Research Article
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Sustainability of livestock production systems in the high jungle of Peru

Abstract

The sustainability of livestock production systems in the districts of Oxapampa, Chontabamba and Huancabamba, Oxapampa Province, Pasco Region, Peru was studied. The methodology used was the MESMIS. For the characterization of the livestock systems, the producers were grouped into three groups: traditional extensive livestock system, semi-extensive livestock system and extensive livestock system. In the first instance, the environmental sustainability, economic sustainability and social sustainability with their respective indicators were partially evaluated, to later evaluate it in a comprehensive way through IGS (general sustainability index) and finally to corroborate the grouping of producers, through the analysis agglomerative hierarchical cluster. Through the MESMIS analysis, the traditional extensive livestock system was the most sustainable in the environmental, economic and social dimension, obtaining the highest IGS. Subsequently, the same producers with their environmental, economic and social indicators were subjected to the agglomerative hierarchical conglomerate analysis, there is a cluster with the same selected producers, in the framework MESMIS, which are part of the traditional extensive system.

Keywords: MESMIS, system, agglomerative hierarchical cluster

Volume 7 Issue 4 - 2022

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Received: October 18, 2022 | **Published:** October 27, 2022

Introduction

The problems in livestock production systems have changed their economic situation in the study area of the districts of Oxapampa, Chontabamba and Huancabamba, located in the Province of Oxapampa, Pasco Region, considered as the high jungle or jungle fringe of Peru. According to INEI,[1] these have registered an agricultural PEA of 75.5%, 71.2%, 53.5% and 59.6%, during the years 1972, 1981, 1993 and 2007, respectively. This record of decrease may be due to cumulative factors such as the introduction of passion fruit cultivation, urbanization of areas where livestock systems existed, increase in degraded areas, etc.

The studies that have been carried out on the agricultural situation of the districts and/or provinces of Oxapampa are based almost specifically on the economic part or a specific approach to a crop or animal, unilaterally and not comprehensively. But the development of a people is not necessarily synonymous with economic growth, rather this is only one of the means to achieve development.

In the study area, according to our research, three livestock production systems can be characterized: traditional extensive livestock production system, extensive livestock production system, semi-extensive livestock production system. However, changes are becoming more noticeable in the structure of these livestock systems, with some systems noticing that livestock activity is ceasing to be their main economic activity and in other livestock systems, such as the traditional one, it is becoming extinct. For this reason, it is appropriate to carry out an evaluation of the sustainability of these livestock production systems, and based on the results, be able to make recommendations in university research, projects and District, Provincial and Regional agricultural plans so that the sustainability of livestock production systems have a balance in the dimensions of sustainability: environmental, economic and social.

The general objective of this research was to evaluate the sustainability of livestock production systems in the districts of Oxapampa, Chontabamba and Huancabamba, Oxapampa Province, Pasco Region. The specific objectives were: to evaluate the sustainability (environmental, economic and social) of the livestock production systems in the districts of Oxapampa, Chontabamba and Huancabamba, of the Province of Oxapampa through the MESMIS framework, as well as to corroborate the grouping of the producers, through the agglomerative hierarchical cluster analysis of the different production systems in the districts under study previously identified with the MESMIS framework.

Since the MESMIS program was created (1995) in Mexico, and Masera et al.[2] published the MESMIS framework, this methodology in the theory of complex systems and socio-ecological systems provides the basis for studying the sustainability of natural resource management systems.[3] To date, no research on the sustainability of livestock systems in the jungle has been reported in Peru, but they are focused on agricultural systems or specific crops, such as what was done with agricultural farms (cocoa, coffee, and fruit trees) with Merma et al. (2012), in traditional agricultural production in the sierra with Barreto et al.,[4] in cassava cultivation with Meza & Julca,[5] in plate and mandarin with Collantes et al.,[6] in quinoa with Pinedo et al.,[7] in granadilla with Romero et al.,[8] in amaranth with Mejía-Valvas et al.,[9] however, at the level of other South American countries, progress has been made in a variety of sustainability studies as mentioned by Astier et al.,[3] that the MESMIS methodology is a tool used internationally, with more than one hundred case studies, which seeks to facilitate the path towards the sustainable development of the territories.

