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Assessment of Sustainability of Dairy Sheep Farms in Castilla y León (Spain) Based on the MESMIS Method

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Abstract

A livestock system is a productive unit, but in addition, if it pursues an optimal use of natural resources, it can increase overall sustainability. In order to evaluate the fulfillment of this objective, it is necessary to carry out a diagnosis of the system to describe and evaluate its degree of sustainability. One methodological option for this diagnosis is the construction of sustainability indicators. The MESMIS method is a methodological tool that analyses the interrelations between the results of the environmental, social and economic dimensions through a battery of indicators. The aim of this work is to assess the sustainability, using the MESMIS methodology, of different management systems of a sample of dairy sheep farms in Castilla y León (Spain). In general, the semi-extensive group obtained the highest overall score (8.40), and the intensive group achieved the highest volume of productivity. In conclusion, semi-extensive systems were more sustainable than intensive or semi-intensive systems in all attributes, especially those related to stability, adaptability and equity.

Keywords: sustainability, MESMIS, diagnosis, dairy sheep farms, livestock

1. Introduction

Sustainable development was proposed as a response to the growing awareness of determining relationships among social and economic development, global, regional, local and rural environments, and population growth with its continuous urban concentration [1]. Despite the high complexity associated with sustainable development, efforts to achieve it have become common practice at all levels of public policy, from governmental laws [2] to regional and private decision making [3] because of the potential consequences of not achieving it; i.e., that the environment's capacity to ensure a certain welfare level would actually be disrupted [4] with serious effects on human societies [5]. Achieving sustainable development requires a substantial, complex and persistent effort, yet addressing the widely acknowledged necessity of how best to measure it is the first step.

Identifying sustainable development indicators at the microeconomic level raises the question of which information is relevant because sustainable development involves three interconnected components that must be addressed per productive unit; viz., environment, equity, and futurity (the ability to manage resources in a long-term perspective and with appropriate respect for future generations). The interdependence can be reflected by several economic, social, and environmental variables that are interconnected and to the additional dimension of time, which emphasizes the long-term perspective [6].

An assessment of a system that describes and quantifies sustainability requires identifying the limitations that affect its operation, the causes behind these limitations, and identifying the potentialities. Thus, proposals can be made to improve farms in accordance with the producer's real requirements [7].

Evaluating sustainability is not an easy task; it is a complex task to integrate all edges of the concept to reach a single conclusion on the ecological, social, and economic characteristics and implications of a given system. However, there is also a vital need to identify indicators to assess the relative degree of sustainability of proven production systems, especially those in the rural sector [8], which are needed to develop policies that promote respectful practices that are consistent with sustainability.

Among the efforts to make the sustainability of complex production systems operational based on indexes, indicators and frameworks [9], the Framework for the Assessment of Natural Resource Management Systems incorporating Sustainability Indicators (MESMIS) [7] has played a leading role in sustainability assessments because it was one of the first to use a multidimensional approach in addressing the sustainability of agricultural production systems.

This study assessed the sustainability of 17 dairy sheep farms in Castilla y León (Spain), clustered into three management styles; i.e., semi-intensive, intensive, or semi-extensive, based on the MESMIS. To evaluate the results from that method, the statistical analyses were used to assess the indicators of each attribute and the management system.

2. Methods

MESMIS is a method of analysis that helps to quantify sustainability through a comprehensive analysis of management systems. It is based on the interrelationships between environmental, social, and economic processes [10], and aims to maintain or improve productivity, reduce risks and uncertainty, protect resources and prevent soil, water and biodiversity degradation, without diminishing the economic viability of the system [11]. MESMIS includes the local factor as a fundamental diagnostic component, identifies endogenous responses, which makes it a method that is permanently under construction [7]. The assessment must be comparative and cyclical, and it begins characterizing the system, the integration of indicators, and the formulation of conclusions and recommendations for improving the management system.

MESMIS requires the following phases [7]:

1. Definition and description of the farms assessed.
2. Characterization of the management systems.
3. Selection of indicators and development of attributes.

- 4. Tool’s global assessment and sustainability measurement.
- 5. Proposal of corrective or improvement measures.

This work compiles a set of contributions generated by the Castilla y León team that was involved in the R + D + i research project of the National Institute of Agricultural Research “Incidence on the quality of products and the environment of different livestock farming systems with small ruminants of dairy aptitude. Use of economic, social and environmental indicators and final typification of systems”. The project was within the Sub-program of fundamental research projects oriented towards agricultural resources and technologies in coordination with the Autonomous Regions [“of Spain”]. The aim of the project was to evaluate agricultural and livestock sustainability based on the NAIA indicator system in four Spanish Autonomous Communities; i.e., Castilla y León, Navarra, País Vasco, and Andalucía. The project modified the original NAIA method, which is typically applied to livestock farms, to adapt it to the analysis and diagnosis of small ruminant farms (sheep and goat). The final NAIA method involves the calculation of 133 variables, which are assigned to one of 20 indicators that are integrated into three dimensions, see **Table 1**. All the information about the original tool and its indicators is available at <https://neiker.eus/en/patents-and-varieties/>.

The distribution of indicators in the NAIA method is a classical version of structural analysis that is divided into functional categories; viz., economic, social and environmental. The method was developed as a proposal for improving farms and a solution manual for institutions. Therefore, it is reasonable that it replicates that traditional scheme and focuses attention on those aspects that depend directly on livestock management and administration. The variables and indicators used in the project were adapted and organized for the construction of the MESMIS attributes.

- 1. Productivity: ability of the agro-ecosystem to provide the required level of goods and services. It is the value of the attribute in a given period.

	Economic	Social	Environmental
Indicators	Profitability (8)	Employment Characteristics (7)	Livestock/Surface balance (5)
	Autonomy (6)	Employment creation (4)	UAA ^a used and management (7)
	Diversification and risk (6)	Life quality (5)	Soil nutrients balance (8)
	Cost structure (4)	Employment quality (17)	Effluents management (4)
	Stability (3)	Animal Welfare (9)	Natural resources and diversity (7)
		Traditional systems and landscapes (8)	Energy (7)
		Product quality and proximity (9)	Emissions (4)
		Gender (5)	

^aUtilized agricultural area (UAA), is the total area taken up by arable land, permanent grassland, permanent crops and kitchen gardens used by the holding, regardless of the type of tenure or of whether it is used as a part of common land. (number of variables involved in each of the indicators).

Table 1.
NAIA method: Dimensions, indicators, and variables.

2. Stability: property of the system that is in a state of dynamic equilibrium.
3. Adaptability: capacity to find new balances that maintain the productive potential “vis à vis” external changes. This attribute includes aspects related to the diversification of activities or technologies processes of social organization, training of human resources, and learning.
4. Resilience: capacity of the system to return to an equilibrium or to maintain its productive potential after suffering severe disturbances (e.g., catastrophic events, hurricanes).
5. Reliability: capacity of the system to maintain productivity or benefits near balance levels when facing normal environmental disturbances.
6. Autonomy: capacity of the system to regulate its interactions with the outside.
7. Equity: ability of the system to fairly distribute the benefits and costs of natural resource management intra- and inter-generationally.

The sustainability assessment is performed and is valid for the following, only:

- a. Specific management systems in a given location and within a certain social and political context.
- b. A previously defined spatial scale (plot, production unit, community or watershed).
- c. A priori defined temporal scale.

The analyses presented in this paper met all of the conditions required for the results to be consistent. The selection of the indicators needed for the construction of the attributes was based on the NAIA method. **Table 2** shows the relationships between the NAIA indicators and the MESMIS attributes which make the MESMIS more concrete.

In the NAIA and MESMIS adaptation, two attributes have been merged into other categories as follows:

- Resilience has been merged with Adaptability based on the understanding that the possibility of finding a balance again includes the development of a scenario that is consistent with a previous safe and reliable scenario.
- Reliability has been merged with Stability and Productivity because an adequate combination of the two provides a strong economic balance “vis à vis” disturbances in the system.

Thus, the proposed MESMIS scheme is organized around the following five attributes: Productivity, Stability, Adaptability, Autonomy, and Equity (see **Table 6** and **Table 7** (bis) of the appendice).

