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; Ikeder, 1997; Smith and McDonald, 1998; Smith and McDonal, 1998; FAO, 1993; Altieri, 1994; Smith and McDonal, 1998) 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” 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

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.

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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).

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...
(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
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
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>
<thead>
<tr>
<th>EVALUATION AREA</th>
<th>WITHOUT FINANCIAL SUPPORT</th>
<th>WITH FINANCIAL SUPPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mx/M</td>
<td>O/M</td>
</tr>
<tr>
<td>Environmental</td>
<td>82</td>
<td>66</td>
</tr>
<tr>
<td>Economy</td>
<td>136</td>
<td>234</td>
</tr>
<tr>
<td>Social</td>
<td>98</td>
<td>122</td>
</tr>
<tr>
<td>SUSTAINABILITY</td>
<td>105</td>
<td>141</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>FARM GROUP</th>
<th>Maronesa local breed</th>
<th>Mixed cattle breeds</th>
<th>Other cattle breeds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mountain</td>
<td>Valley</td>
<td>Plateau</td>
</tr>
<tr>
<td>Productivity/Profitability</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Stability/Resilience/Trust</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Adaptability</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Equity</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Autonomy</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>SUSTAINABILITY</strong></td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

Source: The authors’ findings.

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

<table>
<thead>
<tr>
<th>FARM GROUP</th>
<th>Maronesa local breed</th>
<th>Mixed cattle breeds</th>
<th>Other cattle breeds</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Mountain</td>
<td>Valley</td>
<td>Plateau</td>
</tr>
<tr>
<td>Productivity/Profitability</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Stability/Resilience/Trust</td>
<td>+</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Adaptability</td>
<td>-</td>
<td>-</td>
<td>+</td>
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<tr>
<td>Equity</td>
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<tr>
<td>Autonomy</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>SUSTAINABILITY</strong></td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

Source: The authors’ findings.
APPENDIX

<table>
<thead>
<tr>
<th>Elements of the cattle production systems under study (reference and alternatives)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SYSTEM ELEMENTS</strong></td>
</tr>
<tr>
<td><strong>BIophysical</strong></td>
</tr>
<tr>
<td>Agricultural subsystem</td>
</tr>
<tr>
<td>Animal rearing subsystem</td>
</tr>
<tr>
<td>Maize silage; rainfed pasture; irrigated permanent grassland/wetland; permanent wasteland meadow; Maroneza cattle; mixed-breeds cattle and Friesian trunk cattle.</td>
</tr>
<tr>
<td>Silvicultural subsystem</td>
</tr>
<tr>
<td><strong>TECHNOLOGY AND REARING FEATURES</strong></td>
</tr>
<tr>
<td>Agricultural subsystem</td>
</tr>
<tr>
<td>Silvicultural subsystem</td>
</tr>
<tr>
<td><strong>TECH and REARING FEATURES</strong></td>
</tr>
<tr>
<td>Technology</td>
</tr>
<tr>
<td>Labour force</td>
</tr>
<tr>
<td>Soil management</td>
</tr>
<tr>
<td>Pest, disease, and weed management</td>
</tr>
<tr>
<td><strong>Producers</strong></td>
</tr>
<tr>
<td>Production units</td>
</tr>
<tr>
<td>Production organisation</td>
</tr>
</tbody>
</table>

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

References