Materials and methods

Study area

The study was developed in the Province of Oxapampa, in the districts of Oxapampa, Chontabamba and Huancabamba, these districts are located at: 10º35'25", 10º34'15", 10º23'00" south latitude, and 75º23'25", 75º30'00", 75º32'00" west longitude, with an altitude of: 1814 masl, 2000 masl, and 1666 masl, respectively (Figure 1).

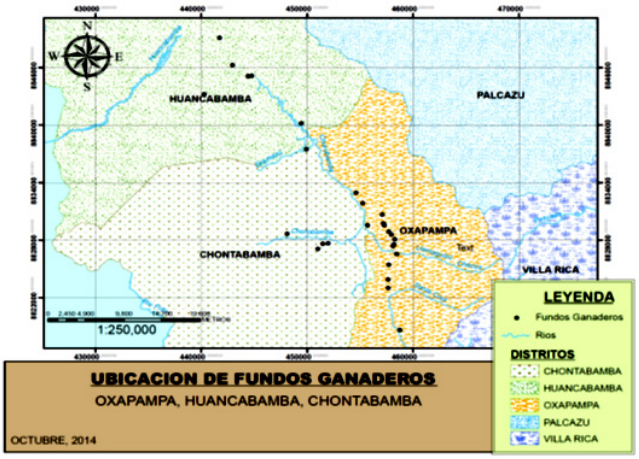

Figure 1 Location of cattle farms in the Province of Oxapampa (Peru).
Source: self-made.

The methodology includes the following steps:

Evaluation of the sustainability of livestock production systems through MESMIS.

The following steps defined by Masera et al.,[2] and complementing Sarandon et al.[10]:

i. Characterization of the systems: According to the Biophysical, technological and socioeconomic management characteristics, three types of livestock systems were determined: traditional extensive livestock production system, extensive livestock production system and semi-extensive livestock production system.

ii. Determination of critical points: Masera et al.,[2] propose the definition of the sustainability attributes mentioned above and affirm in turn that the identification of critical points can be done by asking the key questions: What are the points where the agroecosystem is most vulnerable or presents problems?, and What are the points where it is more robust? According to Alfonso et al.,[11] these critical points can be determined by establishing the weaknesses and strengths of the system, from which indicators will be established.

iii. Selection of diagnostic criteria and indicators: Based on the process shown, the selection of environmental, economic and social indicators of the evaluated livestock systems continued. Likewise, it was complemented with the work carried out by Astier et al.[3]; Perez et al.[12]; Alfonso et al.[11]; Nicoloso et al.[13]

Environmental indicators

Perception of continuity of the producer's system: According to Masera et al.,[3] establishes for the concept of reliability, the capacity of the system to maintain its productivity or profits at levels close to equilibrium, in the face of normal environmental disturbances. The assessment scale used for this indicator was: (4) Positive or with future, (3) Almost optimistic, (2) Fair, (1) A little, (0) Negative. It was adjusted based on expert opinion.

Water accessibility: P Proportion of the population that uses any of the following forms of water supply for drinking: piped water, public intake, protected wells or rainwater (Sedesol, 2004), mentioned by Frausto et al.[14] The assessment scale used for this indicator was: (3) Always, (4) almost always, (2) Only in rains, (1) Less and less, (0) not at all. It was adjusted based on expert opinion.

Soil fertility: Organic matter is important to maintain soil fertility and the good performance of fertilizer use.[15] Since P is a rare element on our planet and essential for life, Tapia et al.[16] The assessment scale used for this indicator was: (4) Very high, (3) High, (2) Medium, (1) Low, (0) Very low. It was adjusted based on the interpretation of soil analysis characterization, from the water, soil, and environment analysis laboratory.[17]

Diversification of main/minor agricultural crops: Productive diversification as a sustainability strategy is useful for the comprehensive development of agriculture, because it captures a set of concerns about agriculture conceived as an economic, social and ecological system.[18] The assessment scale used for this indicator was: (4) Four or more crops, (3) Three crops, (2) Two crops, (1) One crop, (0) No crop. It was adjusted based on expert opinion.

Animal husbandry diversity: Productive diversification as a sustainability strategy.[18] The assessment scale used for this indicator was: (4) Four or more animals, (3) Three animals, (2) Two animals, (1) One animal, (0) No animal. It was adjusted based on expert opinion.