The graphical representations of the results were radial graphs (amoebas). The optimal value for each indicator is the maximum value in the NAIA Tool tables. The maximum and minimum values are the absolute values of the Castilla y León's sample (17 farms). To create each graph, the origin of the data was transformed into a range from 0 to 10. Thus, the system that is closest to the optimum for each

	Overall average	Group average		Overall average	Group average
Management system results			Environmental results		
Sheep	799	890	Cost/ha x 10 (MJ)	164.160	319.040
M ² Built	2412	3013	Net Cost x 1000 (MJ)	6.665.000	8.236.000
M ² /sheep	3.15	3.16	CO ₂ /ha (Kg Eq CO ₂)	17.223	39.123
AWU	3.66	4	Milk quality		
Family AWU	2.33	2	Protein (%)	5.6	5.41
UAA (ha)	68.66	32	Fat (%)	7	6.92
Own UAA (ha)	17.33	14	Omega 6 / Omega 3	4.8	5.98
External UAA (ha)	51.66	18	CLA	0.66	0.61
UAA /sheep (ha/sheep)	0.08	0.03	Alfa-tocopherol	102.42	70.57
Communal Ha	308.33	0	Retinol	63.58	58.07
Economic results			Somatic cells	1,042.84	985.34
Income	240.43	298.56	Life and work quality		
Capital	378.07	437	Life quality	3.12	2.8
Direct expenses	129.94	201.14	Work quality	3	2.2
Indirect expenses	132.1	100.29	AWU: Agrarian Work Unit		
Gross margin	149.73	116.5	UAA: Utilized agricultural area		
Net margin	17.63	16.21			

Annual work unit (AWU) is the full-time equivalent employment, i.e. the total hours worked divided by the average annual hours worked in full-time jobs in the country. One annual work unit corresponds to the work performed by one person who is occupied on an agricultural holding on a full-time basis.

Cost/ha x 10 (MJ) are the direct and indirect energy costs per hectare expressed in megajoules, calculated according to the formulas of [12].

Net Cost x 1000 (MJ) are the direct and indirect energy costs minus the energy inputs derived from the production of lambs and milk expressed in megajoules, calculated according to the formulae of [12].

CO₂/ha (Kg CO₂ Eq) are the greenhouse gas emissions expressed in kilograms of CO₂ equivalent and calculated according to the formulae of [12].

Table 2.
Characteristics of intensive farms.

indicator can be identified. For negative values (i.e., Net Margin), We used mathematical distance to the optimum, therefore, the segment represents the distance to the optimum of either a positive or a negative value.

1. To identify the strengths and weaknesses of the management systems and to provide suggestions for improving their sustainability, the information on the attributes was evaluated globally and by the management system.
2. Similarities in the performance of the three types of management (semi-intensive, intensive, and semi-extensive) were evaluated based on the indicators of each of the attributes. The method involved following two tests:
a) Shapiro-Wilks normality test (normality test for a sample size <50), which establishes the null hypothesis that a sample came from a normally distributed

population, and b) the t-Student test for normal samples and the Kruskal-Wallis (H) non-parametric test for non-normal samples. The results will indicate whether the three types of management for each of the indicators of the attributes has similar performances. The null hypothesis was that the three groups analyzed did not show differential behavior in a given indicator (significance level 0.05).

3. Sample description and farm classification and characterization

Farms were selected based on the knowledge of technicians who worked in this region and the aim was to obtain a sample that was representative of the dairy sheep systems in Castilla y León, which is a landlocked region in the northwestern of the Iberian Peninsula (**Figure 1**). It has an area of 94,225 km² (12% of Spain) and is the largest Spanish region. In 2019, there were 2,689,415 sheep (17.4% of the national total) which made it the Community that had the highest concentration of sheep in Spain.

In that project, an initial classification of management systems was based on four types of farms based on seven discriminating variables, which were analyzed by a Multinomial Logistic Regression model. An instrument was developed to estimate the probability that a farm belonged to one of the four defined groups based on the scheme shown in **Figure 2**.

Once the model was applied to the sample of Castilla y León, it indicated that none of the farms in the sample from Castilla y León fell into the pure extensive group: The distribution of the 17 farms is shown in **Figure 3**.

3.1 Intensive farms

Farms in the intensive group had an average of Utilized Agricultural Area (UAA) of 32 ha (see **Table 2**) and the animals did not use plant resources directly.



Figure 1.
Map of Castilla y León.

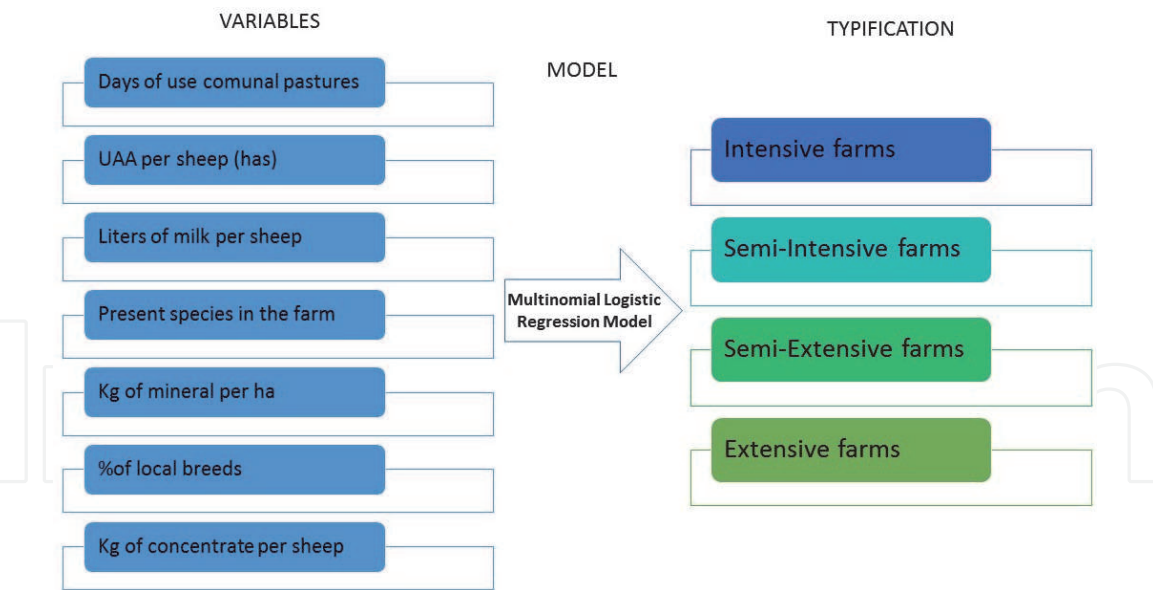


Figure 2.
Typification variables and farm typology.

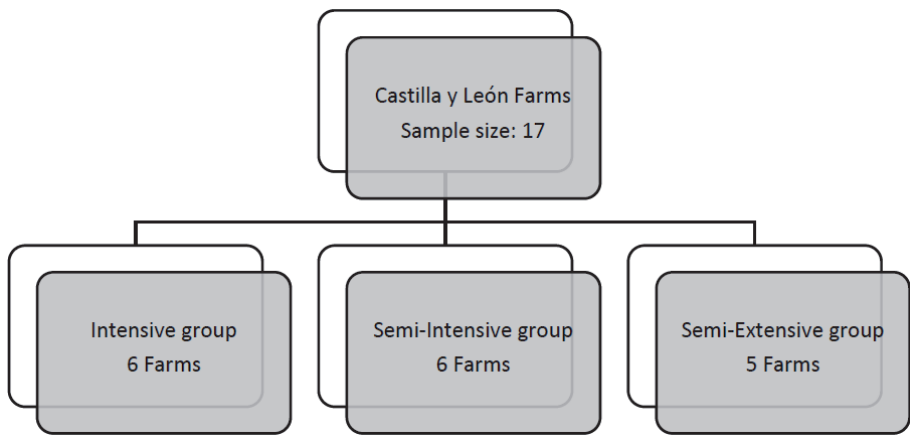


Figure 3.
Distribution of farms among typified groups.

