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Characterization and typification of small-scale goat production systems in the highlands of southeast Peru

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Goat breeding in Peru is one of the main activities of smallholders. Goats are distributed in different agroecological zones and regions of the country, developing under heterogeneity of production systems, making it difficult to understand goat breeders' socioeconomic, technological, and productive situations. This study aimed to characterize and typify the goat production systems in the highlands of southeast Peru. A survey was conducted with 91 goat farmers from five districts of Ayacucho, Peru, using a structured and individualized questionnaire administered on their farms. The socio-economic, productive, and commercial characteristics of the goat production systems were recorded. A multiple correspondence analysis (MCA) and hierarchical classification analysis (HCA) were performed to establish a typology of the smallholders. The results reveal that the breeding system is extensive, where there is no breeding program, with natural pastures and crop stubble being the source of food for the herds. Only slightly more than half (54%) carry out a deworming program. Farmers were categorized into three different groups, corresponding to three different farming systems: Group 1 farmers raised goats solely for home consumption; Group 2 breeders raised goats for both consumption and marketing of surplus products (cheese, milk, and meat), and Group 3 farmed focused on producing cheese and goat kids and selling to local markets. The study provides valuable insights that will help design effective breeding strategies to develop sustainable goat farming in the region, considering different production systems and their respective socio-economic and trade dynamics. This classification will be essential for tailoring development programs to the specific needs of each group, promoting better use of resources, improving productivity, and enhancing the livelihoods of smallholder goat producers in Peru.

KEYWORDS

Ayacucho, goat, highlands, Peru, production systems

Introduction

Peru has a population of 1,774,523 goats and 95,184 goat farmers mainly in Piura and Ayacucho with 17,246 and 9,743 breeders, respectively (Ministerio de Desarrollo Agrario y Riego, 2021). According to geographic areas, goat farming is developed in the tropical dry forests, and on the outskirts of urbanized areas of the coastal valleys where goats graze stubbles (Sarria et al., 2015). In the highlands and Andean valleys, small goat farmers (<50 heads) practice transhumant systems at certain times of the year (Gómez-Urviola et al., 2016). In goat farming, extensive systems are the most predominated classified as a low-tech and subsistence activity (Arroyo, 2006), where natural pastures and some harvest by-products are the main sources of food (Gómez-Urviola et al., 2016). Thus, it is essential to efficiently improve the production process, maximizing the herd's productivity (Angón et al., 2017). Peru has a relatively low *per capita* consumption of goat meat, averaging only 0.2 Kg per inhabitant per year (Ludeña et al., 2021), due to the limitations for its consumption such as: low promotion of goat meat consumption, poor marketing chain, the lack of knowledge of the nutritional properties, and the dietary habits of Peruvians.

Goat farming plays an important role in small-scale family farming, characterized by having scarce economic resources, especially, those settled in rural areas (Nguluma et al., 2022). Characterizing the goat production systems with technical and non-technical management is the main step in establishing development policies in the livestock sector (Ruiz et al., 2008; Ruíz et al., 2019). Productive units with good management practices stand out for their productive efficiency, proving to be resilient species to the challenges and abrupt changes of the environment, despite the existing heterogeneity between breeders (Mena et al., 2016; Koluman Darcan and Silanikove, 2018). On the other hand, goat farming has contributed to preserving their ecosystems by avoiding forest fires and soil deterioration with controlled grazing (Ruiz-Mirazo et al., 2011; Tumusiime et al., 2022), and is considered a small ruminant with the least impact on climate change due to the low emission of methane (Koluman Darcan and Silanikove, 2018; Organización de las Naciones Unidas para la Agricultura y Alimentación, 2017).

More than 80% of the goat population in Peru is creole goats as a result of continuous crossbreeding with specialized breeds introduced since 1930 (Gómez-Urviola et al., 2016). Despite the low production rates of creole goats, their characteristics, such as rusticity and adaptation capacity, allow them to be maintained in farmers' herds (Villacres Matias et al., 2017; Gómez-Urviola et al., 2016). Therefore, this ruminant might play a relevant role in the future considering climate change scenarios (Organización de las Naciones Unidas para la Agricultura y Alimentación, 2017; Pragna et al., 2018; Koluman Darcan and Silanikove, 2018). However, creole goats have been forgotten by development programs and competent authorities (Laouadi et al., 2018).

Unfortunately, Peru has few reports on the characterization of small-holders' goat production systems (Perevolotsky, 1999), where it is necessary to know and discuss the productive (food, health, and reproduction), social, and cultural factors that would be influencing the production processes (Nampanzira et al., 2015; Gómez-Urviola et al., 2016), and it would help to typify the traditional goat breeding systems as a basis for the sustainable development of goat farming in the country (Sow et al., 2021). The present study aimed to characterize and typify the goat production systems in the southeast highlands of Peru to better understand goat breeders' socioeconomic, technological, and productive situation.

Methods

Description of the study area

Five districts of Ayacucho, Peru were selected (Figure 1), considering their representativeness in the number of goat farmers: Ocaña, Chuschi, Accomarca, Pacaycasa, and Santillana. These districts belong to the highlands of southeast Peru, characterized by large dry areas, mountains, cliffs, and inter-Andean enclaves where animals use shrublands and grasslands, with a rainy season between December and March, and a dry season during May and October. The temperature ranges from 0.1°C in July to 28.7°C in November, with a monthly rainfall of 5.5–154.7 mm (Servicio Nacional de Meteorología e Hidrología del Perú, 2018). The cultivation of cereals (corn, peas, barley, and wheat) and animal husbandry are the main economic activities.