Ability to adapt to environmental and political changes: For Masera et al.,[3] establishes for the concept of adaptation, the ability of the system to find new levels of balance, providing benefits, before long-term changes in the environment. The assessment scale used for this indicator was: (4) As the livestock-agricultural-forestry system is maintained over the years, being that the forestry is also considered important, (3) As the livestock-agricultural system is maintained at Over the years, although forestry is not considered as important as a tertiary complement, (2) As the agricultural-livestock system is transformed into a livestock-forestry-agricultural system, giving it a harmonious sequence with the nature in which it lives, considering that reforestation is essential for the area in which, (1) As the agricultural-livestock system is transformed into a livestock-agricultural-forestry system, considering reforestation as something complementary, although not immediate, (0) As the agricultural it is imposed on livestock over the years, considering reforestation as something tertiary or they do not consider it. It was adjusted based on the opinion of experts and the researcher.

Economic indicators

According to Masera et al.,[3] when analyzing various economic indicators, defines the economic return or net income (utility), as the difference between gross income and costs. This definition is applicable to any agricultural activity such as those mentioned below.

Livestock utility for milk production: The valuation scale used for this indicator was: (4) Very profitable, (3) Fairly profitable, (2) Little profitable, (1) Very little profitable (0) Not profitable. It was adjusted based on the opinion of experts and the researcher.

Livestock profit from the sale of bulls: La escala de valoración utilizada para este indicador fue: (4) Bien rentable, (3) Regular rentable, (2) Poco rentable, (1) Muy poco rentable (0) No rentable. Se ajustó en base a la opinión de expertos y del investigador.

Agricultural utility for passion fruit production: The valuation scale used for this indicator was: (4) Very profitable, (3) Fairly profitable, (2) Little profitable, (1) Very little profitable (0) Not profitable. It was adjusted based on the opinion of experts and the researcher. It was adjusted based on the opinion of experts and the researcher.

Agricultural utility for coffee production: The valuation scale used for this indicator was: (4) Very profitable, (3) Fairly profitable, (2) Little profitable, (1) Very little profitable (0) Not profitable. It was adjusted based on the opinion of experts and the researcher.

Social indicators

Internally generated or family jobs: Sccording to Eguren et al.,[19] in Peru, most of the employment is concentrated in agricultural activities. During the period (2008-2012), of the total number of employed persons in Peru, around a quarter were working in the agricultural sector, according to official figures from the INEI. The assessment scale used for this indicator was: (4) Four workers who are from the family, (3) Three workers who are from the family, (2) Two workers who are from the family, (1) Worker is from the family, (0) None. The scale used by the INEI, population and housing census (2012) was taken as a reference and adjusted based on the opinion of experts.

Production (destination) for consumption of main/secondary livestock products: Livestock production, sheep and cattle, is conserved as far as possible, trying rather to increase it than to sell it. She constitutes the "capital or savings" of the family and is only sold in cases of extreme need. Rather, the by-products derived from it are intended for sale (milk, cheese). The production of eggs, chicken, is destined mainly for sale and some is reserved for consumption.[20] The assessment scale used for this indicator was: (4) Everything is sold, (3) A large part is sold, (2) Approximately half is sold, (1) A little is sold, (0) Nothing is sold (everything consumes). It was adjusted based on the opinion of experts and the researcher.

Production (destination) for consumption of main/minor agricultural products: Regarding the destination of agricultural production, it should be noted that industrial production is destined almost entirely for the market, whether it is taken after transforming it into by-products or not. This is the case of coffee, corn, which is sold almost without further processing. On the other hand, the sugar cane produced by these independent producers goes to the market after being transformed into chancaca and cañazo or aguardiente in the Coast, Sierra and Selva. The by-products are destined mainly for consumption and a small surplus goes for sale to the different markets of the country.[20] The assessment scale used for this indicator was: (4) Everything is sold, (3) A large part is sold, (2) Approximately half is sold, (1) A little is sold, (0) Nothing is sold (everything consumes). It was adjusted based on the opinion of experts and the researcher.