The average agricultural area per adult ewe was 0.03 ha/ovine, which was 62% less than the average of all farms. On average, flocks had 890 adult ewes. The average total income per ewe was 298.56 euros. Capital endowments per ewe were 437 euros, which was higher than the overall average. Direct expenses per ewe were 54% higher than was the average of all farms (201.14 vs. 129.94). The gross margin per ewe was 116.50 euros (33% less than the overall average).

That group of farms has activities that require high energy efforts and emit large amounts of greenhouse gases, which is similar to the results obtained in previous studies [12] who found that the highest carbon footprint indicators occurred in farms that had management systems that were dependent on high consumption of external inputs. Milk from intensive farms had the lowest protein and fat-soluble vitamin content among the three groups. The data indicated an unhealthy lipid profile, which was due to the low proportion of green pasture in the diet. Furthermore, the group had the lowest somatic cell concentrations of the three groups. At the start of the project, a survey on the social conditions linked to each of the farms indicated that the farmers in this group had an average perception of life quality of 2.8, and a work quality of 2.20, which indicated an overall dissatisfaction that was lower than was the overall average.

	Overall average	Group average		Overall average	Group average
Management system results			Environmental results		
Sheep	799	824	Cost/ha x10 (MJ)	16.416	11.908
M2 Built	2412	2214	Net Cost x 1000 (MJ)	6.665	6.392
M2 /sheep	3.15	2.8	CO ₂ /ha (Kg Eq CO ₂)	17.223	7.994
AWU	3.66	4	Milk quality		
Family AWU	2.33	2	Protein (%)	5.6	5.51
UAA (ha)	68.66	68	Fat (%)	7	6.82
Own UAA (ha)	17.33	27	Omega 6 / Omega 3	4.8	5.15
External UAA (ha)	51.66	41	CLA	0.66	0.65
UAA /sheep (ha/sheep)	0.08	0.08	Alfa-tocopherol	102.42	75.63
Communal Ha	308.33	160*	Retinol	63.58	60.33
Economic results			Somatic cells	1,042.84	1,119.59
Income	240.43	255.96	Life and work quality		
Capital	378.07	366.68	Life quality	3.12	3.17
Direct expenses	129.94	111.94	Work quality	3	2.83
Indirect expenses	132.1	171.05	* two farmers		
Gross margin	149.73	200.06			
Net margin	17.63	29			

Table 3.
Characteristics of semi-intensive farms.

3.2 Semi-intensive farms

Semi-intensive farms had an average UAA of 68 ha (see **Table 3**), which was similar to the average of all farms. Two farmers use communal pastures, which had an average of 160 ha. The agricultural area per adult ewe was 0.08 ha. They had built facilities that were, on average 2,214 m2, that is, 2.8 m2 per adult animal, which is slightly lower than the average of all the farms. Average Total income per ewe was 255.96 euros. The investments made on the farm were 366.68 euros per ewe, with an inverse relationship between the intensification of production and the endowments of the capital factor per productive unit. Direct expenses per sheep were significantly lower than was the average for all farms. Indirect costs were 29% higher than was the average for all farms. The gross margin per sheep was 200.06, and the net margin was 128% higher than was the overall average.

Those farms are energy-intensive, although less so than the overall average, and emit moderate amounts of greenhouse gases, similar to the amounts reported by previous studies [12]. Milk from those farms had protein and vitamin levels that were close to the overall average. Fat levels were the lowest and somatic cell content was highest among the three groups. Those farms reported a higher-than-average life quality and a lower than average work quality.

3.3 Semi-extensive farms

Semi-extensive farms had a UAA of 106 ha (see **Table 4**). Those were farms in which the animals made more daily use of plant resources than did the other groups.

	Overall average	Group average		Overall average	Group average
Management system results			Environmental results		
Sheep	799	685	Cost/ha x 10 (MJ)	16.416	3.242
M2 Built	2412	2009	Net Cost x 1000 (MJ)	6.665	5.106
M2 /sheep	3.15	3.5	CO ₂ /ha (Kg Eq CO ₂)	17.223	2.018
AWU	3.66	3	Milk quality		
Family AWU	2.33	3	Protein (%)	5.6	5.93
UAA (ha)	68.66	106	Fat (%)	7	7.31
Own UAA (ha)	17.33	11	Omega 6 / Omega 3	4.8	2.96
External UAA (ha)	51.66	96	CLA	0.66	0.73
UAA /sheep (ha/sheep)	0.08	0.15	Alfa-tocopherol	102.42	172.79
Communal Ha	308.33	521	Retinol	63.58	74.11
Economic results			Somatic cells	1,042.84	1,119.74
Income	240.43	152.05	Life and work quality		
Capital	378.07	321.04	Life quality	3.12	3.2
Direct expenses	129.94	66.1	Work quality	3	3.6
Indirect expenses	132.1	123.52			
Gross margin	149.73	129.21			
Net margin	17.63	5.69			

Table 4.
Characteristics of semi-extensive farms.

The agricultural area per adult sheep was 87% higher than the average of all farms. On average, there were 685 adult sheep and facilities built to provide 3.5 m²/ewe, which was the highest average available area of all the farms. The total income per sheep was significantly (63.2%) lower than the average. The amount of direct expenses incurred on the farms was half of the overall average. Indirect costs were below the group average. The gross margin was slightly less than was the group average. The net margin was 32.3% of the overall result.

Those farms required less energy and emitted less greenhouse gases than did the other groups, similar results were obtained in previous studies [12]. Milk produced in semi-extensive farms had the highest protein, fat, and vitamin content levels. The lipid profile was the healthiest of the three types of farms. Milk from these farms had the highest vitamin content. The somatic cell content was close to the overall average. Life and work quality were higher than the overall average.

4. Results

4.1 Attributes results of typified groups

The Productivity attribute is related to the economic performance of the farms and their capacity to generate goods and services, and comprises 12 indicators, the results of which are shown in **Figure 4**.

The productivity attribute had a logical pattern determined by the different production systems, and the most extensive farms had the best results in the indicators directly related to environmental protection, as follows:

- a. They were the most efficient in the use of direct and indirect energy.
- b. They had the highest values regarding phytosanitary pressure, defined as the proportion of the UAA that is treated with this type of products, which indicates that this system did not use this type of supplement in the farm's agricultural tasks.
- c. They opt for the use of organic matter as a means to provide nutrients to the soil. The group had an average of 100% of its UAA that was treated with organic matter.
- d. Regarding the economic indicators, these farms required the lowest volume of milk production to achieve the reference income in the sector, and had the highest gross margin without subsidies.

The most intensive systems had those that obtained the highest value in the carbon footprint relative to the total kg of milk produced and to the net margin. That relationship is precisely what made this good result possible because these farms produce the highest volumes of milk and those that achieve the highest net margin per liter and per family work unit. Those economic results clearly verify their productivity vocation.

The weight of the capitalization, which is the importance of the structure to production, for this type of farm was lower than that of the other types. This concept is the ratio between the indirect expenses borne by the activity and the gross production, and, by obtaining higher production volumes, this expense is diluted. In addition, those farms were at the extreme of the values obtained in the