Sample size and data collection

According to Ministerio de Desarrollo Agrario y Riego (2021), the districts of Ocaña, Chuschi, Accomarca, Pacaycasa, and Santillana present a total of 270, 208, 374, 434, and 619 smallholder goat farmers, respectively. A descriptive cross-sectional study was carried out, in which the sample was estimated using a random sampling stratified according to population size. A sampling error of 10% and a 95% confidence interval (1.96) were used.

Questionnaire-based face-to-face interviews were conducted with 91 goat farmers between May and August 2023. The interviews were distributed in agricultural units established in the districts of Ocaña (n = 13), Chuschi (n = 10), Accomarca (n = 17), Pacaycasa (n = 21), and Santillana (n = 30). The survey was primarily made up of closed-ended questions and was organized into four key sections to gather comprehensive information: 1) General information, 2) Socioeconomic data, 3) Productive data,

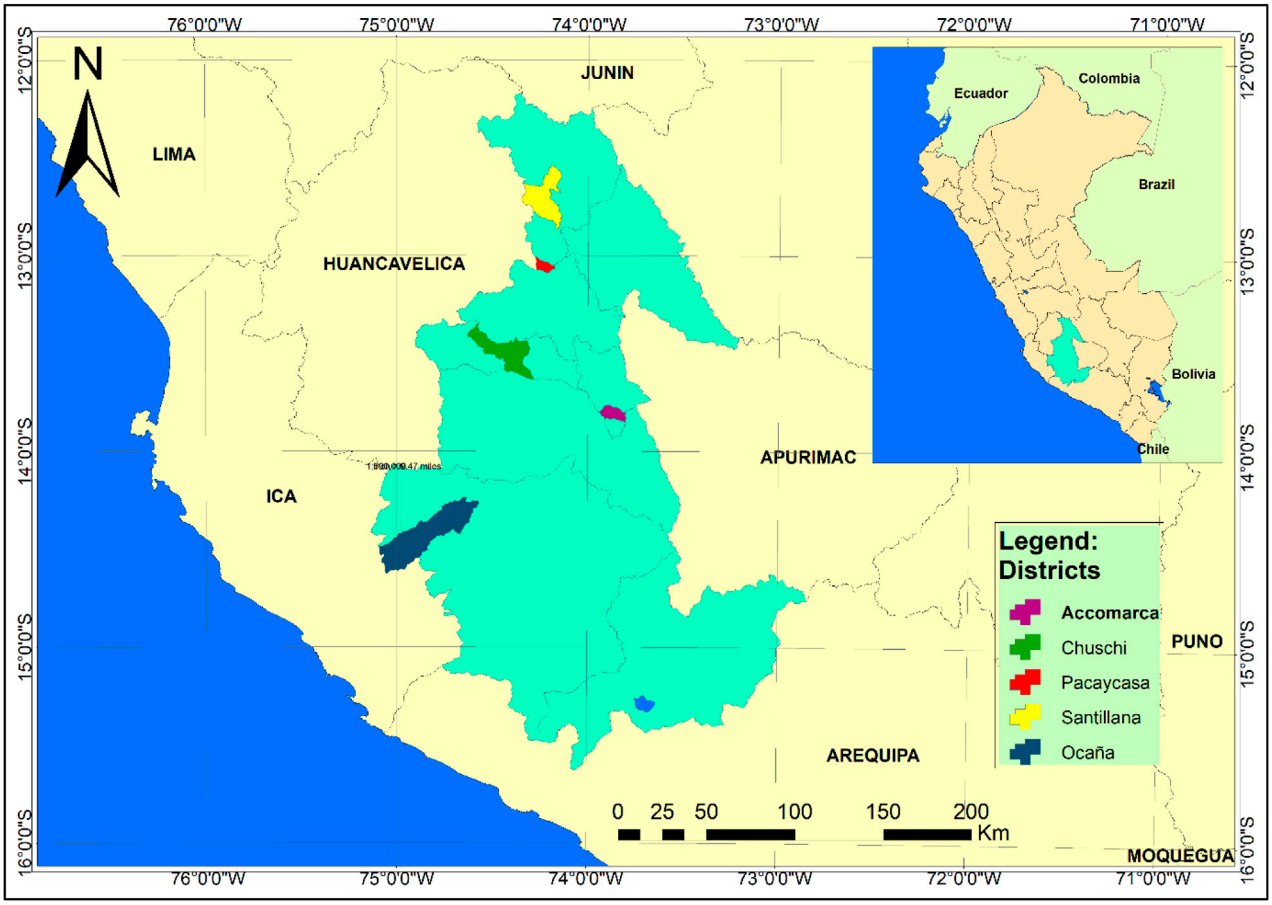

FIGURE 1
Study area of Ayacucho, Peru, indicating the districts covered by the survey.

and 4) Commercialization. The interview was conducted by a professional who perfectly understands the local languages (Quechua and Spanish), to obtain more accurate and concise declaratory information.