Education level: Highest level of studies completed or in progress, regardless of whether they have been completed or are incomplete, according to EUSTAT.[21] Considered as an indicator of quality of life, it is being measured through studies of both parents and children. The rating scale used for this indicator was: (4) Superior/superior, (3) Secondary/superior, (2) Primary/superior, (1) Secondary/secondary (0) Primary/primary, secondary. It was adjusted based on the scale used by Díaz (2017), and adjusted with the opinion of experts.

Family democratization: According to ENAHO,[22] mentioned by Eguren et al.,[19] the contribution of family farming (AF) to the EAP employed in the agricultural sector in Peru represents 83% of the total number of employed in the sector. 32% highlighting the role of women. The assessment scale used for this indicator was: (4) Father, mother and children, (3) Children, (2) Father and Mother, (1) Father or Mother, (0) none. It was adjusted based on expert opinion.

Technological innovation: According to Martinez et al.,[23] technological innovation, is not the product of a sequential process, but is conceived as a learning system influenced by endogenous and exogenous factors. Therefore, it is about continuous, iterative and gradual processes of gradual problem solving. The assessment scale used for this indicator was: (4) Own, inquiries and IP (public institutions), (3) Own, and IP, (2) Private recommendations and public institutions, (1) Private recommendations, (0) No one. Adjusted based on expert opinion.

Applicability of technology package producers: According to Sánchez et al.,[24] those policies that facilitate the acquisition of new agricultural technologies and that, in addition, offer complementary technologies and training, can make producers not only more likely to adopt new technologies but also make more efficient use of them; thus improving their productivity levels. The assessment scale used for this indicator was: (4) Permanently, (3) Almost always, (2) From time to time, (1) Almost never, (0) Does not apply. It was adjusted based on expert opinion.

Independence of consumption of external inputs: According to Gomero),[18] there are two types of agriculture, peasant and commercial, the latter being characterized by the high use of external inputs, closely linked to the market. The assessment scale used for this indicator was: (4) Average of: % of family consumption, % of animal feed and % of agricultural use is ≤20%, (3) Average of: % of family consumption, % of feed animal and % of agricultural use is ≤30%, >20%, (2) Average of: % of family consumption, % of animal feed and % of agricultural use is ≤40%, >30%, (1) Average of: % of family consumption, % of animal feed and % of agricultural use is ≤50%, >40%, (0) Average of: % of family consumption, % of animal feed and % of agricultural use is > 50%. It was adjusted based on expert opinion.

Self-entry from the agricultural system: According to Eguren et al.,[19] the different types of family farming are distinguished mainly by the quantity and quality of assets available, by their greater or lesser link to the market, by the technologies used and the degree of dependence of the family on income from of the farm itself (differentiation of income). The assessment scale used for this indicator was: (4) >80%, (3) >70%, ≤80%, (2) ≥60%, <70%, (1) ≥50, <60, (0) <50%. Adjusted based on expert opinion.

Institutional dependency: A common characteristic of agricultural banking is that small producers are prioritized because in Latin America poverty is more accentuated in rural areas, the level of competitiveness is low and agricultural credit is limited, Alide.[25] The assessment scale used for this indicator was: (4) None, (3) A little, (2) Regular, (1) Quite a bit, (0) Completely. It was adjusted based on the opinion of experts and the researcher (Table 1).

a. Standardization of the indicators for each dimension: environmental, economic and social: To allow comparison of livestock systems and facilitate analysis, the data were standardized by transforming it to a scale for an indicator from 0 to 4, with 4 being the highest sustainability value and 0 the lowest.[10]

b. Measurement and monitoring of indicators: The average values of the farm indicators were obtained according to each livestock production system to which they belong. Information with which the sustainability graphs were prepared according to the MESMIS framework for the monitoring analysis

c. Weighting of the indicators: In order to obtain the sustainability indicators, the indicators and sub-indicators have been organized for each sustainability dimension using the "multi-criteria type" methodology.[26]

d. Based on the analysis of local conditions and the degree of knowledge of the researcher about the study area, the methodology proposed by Sarandón et al.[10] referring to the description of sub-indicators and their units of measurement and the weight of the indicators, which is reflected in the final formulas (Table 2).