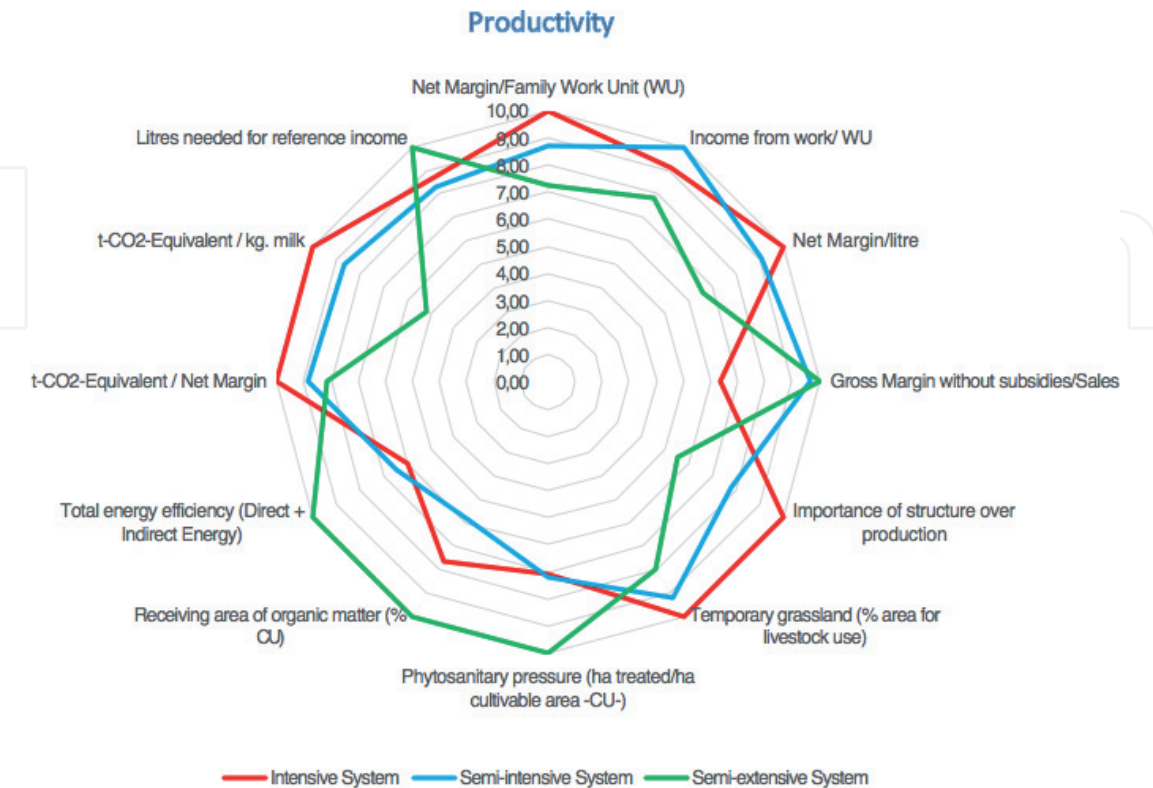


Figure 4.
Productivity attribute of typified groups.

livestock use of sown pastures because they did not use this means of production. On average, semi-intensive and extensive farms used 5.6% and 13.6% of the UAA in that manner, respectively.

The semi-intensive group occupied an intermediate position in almost all of the indicators, and obtained was optimal in the result of labor income per work unit, only, which aims to measure the remuneration of total labor (family and salaried) after deducting the capital opportunity costs.

The Stability attribute reflects the farm's capacity for innovation and its commitment to the environment (**Figure 5**).

The results of the stability attribute were highest in the semi-extensive group.

- Those farms showed the lowest importance of the costs that have financial risk, which are those affected by the interest on loans and those payable in the short term.
- They had the lowest amounts of nitrogen excreted per unit of UAA.
- They had the best slurry and manure pit management. All were professional farms that were used by the owner, exclusively with dedication.
- They had the best prospects regarding the possible continuation of the activity, possibly, because they had the highest proportion of family labor.
- Those farms reported the highest work quality.
- In aspects of grazing, such as the availability of sheepfolds, grazing of reproductive cattle and adequate grazing, the semi-extensive group had the highest scores.

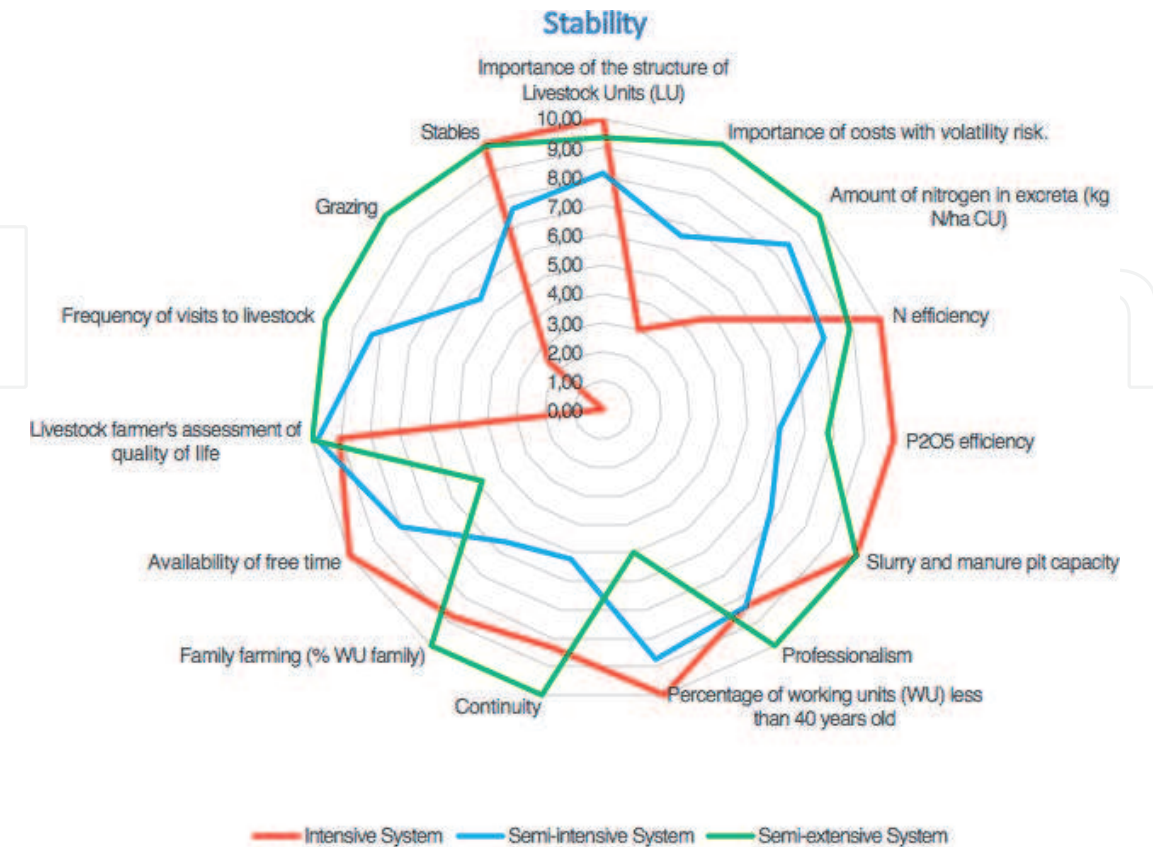


Figure 5.
Stability attribute of typified groups.

- In aspects of stabling, such as the availability of >10 m² per livestock unit, the availability of free stall areas, bedding care and cleanliness, the maintenance of an adequate temperature and protection, and the availability of sufficient watering and feeding troughs, the semi-extensive group had the highest scores, together with the intensive group, among the three groups.

Farms in the intensive group, which had the largest herds, and more production units, had the best weight of the farm's structure on each livestock unit, following in the wake of the productivity attribute. Those farms also have the best efficiencies between nitrogen and phosphate farm outputs and inputs. They were the least aged farms, and mechanization gave them more free time, although they reported a low work quality. The semi-intensive group, as in the previous attribute, is positioned in the intermediate between the extremes marked other groups.

The Adaptability attribute reflects the flexibility of farms and their ability to adapt to a changing environment, and was the attribute in which the typified groups were most divergent (**Figure 6**).

The semi-extensive group had the best values for the following four attributes:

- Those were the farms that, according to the technician and the owner of the farm, had the highest diversification of their customers, which gave them the highest commercial independence.
- They had the farmers with the lowest stocking density per hectare of UAA.
- They had the most sustainable management in the area because they used techniques such as crop rotation or association, improvement of natural pastures, use of composting, fallow land, and integrated pest control.