With the information obtained, the smallholders were classified as: infra-subsistence farmers, subsistence farmers, intermediate farmers, and remaining farmers according to small-family farming in Peru (SFF) (Organización de las Naciones Unidas para la Agricultura y Alimentación, 2017). This classification was made based on family or nonfamily nature, size or scale, productive orientation, technified breeding, and the extensions of arable land and livestock extensions owned by the farmer.

Statistical analysis

The statistical analysis of all the information was carried out using R Software (version 4.3.1). For characterization, the data were analyzed descriptively based on frequencies by contingency table and percentage. To classify the herds, 15 variables of the questionnaire were chosen, based on their relevance to the herds of small producers, and a multivariate analysis based on multiple correspondence analysis (MCA) and hierarchical classification analysis (HCA) were performed using the FactoMineR package (Lê et al., 2008). The variables chosen for the analysis of MCA and HCA were defined according to the economic, social, and productive factors; which are detailed in Table 1.

The MCA is a statistical data analysis tool used to describe, explore, and summarize, which allows the visualization of the association of a given set of categorical variables in small dimensions (Algañaraz, 2016; Sow et al., 2021). HCA is a multivariate technique that groups elements or treats variables to maximize homogeneity or difference between groups (Vilà-Baños et al., 2014). These methods are often used to analyze questionnaire data (Pagès and Josse, 2014).

The differences between clusters were evaluated using Fisher's chi-square and exact test to assess whether the selected variables had significant differences between groups.

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TABLE 1 Codes for qualitative variables and modalities were included in the multiple correspondence analysis (MCA).

Variables	Code	Modalities
Districts	District	Ocaña
		Chuschi
		Accomarca
		Pacaycasa
		Santillana
Small family farming classification	SFF_class	Infra-subsistence
		Subsistence
		Intermediate
Education level	Edu_level	No schooling
		Elementary, incomplete
		Elementary, complete
		High school, incomplete
		High school, complete
		Higher, incomplete
		Higher, complete
Time as a breeder	Time_breeder	Less than 5 years
		5–10 years
		10–20 years
		20+ years
Income source	Incom_sourc	Crop
		Livestock
		Commerce
		Crop and livestock
Production objective	Prod_object	Milk
		Meat and milk
		Self-consumption
Total Unit Area	Unit_area	0.5 Ha
		0.5–1 Ha
		>1–2 Ha
		>2 Ha
Irrigation system	Irrig_system	Surface irrigation
		technified irrigation
		Without irrigation
Mixed farming	Mix_farm	Yes
		No
Land tenure	Land_ten	Own
		Communal
		Own and communal
Sources of Water	Sourc_water	River
		Irrigation canal
		Drinking troughs
		Others
Litter size	Lit_size	Simple
		Double
Reason for removing animals	Remov_anim	Age
		Health Condition
		Elimination
		Others
Milk production	Milk_prod	1 kg
		1 < 2 kg
Deworming period	Dewor_per	2 times a year
		Once a year
		If necessary
		Not done

(Continued in next column)

TABLE 1 (*Continued*) Codes for qualitative variables and modalities were included in the multiple correspondence analysis (MCA).

Results

It was evident that in southeastern Peru, goat breeding is one of the main livestock activities that are practiced in inhospitable and inaccessible areas, where other production species (cattle, sheep, and camelids) are not found. Most of the producers are older adults who are unaware of good management practices for raising goats. Goats graze extensively without any feeding program, non-existent genetic improvement plan, few producers who manage a deworming program, rustic roosts made of materials from the area (stone, tree branches, and wood) or in the open air, which do not favor animal welfare, and a lack of technical assistance from experts are factors that influence milk and meat production, and indeed marketing.

Socio-economic characteristics

The proportion of interviewees was 66% women and 34% men. The majority of the farmers had completed elementary school (30%), followed by those who completed high school

(20%) and had incomplete high school (18%). It was found that 14% of farmers were illiterate, and only 2% had attended university. Smallholders older than 35 years represented 83% of all the interviewees.

Women were responsible for making decisions about herd management. For smallholders, the main purpose for goat keeping was obtaining milk or meat for home consumption to ensure their food security (44%), and if there was cheese surplus, it was offered to local markets (40%).

Almost half of the farmers were involved in livestock more than 20 years ago (43%), with the priority of improving the genetic quality of their animals to increase milk and meat production. The farmers interviewed stated that they lacked technical assistance.

Production characteristics

Production system

The breeding goat systems were a mixed production system, where 43% of the breeders had less than 0.5 hectares, 33% between 0.5 and 1 hectare, and 4% with more than 2 hectares. The main source of income for farmers was crop production (55%), followed by livestock (31%). It was found that 68% of farmers kept their goats without other species, while 32% were associated with other species such as cattle and sheep. More than half of farmers use their lands for crops (69%), while 29% of them use natural grasslands and only 2% cultivate pastures. Almost half of the breeders (51%) reported that their biggest challenge was a lack of knowledge about good breeding practices, which significantly affected their herds. Herd size was represented by 35 ± 40 animals, categorized as: adult does (45.4%), bucks (2.9%), doelings (17.7%), kids (22.4%), kids post-weaning (7.2%), and wether (4.4%).