The value of each macro indicator is a quotient whose numerator is the weighted sum of indicators and sub-indicators and the denominator

is the number of variables taking into account their weighting. Finally, with the data from the macro indicators, the general sustainability index is calculated, valuing the three dimensions equally:

General Sustainability Index (GSI)=(EI+EcI+ SI)/3

Terms:

A. To consider a farm as sustainable, the General Sustainability Index (ISGen) must be greater than 2

B. None of the three dimensions evaluated should have a value less than 2.[10]

Table 1 Table of indicators and sub-indicators

Environmental dimension (ED)	Dimension economic (DE)	Dimension social (DS)
A.- Perception of continuity of the producer's system	A.- Livestock utility	A.- Family sustainability
B.- Soil conservation	A1. Livestock utility in milk production	A1.- Internally generated or family jobs
B1.- Access to water	A2.- Livestock profit from the sale of bulls	A2.- Education level
B2.- Soil fertility P (ppm)	B.- Agricultural utility	A3.- Family democratization
B3.- Soil fertility MO (%).	B1. Agricultural utility for coffee production	B.- Production destination
C.- Productive diversity	B2. Agricultural utility for passion fruit production	B1.- Production for sale of main livestock products
C1.- Diversification of main agricultural crops		B2.- Production for self-consumption of secondary livestock products
C2.- Diversification of secondary agricultural crops		B3.- Production for sale of main agricultural products
C3.- Diversity of raising minor animals		B4.-Production for self-consumption of secondary agricultural products
D.- Ability to adapt to environmental, economic and political changes		C.- Technological innovation
		D.- Applicability of technology package producers
		E.-Independence of consumption of external inputs
		F.-Self-income from the agricultural system
		G.- Institutional Dependency

Source: self made

Table 2 Weighting table of the sustainability indicators

$$\text{Environmental Indicator } (\text{EI}): \frac{A + 2\left(\left(2B1 + B2 + B3\right)/4\right) + 2\left(\left(C1 + C2 + C3\right)/3\right) + D}{6}$$

$$\text{Economic Indicator } (\text{EcI}): \frac{2\left(\left(2A1 + A2\right)/3\right) + \left(B1 + B2\right)/2}{3}$$

$$\text{Social Indicator } (\text{SI}): \frac{\left(A1 + A2 + A3\right)/3 + \left(B1 + B2 + B3 + B4\right)/4 + B5 + B6 + B7 + C + D}{7}$$

$$\text{General Sustainability Index } (\text{GSI}) = \left(EI + EcI + SI\right)/3$$

Source: self-made

Exploratory analysis of livestock production systems through multivariate analysis

Through the agglomerative hierarchical cluster method, using the sample of producers and their environmental, economic and social indicators, it was sought to naturally conglomerate the producers of the livestock systems, where each group is a homogeneous producer among themselves and between each group of producers there will be heterogeneity. Using the Euclidean distance as a measure of similarity with the following clustering methods: average or intergroup linkage (between groups), intragroup linkage (within group), nearest neighbor. Likewise, the squared Euclidean distance measure of similarity was used with the following clustering methods: median clustering, centroid clustering, and Ward method.

Through the SPSS program, the unique solution of three numbers of clusters was used, because in the MESMIS framework there are three livestock systems under evaluation, in order to compare the results if the same producers grouped in the MESMIS framework are in the clusters of the multivariate analysis.

Results and discussion

Sustainability assessment of livestock production systems using the MESMIS framework

According to the analysis through the use of indicators, established by Sarandón et al.,[10] it is appreciated that the three livestock production systems are sustainable, having an IGS greater than 2.

Obtaining that the traditional extensive livestock production system has greater sustainability with 2.96, while the other two livestock systems, livestock production system semi extensive and extensive have similar sustainability with 2.32. Likewise, a low variability of 15% can be seen in the general sustainability (GSI) between the livestock production systems. Through these sustainability indicators, greater sustainability and greater variability were found in the indicators that were evaluated in the environmental dimension and social dimension (IA: 2.61, CV: 16%; IS: 2.61, CV: 17%) than in the economic dimension (IE: 2.39, CV: 10%) (Table 3) (Figure 2).