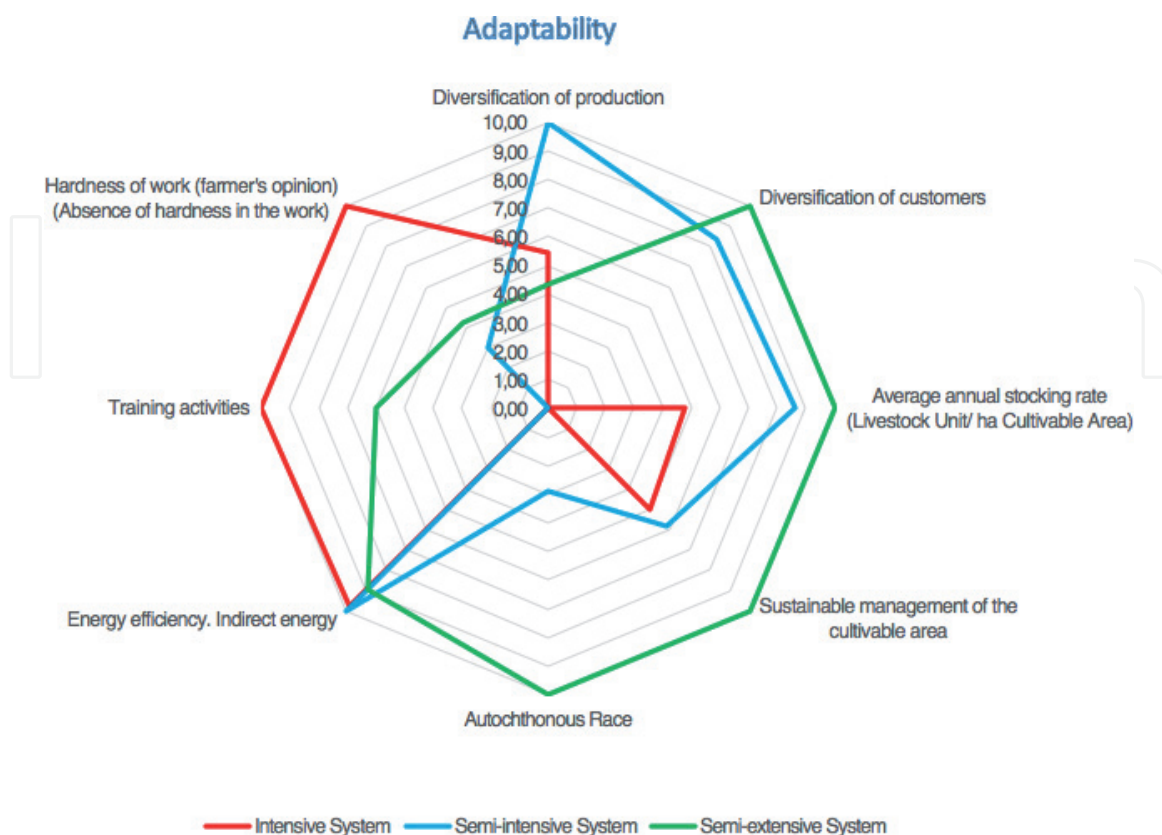


Figure 6.
Adaptability attribute of typified groups.

- Most used native breeds, which have been selected for their hardiness and are committed to maintaining the genetic diversity of the breed.

Farmers in the intensive group were those who had participated the most in training activities and those who felt that the work that they performed on the farm was the least arduous. To carry out strenuous tasks they had machinery at their disposal, which Meant that they had fewer muscular or skeletal problems. In addition, they had not had any significant work accidents, they had pre-established routines, and valued not having a boss.

The semi-intensive group had the most efficiency in the use of indirect energy and they were the most diversified in the products they produced, which allowed them to be less influenced by the volatility of milk prices as their main product.

The Autonomy attribute reflects the degree of self-management of costs and the area devoted to self-consumption (**Figure 7**).

In the Autonomy attribute, the semi-extensive group had the best values for seven indicators:

- Its farmers had the highest food autonomy, the process of re-employment of their agricultural productions gave them independence and self-management in the structure of animal feeding.
- They had the highest labor autonomy because their workforce was mostly family labor.
- They had the highest ratio of direct and indirect costs and the average price received for each liter of milk produced, probably because of the previously described process of food autonomy.

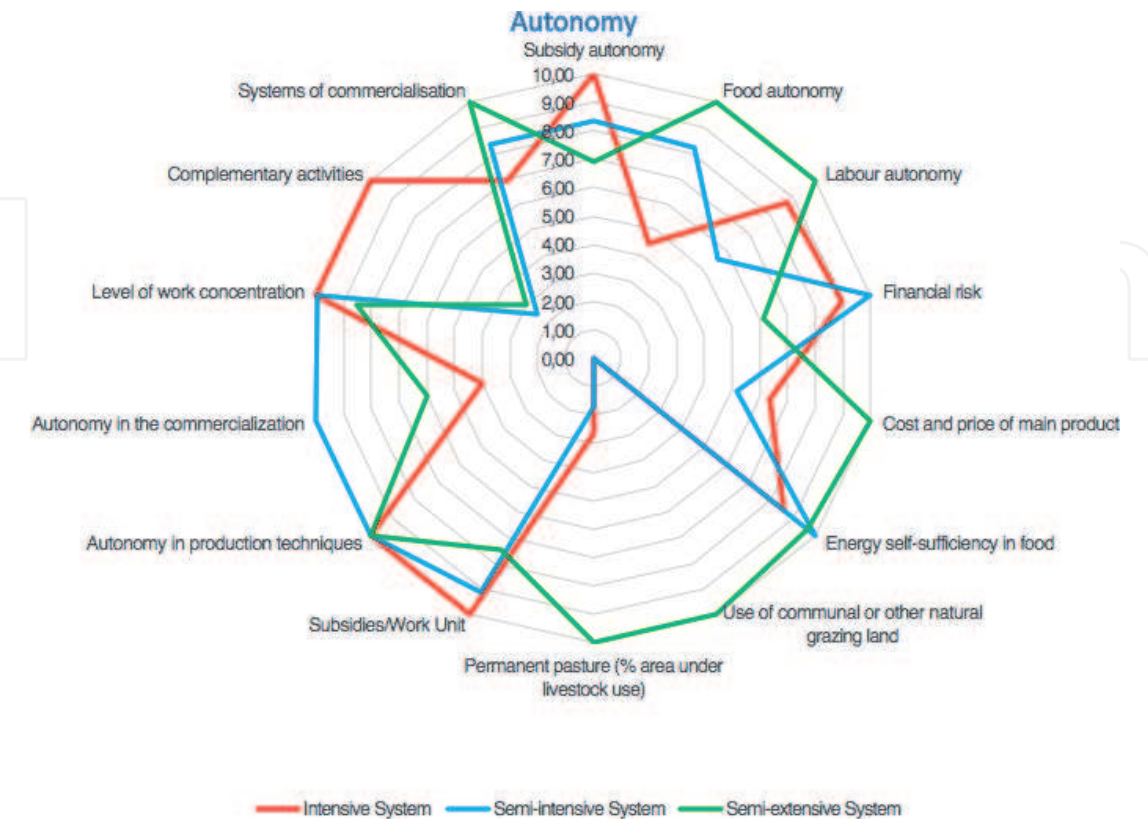


Figure 7.
Autonomy attribute of typified groups.

- They were the farms that used communal and permanent pastures for livestock feeding the most.
- In their marketing, they mostly used cooperative sales or short channels, which should have given them more marketing autonomy, but they did not feel that was the case, as is shown in the corresponding indicator.

Farms in the intensive group were the least independent on aid and subsidies. The process of production intensification produced the most stable distribution of work throughout the year because of the planning of the lambing periods.

The semi-intensive group had the best food energy balance and had the highest perception of autonomy in the management and marketing of their products, even though they were in an intermediate position within the systems they use, which means that they are mostly subordinate to industries and cooperatives. The level of work concentration was similar to that of the intensive group.

Farmers in all groups felt that they had autonomy in making decisions on the techniques and production methods that they used on their farms.

The Equity attribute reflects the social and environmental function of the farm, its commitment to the deterioration of the environment, and the gender perspective in farm management (**Figure 8**).

In the Equity attribute, the semi-extensive group had the one that obtained the best values in 10 of the 15 indicators.

- Semi-extensive farms had high natural value elements.
- They had the best results in carbon footprint per unit of productive factor (land and labor), which allows them to compensate for the poor Productivity attribute.