Feeding

The feeding was always based on natural resources such as pastures, shrubs, and trees (Table 2), and more than half of the producers (56%) complemented with fodder and hay during the dry season. The sources of water for goats were rivers, ditches, and drinking water. Most breeders grazed their goats in communal areas (74%), 10% of them used their own, and 16% used both areas.

Health

The herds were not monitored by qualified health technicians, and producers lacked a sanitary calendar. Despite this, breeders did perform deworming, with 18% doing it once a year, 24% twice a year, and 1% three times a year, while 46% did not deworm at all. The deworming typically occurs at the start and end of the rainy season.

Productive and milking management

Twenty-eight percent of the breeders carried out castration. Continuous mating was recorded in all herds, using rented males (14%) or males of their herds (70%), where bought within the region (10%), or from outside the region (4%). The majority of the producers tend to perform manual milking in their pens (95%), without any sanitary measures, registering a production of 1 kg of milk per goat during four or 5 months of production (68%).

Sales

Most breeders use their products (milk, cheese, meat, skin, and manure) for self-consumption (80%) and only sell when there are surpluses. Producers who marketed their products did not have a sales record, which is a fundamental tool for economic assessment. More than half of breeders (63%) sold goat kids at four (13%) or 5 months (48%) of age. There was not any type of external financing to which breeders could have access.

Typology

Multiple correspondence analysis (MCA) was applied to 15 variables (Table 1). Each dimension of MCA explained the amount of variation, and only the first two dimensions (17.1% of the total variance) were retained, compared to other dimensions that had few contributions to the total variance (Figure 2).

The MCA was carried out on 15 variables and 54 modalities that contributed to the formation of 2 dimensions. Figure 3 shows the distribution of the herd modalities according to the first (8.8%) and second (8.3%) size. In the first dimension, positive coefficients were cattle ranchers from the districts of Ocaña, Pacaycasa, and Accomarca, who have lands greater than 1 hectare. Their goats graze freely in their own and communal areas; producers aim to produce milk and meat for the market, and with their main source of income besides crops and trade. The negative coefficients were the producers of the districts of Santillana and Chuschi with extensions of lands less than 1 hectare; their breeding objective was for self-consumption, with the eventual sale of milk when there were surpluses. In the second dimension, the positive coefficients are made up of subsistence and middle-class farmers, their main source of income was goat breeding, using milk and meat for sale, and their herds were dewormed 1 to 2 times a year. The negative coefficients are made up of subsistence farmers, the objective of goat breeding was for self-consumption; their main source of income was crops using technified irrigation. Some herds were dewormed when sick, while the “healthy ones” were never treated.

The representation of the variables in dimensions 1 and 2 is shown in Figure 4. The Ocaña goat breeders were better represented, followed by breeders who raised goats for self-consumption, breeders with less than 0.5 hectares of land, herds that drank water from the ditch, and those that were

TABLE 2 List of natural pastures from which goats eat in study areas.

	Herbs	Shrubs	Trees	Cactaceae
Chuschi	*Trifolium* spp. (Wild clover) *Bouteloua curtipendula* (Banderilla) *Bromus catharticus Vahl* (Cebadilla) *Sporobolus indicus* (Kikuyo)	*Acacia macrantha* (Huarango) *Baccharis latifolia* (Chilca) *Colletia spinosissima* J. *Gmelin* (Tacsana) *Otholobium pubescens* (Huallhua) *Opuntia apurimacensis* (Ayrampo)	*Escallonia resinosa* (Chachas)	*Agave americana* L. (Cabuya, penca)
Ocaña	*Trifolium* spp. (Wild clover) *Bromus catharticus Vahl* (Cebadilla) *Sporobolus indicus* (Kikuyo)	*Acacia macrantha* (Huarango)	*Escallonia resinosa* (Chachas) *Kageneckia lanceolata* (Lloque) *Eriotheca vargasii* (Pati)	*Corryocactus brevistylus* (Sanky)
Santillana	*Trifolium* spp. (Wild clover) Ancusa *Bromus catharticus Vahl* (Cebadilla) *Cantua buxifolia* (Qantu, cantata)	*Acacia macrantha* (Huarango) *Baccharis microphylla* (Tayanca)	*Eriotheca vargasii* (Pati) *Kageneckia lanceolata* (Lloque) *Escallonia resinosa* (Chachas)	*Agave americana* L. (Cabuya, penca)
Accomarca	*Trifolium* spp. (Wild clover) *Bromus catharticus Vahl* (Cebadilla)	*Acacia macrantha* (Huarango) *Colletia spinosissima* J. *Gmelin* (Tacsana)	*Polylepis* spp. (Queñua) *Kageneckia lanceolata* (Lloque) *Escallonia resinosa* (Chachas)	*Agave americana* L. (Cabuya, penca)
Pacaycasa	*Trifolium* spp. (Wild clover) *Bromus catharticus Vahl* (Cebadilla) *Bouteloua curtipendula* (Banderilla) *Sporobolus indicus* (Kikuyo)	*Caesalpinia spinosa* (Tara) *Acacia macrantha* (Huarango)	*Escallonia resinosa* (Chachas) *Escallonia myrtilloides* (Tasta) *Kageneckia lanceolata* (Lloque)	*Agave americana* L. (Cabuya, penca)