Table 3 Indicators of sustainability of livestock production systems

Productive systems	Environmental dimension	Economic dimension	Social dimension	Sustainability	
	ED	EcD	SD	GSI	Sustainability
Production system Traditional extensive livestock	3.1	2.67	3.11	2.96	Si
Production system Semi-extensive livestock	2.31	2.26	2.39	2.32	Si
Production system extensive livestock	2.42	2.23	2.31	2.32	Si
Average	2.61	2.39	2.61	2.53	
C.V (%)	16	10	17	15	

Source: self-made

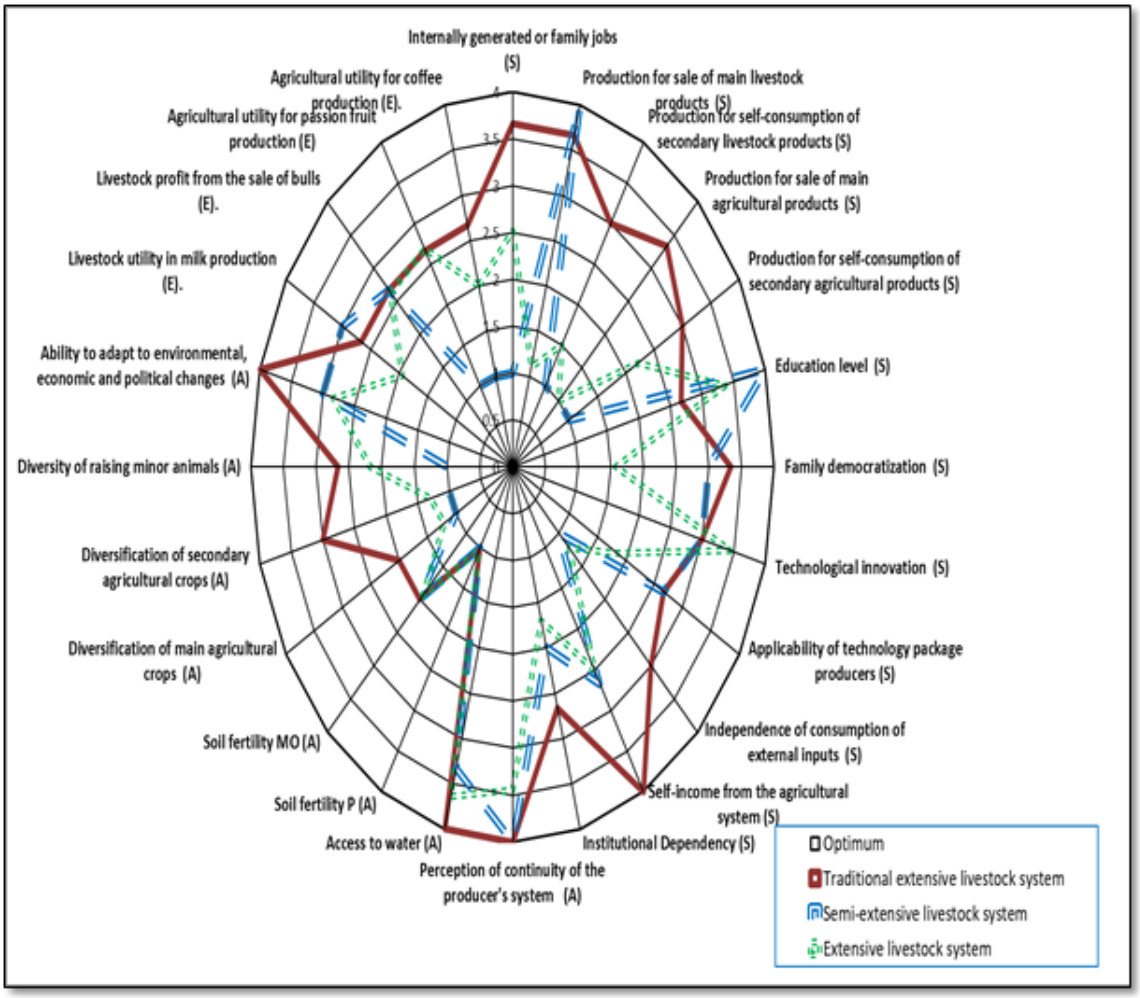

Figure 2 Sustainability result of livestock production systems.

