De l'Évaluation de la Durabilité des Exploitations Agricoles à Partir de la Méthode IDEA à la Caractérisation de la Durabilité de la «Ferme Européenne» à partir d'IDERICA*. In: Colloque International «Indicateurs Territoriaux du Développement Durable, 1 et 2 Décembre 2005,