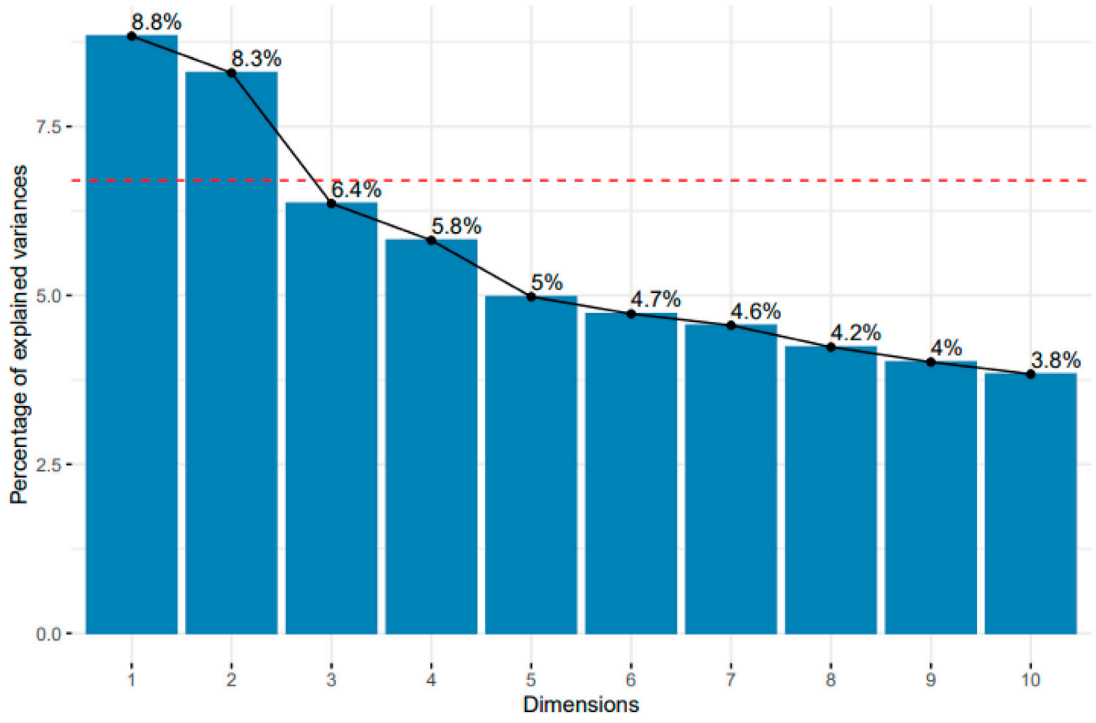

FIGURE 2
Percentage of the contribution of each dimension of the multiple correspondence analysis (MCA) to the total variance.

not dewormed. Breeders who achieved incomplete high school, with 10–20 years of breeding, and those who grazed their herds on communal and their lands, were the ones who had a low representation in dimensions.

The hierarchical classification typed three groups (Table 3; Figure 5). The chi-square test revealed a statistically significant difference between the groups for all variables ($p < 0.001$), except for mixed farming