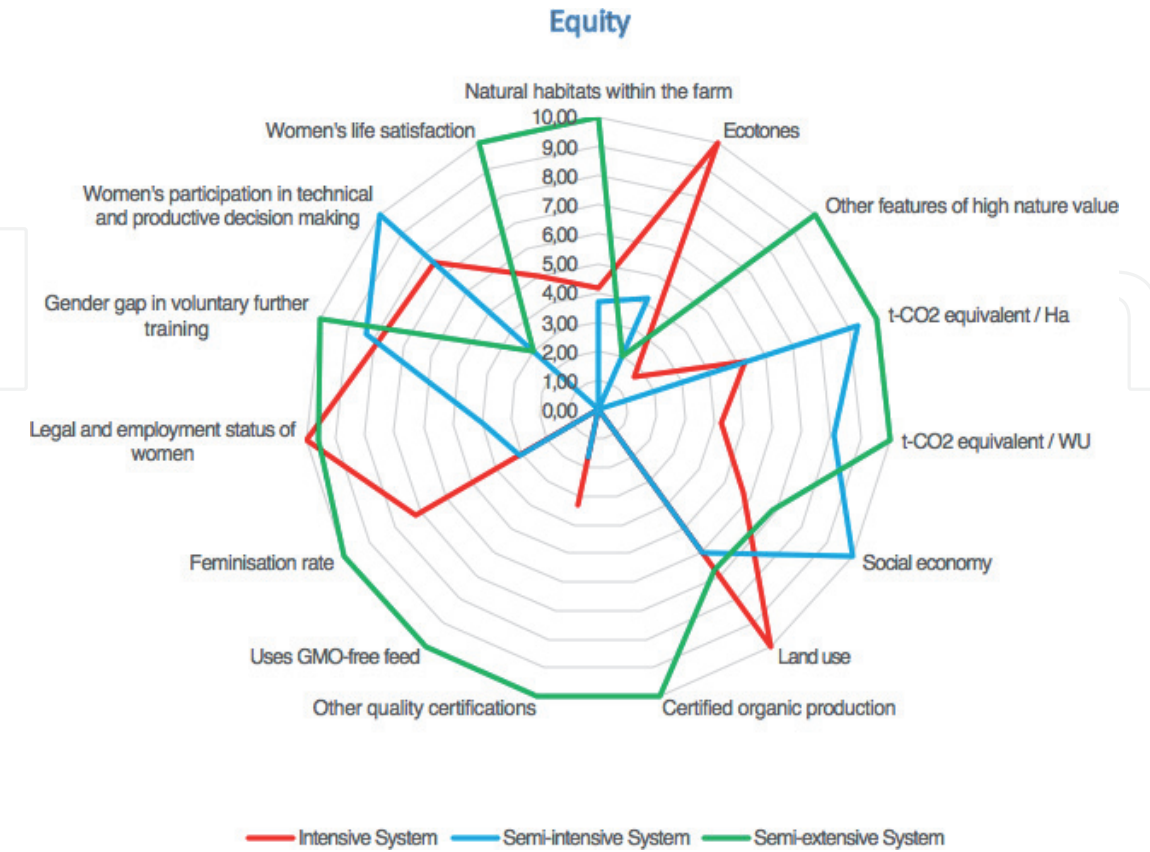


Figure 8.
Equity attribute of typified groups.

- They mostly practiced organic production, which caused them to use genetically modified organism-free food and even have productions with other quality labels.
- The semi-extensive group had the highest rate of feminization in their workforce and there was gender equity in the training processes. Women on those farms are the ones who reported the best life quality.

The intensive group had the most results in the presence of diverse ecosystems in their farms, which gave them a high biological richness, and had the lowest area managed per work unit, which is consistent with the management system to which it refers. In addition, that group had women in the best legal and working conditions, slightly higher than that of the semi-extensive group.

The semi-intensive group stands out because its farms were either associations or farms that had shared ownership, were jointly managed, and shared not only the work on the farm but also the decisions, rights, quotas, and subsidies, and had the highest for the participation of women in the farm decisions.

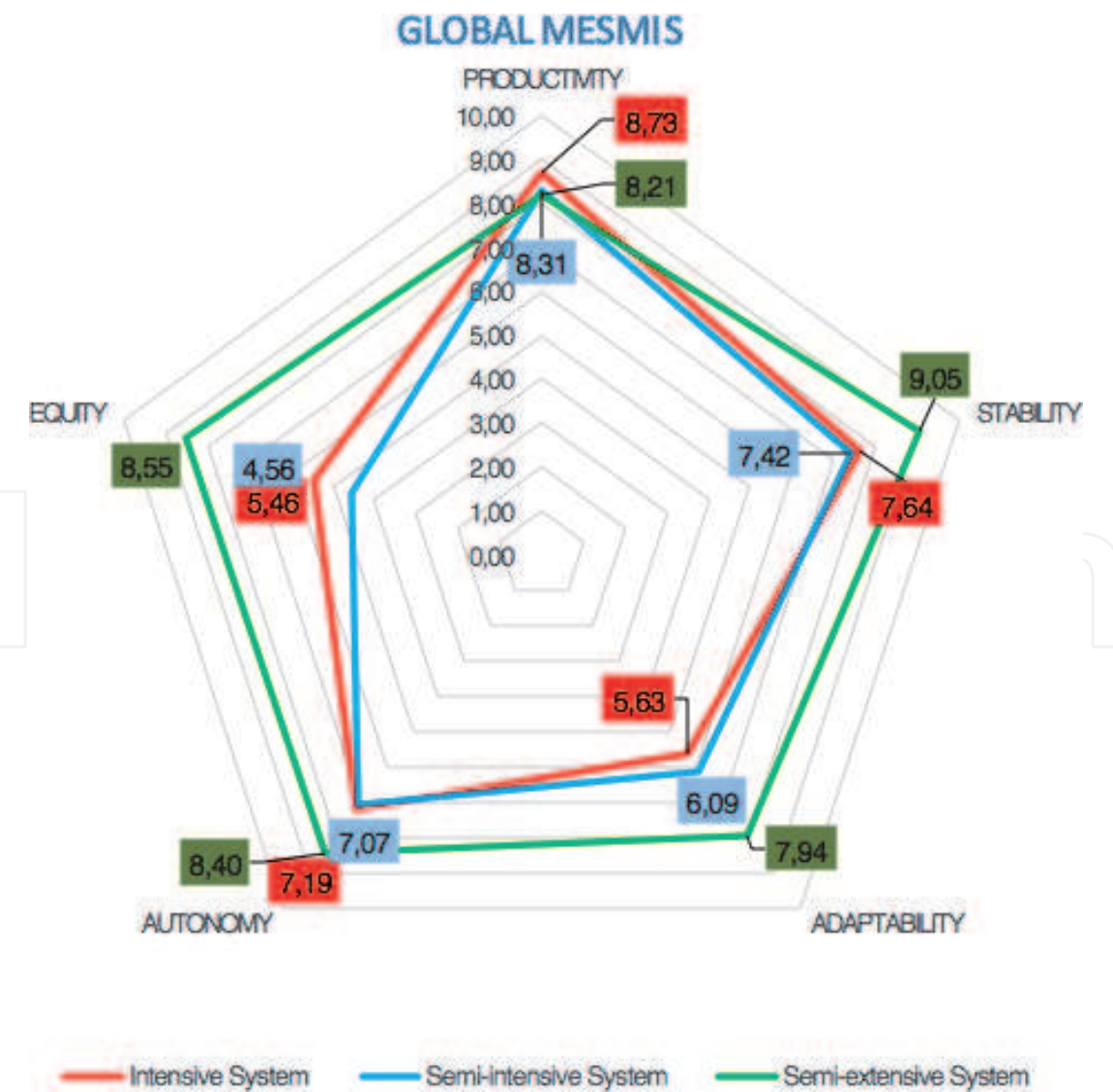


Figure 9.
Global MESMIS of typified groups.

4.2 Global MESMIS of typified groups

The Semi-Extensive group had the best Stability, Adaptability, Equity, and Autonomy, which is reflected in an almost perfect pentagon (see **Figure 9**). The Intensive group had the group with the highest productivity.