Source: self-made

Exploratory analysis of livestock production systems through multivariate analysis

When performing the analysis with the proximity distance, the Euclidean distance and with the clustering methods: average or intergroup linkage, intragroup linkage, nearest neighbor, a conglomerate was obtained with the same selected producers: Ernesto Frey, Cali Rubio, Eriberto , within the MESMIS framework, which are part of the traditional extensive system. Being this traditional extensive system the one that has obtained the highest general sustainability index (GSI). Likewise, with the proximity distance, the squared Euclidean distance, and with the centroid clustering, median clustering, and Ward method methods, a conglomerate was also obtained with the same producers selected in the MESMIS, which are part of the system. extensive traditional and with the highest GSI (Figure 3).[27,28]

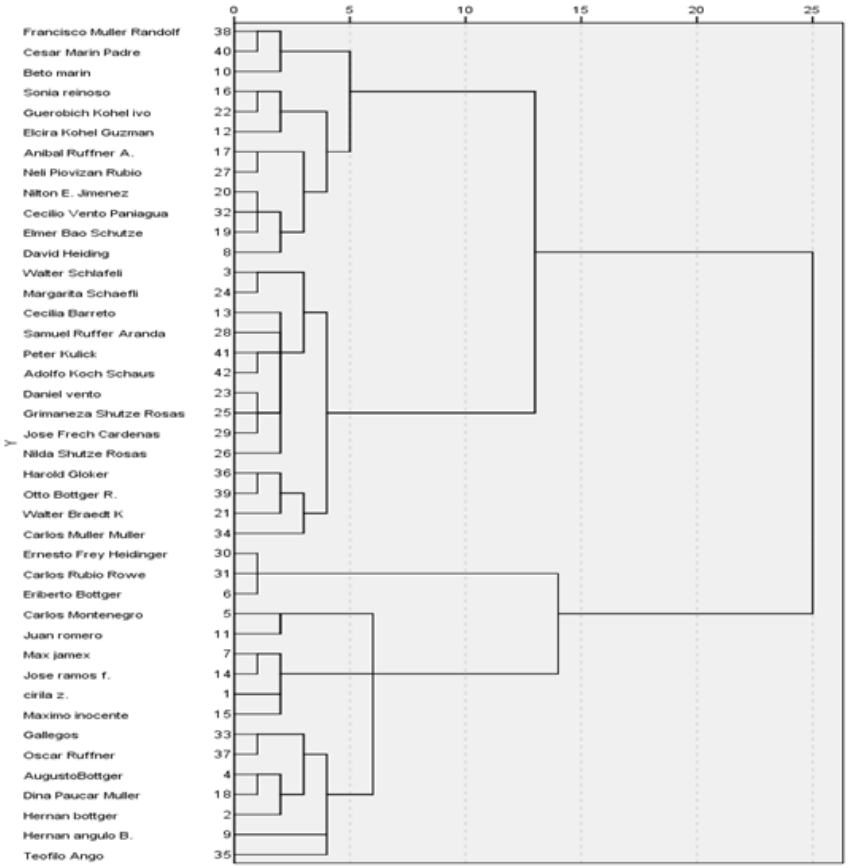

Figura 3 Ward method cluster membership dendrogram.

Source: self-made.

Conclusion

All the livestock systems studied are sustainable, the most sustainable being the traditional extensive livestock system. The variables that define the grouping of livestock production systems are, in the environmental dimension: accessibility to water, diversification of main and secondary agricultural crops, diversity of raising small animals, capacity to adapt to environmental, economic and political changes, perception continuity of the producer system, soil fertility; in the social dimension: jobs generated in the family, production for self-consumption of secondary agricultural and livestock products, family democratization, independence from income outside their agricultural system, institutional dependency, production for the sale of main agricultural and livestock products, permanence of the producers in the technological package; in the economic dimension: profit from the sale of coffee, profit from the sale of milk, profit from the sale of bulls. The result of the agglomerative hierarchical cluster analysis corroborates the grouping of a coincident cluster, whose producers are members of the traditional extensive production system in the MESMIS framework, a production system that has obtained the highest GSI.

Acknowledgments

None.

Funding

None.

Conflicts of interest

The authors declared that there is no conflict of interest.

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Citation: Pizarro ET, Villacorta HS. Sustainability of livestock production systems in the high jungle of Peru. *MOJ Eco Environ Sci.* 2022;7(4):128–134. DOI: 10.15406/mojes.2022.07.00258