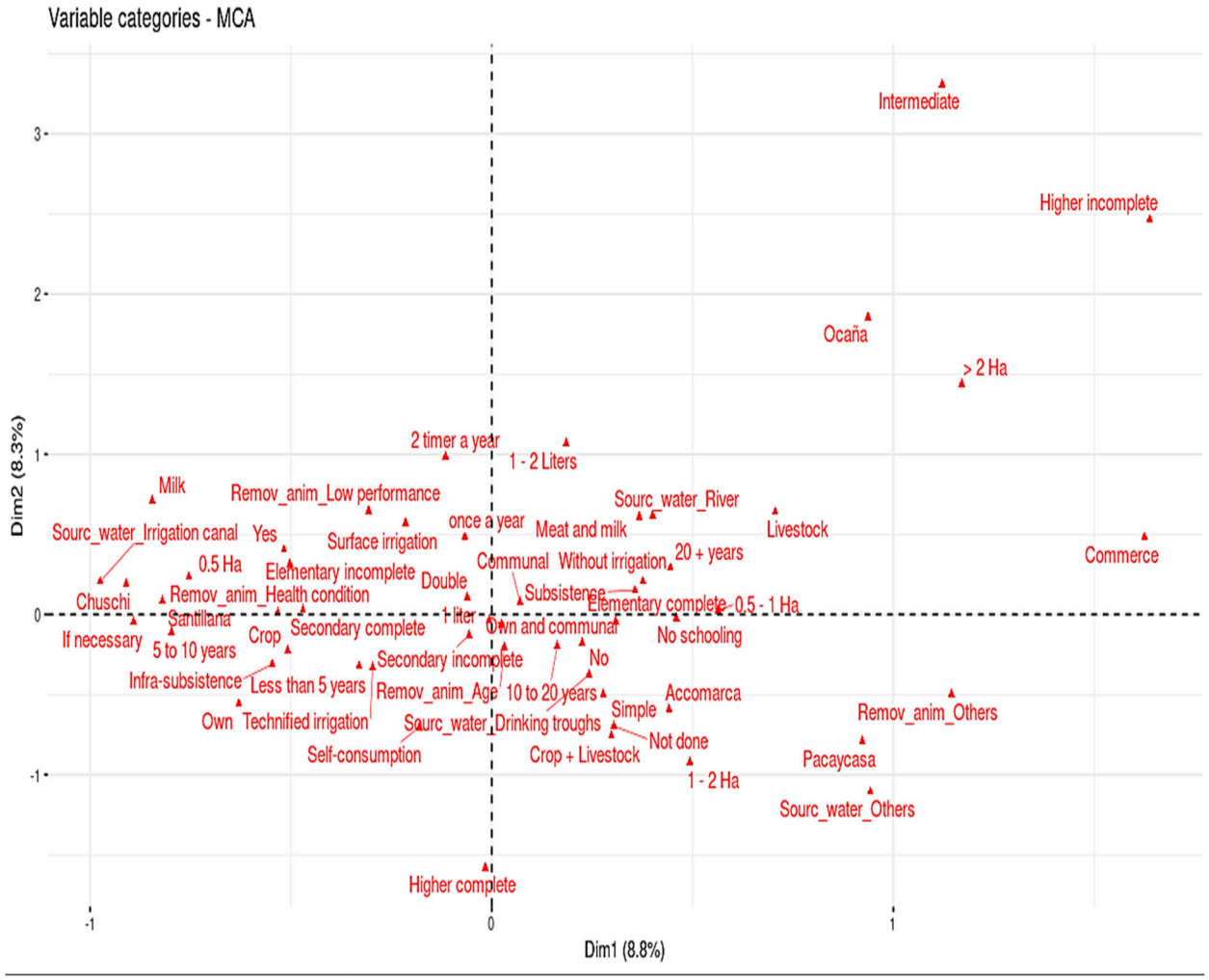

FIGURE 3
Graphical representation of the distribution of modalities for the first (Dim 1) and second (Dim 2) dimensions of the MCA applied to the typology of goat production systems (the meaning of codes is in Table 1).

variables, education level, land tenure, and milk production.

Group 1 (n = 36) was typified as a system in which breeders raised goats only for self-consumption. The Santillana district breeders were classified mainly in this group (83%). According to the SFF classification, more than half of the breeders belong to the subsistence category (58%), with agriculture being their main source of income (89%). Eighty-one percent of the breeders had less than 0.5 hectares of land installed with technified irrigation (67%), The herds drank water from streams (61%), and most of them had twin births (92%). The majority of breeders in this group (71%) dewormed their goats 1 to 2 times a year.

Group 2 (n = 39) was typified as a system in which breeders raised goats for self-consumption and marketing of surplus products (cheese, milk, and meat). This group classified breeders mainly from the Accomarca (44%) and Pacaycasa (44%). Just over half of the breeders in this group were classified as subsistence producers (59%), with agriculture (51%) and livestock (28%) being their main sources of income. In this group, the breeders had larger extensions of land, between 0.5 and 2 hectares (84%), where some had access to water (46%), while others had access to technical irrigation (44%). Herds taken directly from taps with drinking troughs (62%), and more than half (67%) had twin births. Most of the breeders (74%) did not deworm their herds.

Group 3 (n = 16) was typified as a system in which the goat plays a major role in the economic livelihood of the breeders. This group consisted mainly of breeders from the Ocaña district (69%). Most breeders were in the subsistence category (88%), with goats as their main source of income (81%). The breeders kept the goats to produce cheese and goat kids. Twenty-five percent of the breeders had land extensions greater than