From the results, we have drawn the following conclusions:

- **Productivity:** This is the only attribute in which the Semi-Extensive group was penalized. Which is consistent with the existing studies that has confirmed the productivity theory that underlies management closer to intensification of production.
- **Stability:** In this attribute, the Semi-Extensive group has the best values in 10 of the 15 indicators, and scores 9.05 out of 10 at this pentagon vertex. The Semi-Intensive group had the lowest score. The Intensive group had the best scores in seven indicators and, overall, it slightly exceeded that of the Semi-intensive group, but was some distance from the Semi-extensive group.
- **Adaptability:** The Semi-Extensive group had the highest overall score (7.94) and had the highest value in four indicators. The Semi-intensive (5.63) and Intensive (6.09) groups had much lower scores. These poor results which compromised the possibilities of finding new balances that will maintain their productive capacity vis a vis of external changes.
- **Autonomy:** The number of indicators in which the maximum was reached was very homogeneous among the groups. Overall, the Semi-Extensive group had the highest score (8.40). This data determines, which indicates that this group has the one that shows the highest capacity to control interactions with the outside world based on its priorities, objectives, and endogenous values. The other two groups had very similar scores (7.07 and 7.19).
- **Equity:** The Semi-Extensive group had the highest overall score (8.55), and was placed in the highest value in 10 indicators. The other two groups had very similar scores; the Semi-intensive group did not achieve a satisfactory score and the intensive group exceeded it slightly. Thus, the Semi-Extensive group was the most responsible in inter- and intra-generational terms, which indicated greater continuity between present and future.

4.3 Global statistics of typified groups

The results of the statistical assessment of the similarities in the behaviors of the three management systems regarding the indicators of each attribute are presented in the appendix tables. The equity attribute consists of 11 indicators, for the statistical analysis these have been reduced to six by eliminating the dichotomous indicators. Thus the indicators incorporated for the statistical analysis are: Natural habitats within the farm; Other features of high nature value; t-CO2 equivalent/Ha; t-CO2 equivalent/WU; Land use; Feminisation rate.

Table 8-appendix presents the results of the normality test. Equity is the attribute that presents a normal distribution ($p > 0.05$), so the t-test is used to check for similarities or discrepancies in the indicators that make up this attribute.

For the attributes of productivity, stability, adaptability and autonomy, the null hypothesis was rejected ($p < 0.05$), which determined the need to opt for the

non-parametric H test to detect possible divergences in the behavior of the three systems analyzed.

The results of the H-test for the four attributes (**Table 9**-appendix) are summarized in **Figure 10**, the main differences detected per attribute are:

- Adaptability attribute: this attribute presents 63% of differential indicators, which are directly related to management of autochthonous breeds, hardness in the work; diversification of customers; average annual stocking rate (Livestock Unit/ ha Cultivable Area); Sustainable management of the cultivable area; autochthonous race; hardness of work (farmer’s opinion) (Absence of hardness in the work).
- Productivity attribute: 25% of the indicators show a differential behavior, and logically linked to the productive structure of the farms: importance of structure over production; receiving area of organic matter (% CU) and t-CO2-Equivalent / kg. Milk.
- Stability attribute: two differences detected in the indicators “importance of costs with volatility risk” and “grazing”, representing 13% of the total indicators of the attribute.
- Autonomy attribute: the differential behavior is detected in the food autonomy indicator, which represents 7% of the total indicators of this attribute.

In short, the main differences are detected in indicators clearly related to the characteristics of each management system.

The results of the t-test (**Table 10**-appendix) for the indicators of the equity attribute show that the main differences are in the indicators related to sustainability, e.g. t-CO2 equivalent/Ha. The rest of the differences between management types are in issues related to gender and social involvement of the farms, which undoubtedly opens a positive way towards the concept of sustainability from a social perspective.

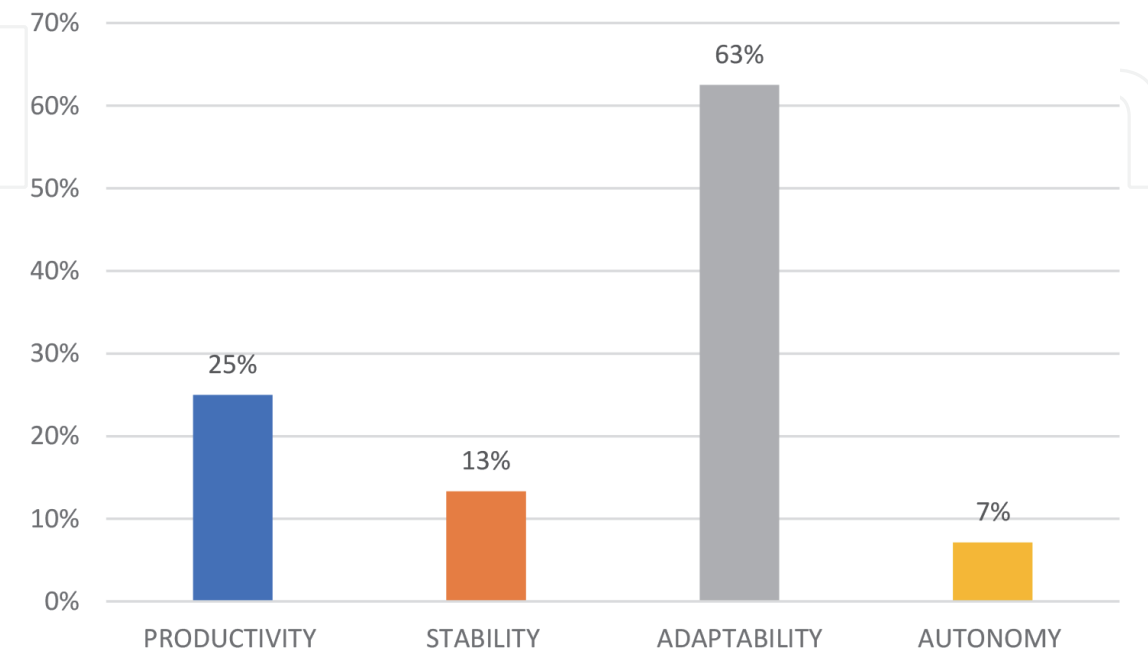


Figure 10.
Indicators for each attribute that had differential behavior (%).

The results of **Figure 9** are reflected in **Figure 10**, which statistically validates the results of the MESMIS method.

5. Conclusions

The attribute information shows that the production units of the most intensive system were the most productive. That said, the Semi-Extensive system performed well, and had an overall score of 8.21. That group was more sustainable than were the intensive systems in all attributes, especially those related to stability, adaptability, and equity.

The Semi-Extensive system responds most comprehensively to the maintenance of a living, articulated, and sustainable natural and rural environment. After the application of the proposed methods, it can be concluded that the initial typification, which was based on seven management indicators, is valid, because three groups that have very specific behaviors have been defined and confirmed by previous studies and experience.

Extensive livestock farming has characteristics [13] that were reflected in the indicators in our study:

- Extensive farming produces high-quality food products; e.g., the analysis of milk quality.
- It allows the use and preservation of ecosystems of high ecological and environmental value, such as “dehesas” and mountain pastures, which is reflected in the environmental indicators.
- It takes advantage of areas such as fallow land, stubble, mountain pastures, and grazing wasteland, which would be difficult to make better use of, which is reflected in the land use indicators.
- In areas that have arid or semi-arid climates, sheep, through traditional practices (grazing, “redileo”), make a contribution to increasing organic matter and preserving the vegetation cover of the poorest soils.
- It contributes to mitigating climate change and promotes branch grazing by the herd, which is an effective means of controlling shrub proliferation and preventing fires.
- It contributes to fixing the population and maintaining the social network in large regions that lack any other possible productive alternatives because of the difficult nature of the environment, which is reflected in the social indicators.
- Other local economic sectors derive directly or indirectly from its activity; e.g., food processing industries, handicrafts, tourism, and hotels, which depend on the maintenance of the landscapes and ecosystems that extensive livestock farming promotes, in addition to the products generated directly.
- They are the only feasible and productive activity that can sustain the important diversity of livestock breeds that are still preserved in southern Europe, which is reflected in the indicator of native breeds.

- This is the most ethical way to manage livestock because it allows the animals to experience a situation of semi-freedom in the open air, respecting the growth rate and living conditions of each species, which is reflected in the grazing ratios.
- It is a very adequate management for the resources derived from the environmental benefits it generates, which are reflected in the energy balances.

Collectively, that information indicates that this is one of the few productive human economic activities that can be truly sustainable. All of those characteristics make it necessary to treat each system individually, and to propose specific measures to promote this type of activity, which renounces some of its profitability for the sake of improving the common good; it must be economically assessed for the positive externalities it generates and its intra- and intergenerational commitment must be rewarded.

The structure of the farms and their relationships with the environment and the surrounding community are essential for the development of their activity and help in solving problems and the self-management of the productive unit because they allow the exchange of information and knowledge, the support management, and training. Generally, an increase in organizational capacity and a greater adaptation of economic, social and environmental structures would be desirable to encourage a transition towards more sustainable management.

6. Proposals for the management systems

Based on an individual analysis of each attribute the following improvement proposals are suggested:

6.1 Productivity

The Semi-Extensive group had the worst economic indicators that involve Net Margin, but not with those that involve Gross Margin, which suggests that this group has to adapt its fixed costs and the structure size to the economic dimension of its income, and especially to the size of its herds, because it is smaller than they are for the other two productive groups. Intensive farming seems to have a cost structure that is adequate for the economic dimension of its activity, even though this type of management requires more investment, but, in the cases studied, it seemed to be appropriate for the real needs of the herd.

In the case of the environmental indicators, the intensive and semi-intensive groups should make the necessary adjustments to increase their sustainability in this attribute. Intensification processes use environmentally unsound practices. Those types of farms depend on distant resources, which increases the carbon footprint and the energy costs needed for their activity. That said, because their output

Systems	Intensive	Semi-Intensive	Semi-Extensive
Kg CO2/ Ha	37.720,45	6.706,59	1.633,57
Kg CO2/ Work Unit	221.619,65	136.909,93	96.763,76
kg CO2/l Milk	1,90	2,56	4,40

Table 5.
Carbon footprint of the different systems.

volumes are much higher, their carbon footprint per unit produced or per net margin is lower; however, in the context of other types of variables such as Work Units or has handled, the results are very different (see **Table 5**) and indicate a need to transform their production methods.

6.2 Stability

In this attribute, the Semi-Intensive group had the worst results, both in social and animal welfare indicators, which suggests that farms in this group need to reconfigure management structure and work structure towards a model that provides a more adequate temporal horizon.

6.3 Adaptability

In this attribute, the intensive group has seriously jeopardized the diversification of its clients, and is extremely vulnerable to fluctuations in it. In UAA and breed management, changes are much more difficult because of the structure of its management system; however, if this idea is combined with Stability regarding the indicator that reflects the opinion of the farmer about life quality, in which the Semi-Extensive group approaches the maximum, it can be concluded that this more intense work does not reduce the quality, so the effect is relativized, although this does not diminish the need to lighten the workload. In addition, farms in the Semi-Intensive group must revise training to incorporate advances that improve farm management.

6.4 Autonomy

The aggregate results are similar. The Semi-Extensive group needs to improve its economic structure; in this case, financial risk and dependence on subsidies are the critical points. The Intensive group needs to improve its marketing systems by expanding its sales channels to allow greater independence and process management. Finally, both this and the Semi-Intensive groups have the option to improve the food sustainability of the farm by their use of pastures.

6.5 Equity

The Semi-Extensive group had excellent results, but the other two groups must make a significant improvement in this attribute, especially in gender-related issues and the women's perception of the satisfaction they derive from the work they perform on the farm.

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Appendices

(**Tables 6, 7, 8, 9 and 10.**)

1.-Productivity	2.-Stability	3.- Adaptability
1. Net Margin/Family AWU*	13. Structure importance on LSU	28. Production diversification
2.Labor income/AWU	14. Importance of costs with volatility risk	29. Client's diversification
3. Net Margin/liter	15. Nitrogen quantity from the excrement (kg N/ha UAA)	30. Average annual stocking rate (LSU/ ha. UAA)
4. Gross margin without subsidies/sales	16. N efficiency	31. Sustainable management of the UAA
5. Importance of the structure on the production	17. P2O5 efficiency	32. Local livestock breeds
6. Temporal pasture (% of land for livestock use)	18. Capacity of slurry pits and manure pits	33. Energetic efficiency. Direct energy
7. Phytosanitary pressure (has treated/has. de UAA)	19. Professionalism	35. Training activities participation
8. Land provided with organic matter (% UAA)	20. % AWU < 40 years	36. Hardness of the work (farmer's opinion) (Absence)
9. Total energy efficiency (Direct+Indirect energy)	21. Continuity	
10. t-CO2-Equivalent / Net margin	22. Family agriculture (%Family AWU)	
11. t-CO2-Equivalent / kg milk	23. Free time availability	
12. Liters required for Reference Rent	24. Farmer's assessment of life quality	
	25. Frequency of livestock visits	
	26. Regarding grazing	
	27. Regarding stabling	

Table 6.
NAIA-MESMIS correspondence.

4.- Autonomy	5.-Equity
37. Subsidies autonomy	51. Natural habitats within the farm
38. Feeding autonomy	52. Ecotones
39. Labor autonomy	53. Other elements of high natural value
40.Financial risk	54. t-CO2-Equivalent / Ha
41. Cost and Price of the main product	55. t-CO2-Equivalent / AWU
42. Feeding autonomy	57. Social economy
43. Use of common or other natural pastures	58. Land occupation (SPG/AWU)
44. Permanent pasture (% area under livestock use)	60. It makes certified organic production
45. Subsidies dependence/autonomy	61. It has other quality certifications
46. Autonomy in production techniques and modes of production	62. It uses GMO-free feed
47. Autonomy in product marketing	56. Feminization index

4.- Autonomy	5.-Equity
48. Level of work concentration	63. Legal and labor situation of women
49. Complementary activities	64. Gender gap in volunteer continuing education
50. Commercialization method	65. Women's participation in technical-productive decision making
	67. Degree of women's life satisfaction

Table 7.
 (bis): NAIA-MESMIS correspondence.

Semi-intensive (n1 = 6);Intensive (n2 = 6); Semi-Extensive (n3 = 5)	
Attribute	Shapiro-Wiks
Productivity	W = 0.758 (p = 0.001)
Stability	W = 0.709 (p = 0.000)
Adaptability	W = 0.880(p = 0.032)
Autonomy	W = 0,648 (p = 0,000)
Equity	W = 0,916 (p = 0,127)

Table 8.
 Normality test.

PRODUCTIVITY	H (Kruskal-Wallis)	p-value
Importance of structure over production	8,459	0,015
Receiving area of organic matter (% CU)	10,908	0,004
t-CO2-Equivalent / kg. milk	8,348	0,015
STABILITY	H (Kruskal-Wallis)	p-value
Importance of costs with volatility risk.	7,607	0,022
Grazing	7,138	0,028
ADAPTABILITY	H (Kruskal-Wallis)	p-value
Diversification of customers	7,183	0,028
Average annual stocking rate (Livestock Unit/ ha Cultivable Area)	12,084	0,002
Sustainable management of the cultivable area	7,022	0,030
Autochthonous Race	12,041	0,002
Hardness of work (farmer's opinion) (Absence of hardness in the work)	8,126	0,017
AUTONOMY	H (Kruskal-Wallis)	p-value
Food autonomy	9,613	0,008

Table 9.
 H-test for productivity attribute indicators.

	t	p-value
Semi-intensive/ Intensive		
t-CO2 equivalent / Ha	−2,805	0,019
Land use	2,706	0,022
Semi-intensive/Semi-extensive		
Natural habitats within the farm	−4,393	0,002
t-CO2 equivalent / Ha	3,987	0,003
Feminization rate	−2,940	0,016
Semi-extensive/Intensive		
Natural habitats within the farm	−3,527	0,006
Other features of high nature value	−4,523	0,001
t-CO2 equivalent / Ha	2,968	0,016
t-CO2 equivalent / WU	3,089	0,013

Table 10.
t-test for equity attribute indicators.

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