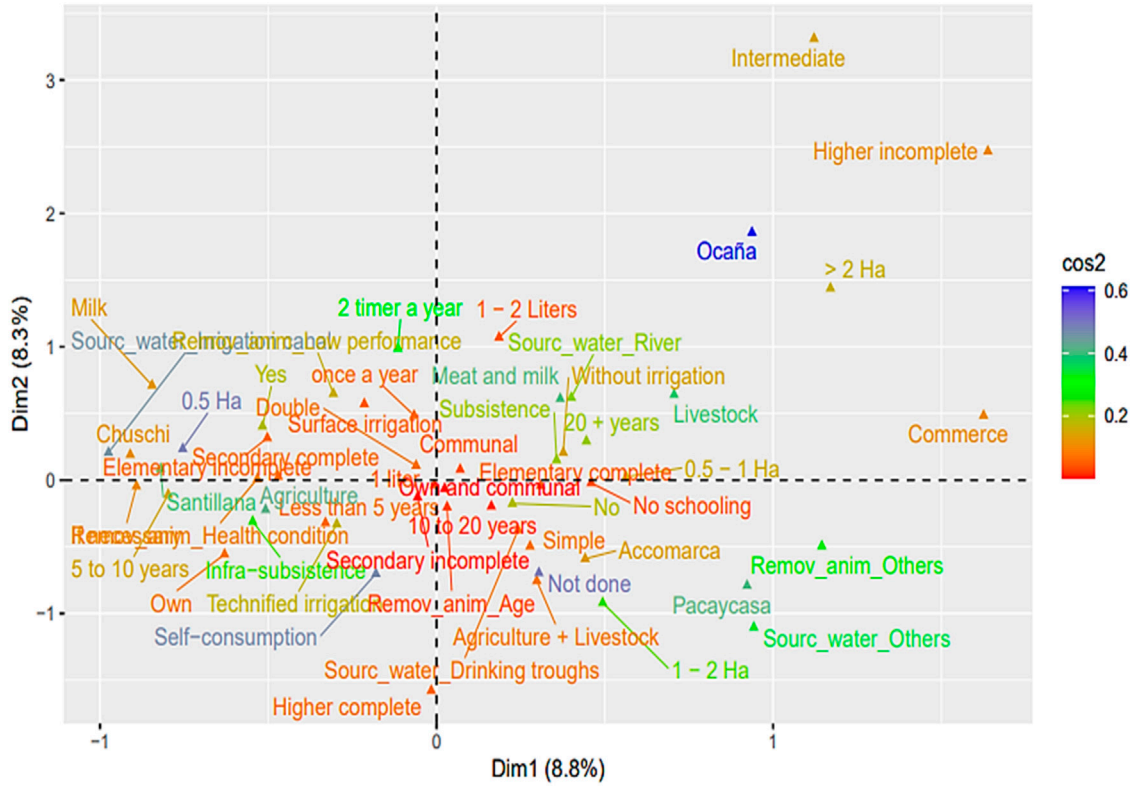

FIGURE 4
Representation of variable categories by dimensions using point clouds (cos^2).

2 hectares. Herds drew water from natural sources such as the river (65%). The breeders of this group mostly dewormed their goats once to twice a year (94%).

Discussion

Socio-economic characteristics

Geographical characteristics influence socio-economic articulations (Torres, 2001). It is important to know the socio-economic situation of smallholders in order to improve goat farming in a sustainable way (Van Arendonk, 2011). In this study, illiteracy was below 15%; in contrast, breeders in the north of Peru exceeded 25% (Temoche, 2019), and Algeria and Senegal showed 44% and 69%, respectively (Laouadi et al., 2018; Sow et al., 2021); while in Ecuador 9% were reported (Villacres Matias et al., 2017). This might be due to the increasing number of schools in rural zones during the last years and the improvement of roads which let them get access to the cities with educational services; since education plays a determining role in the understanding and adoption of new technologies (health, feeding, reproduction and installation) that help improve the goat production system (Vásquez, 2016). Most of the goat farming was inherited through generations but the low percentage of smallholders with less than 35 years old could indicate that young people are not interested in livestock and have decided to find different job opportunities outside of their rural areas.

Unlike the present study (66%), women in northern Peru were found to be less involved in this livestock activity (Temoche, 2019). In Senegal, women (91%) are the main actors in goat breeding (Sow et al., 2021), while the opposite occurred in Algeria (99% men) (Laouadi et al., 2018). The greater prominence of women in goat activity in the sectors of study is because men developed other professions that forced them to travel to the city and develop part-time jobs to contribute to the economy of the family; while women remained mostly at home and were dedicated to care of children and raising livestock.

In this part of Peru, goats were generally raised to ensure the family's food security; although there were breeders who sought economic sustenance with the sale of cheese and yogurt. Similar reports were found in Senegal (Sow et al., 2021) and Tanzania (Nguluma et al., 2020); while in Uganda, they only considered life insurance (Nampanzira et al., 2015). This heterogeneity in the purpose of breeding would be related to the presence of many

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TABLE 3 Distribution of the variables and categories of the respondents for the three groups identified by hierarchical classification analysis.

Variables and categories	Group 1	Group 2	Group 3	Total	*p*-value
District					***
Ocaña	0	0	11	11	
Chuschi	6	3	1	10	
Accomarca	0	17	0	17	
Pacaycasa	0	19	2	21	
Santillana	28	2	0	30	
Small family farming classification					***
Infra-subsistence	21	16	1	38	
Subsistence	15	23	14	52	
Intermediate	0	0	1	1	
Education level					n.s
No schooling	2	7	3	12	
Elementary, incomplete	6	5	3	14	
Elementary, complete	9	13	5	27	
High school, incomplete	8	7	2	17	
High school, complete	11	5	2	18	
Higher, incomplete	0	0	1	1	
Higher, complete	0	2	0	2	
Time as a breeder					***
Less than 5 years	3	8	4	15	
5–10 years	3	4	0	7	
10–20 years	4	10	0	14	
20+ years	6	17	12	35	
Income source					***
Crop	31	20	2	53	
Livestock	4	11	11	26	
Commerce	0	1	2	3	
Crop and livestock	1	7	1	9	
Production objective					***
Milk	6	0	2	8	
Meat and milk	13	8	13	34	
Self-consumption	17	17	1	35	
Total Unit Area					***
0.5 Ha	29	5	6	40	
0.5–1 Ha	6	18	5	29	
>1–2 Ha	1	15	1	17	

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TABLE 3 (*Continued*) Distribution of the variables and categories of the respondents for the three groups identified by hierarchical classification analysis.

Variables and categories	Group 1	Group 2	Group 3	Total	*p*-value
>2 Ha	0	0	4	4	
Irrigation system					***
Surface irrigation	5	3	2	10	
Technified irrigation	24	18	1	43	
Without irrigation	7	18	13	38	
Mixed farming					**
Yes	16	5	5	26	
No	20	13	11	44	
Land tenure					n.s
Own	4	1	2	7	
Communal	25	15	11	51	
Owned and Communal	7	2	3	12	
Sources of Water					***
River	6	1	11	18	
Irrigation canal	22	4	2	28	
Drinking troughs	8	8	3	19	
Others	1	5	1	7	
Litter size					***
Simple	3	8	0	11	
Double	33	10	16	59	
Reason for removing animals					***
Age	11	8	4	23	
Health Condition	13	2	2	17	
Elimination	12	2	1	15	
Others	1	6	4	11	
Milk production					n.s
1 kg	35	18	14	67	
1 < 2 kg	1	0	2	3	
Deworming period					***
2 times	11	2	8	21	
1 time	7	2	6	15	
If necessary	7	2	1	10	
Not done	11	12	1	24	

n.s., not significant ($p > 0.05$); *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

cultural, social, and family traditions, where either the woman or the man has the main role in the goat breeding process (Missohou et al., 2004). Illiteracy also plays an important role in the current situation of small-holders' goat production systems (Agossou et al., 2017; Laouadi et al., 2018; Temoche, 2019).

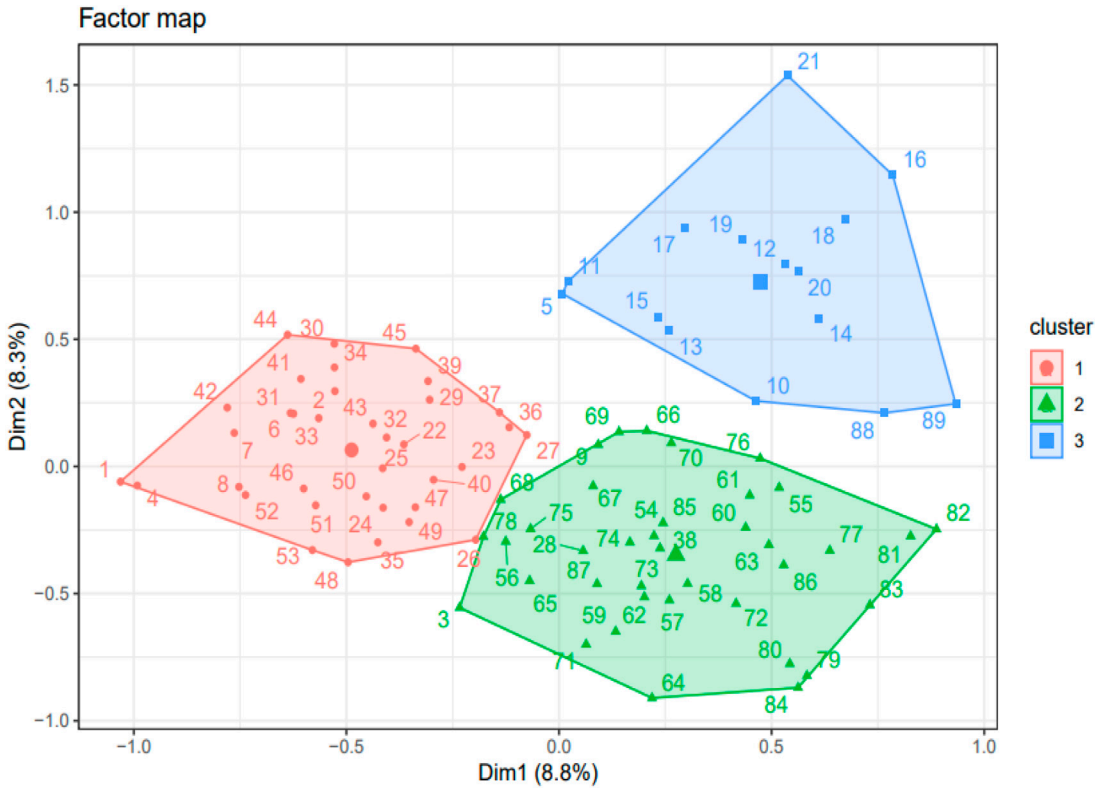

FIGURE 5
Hierarchical classification of goat breeders applied to the typology of goat production systems in the highlands of southeast Peru.

Productive characterization

Production systems can be classified as: extensive, semi-intensive, and intensive, which are determined based on many factors that compete with the heterogeneity of production processes (Morales-Jerrett et al., 2022). In the present study, only 4% of breeders owned land greater than 2 hectares, while in the north of the country, there was higher (14%) (Temoche, 2019), as well as in Ecuador (14%) (Villacres Matias et al., 2017). The planting of crops was the main activity for goat smallholders and they preferred to allocate their lands for crops such as corn, wheat, beans, and peas, turning communal areas into the forage support of most herds.

This study reveals that breeders practice mixed parenting, similar to the methods used in northern Peru (Temoche, 2019). This involves raising different livestock (goats, sheep, and cattle) on the same farm, allowing for efficient use of natural resources, better risk management, and increased sustainability of grasslands through differentiated grazing (Sow et al., 2021). Mixed parenting is also practiced in Brazil (Rodrigues Alves et al., 2017) and other African countries (Moula et al., 2017; Laouadi et al., 2018; Nguluma et al., 2022), however, these countries have different populations, policies, and sociocultural traditions that influence the production systems.

Forage management

The availability of food resources is determined by the agroecological conditions where goat farming is developed, and there may be different sources of food (Nguluma et al., 2022). In this study area, the herds had natural meadows as their main source of food, with producers feeding them with crop by-products (corn husk dried, wheat straw, and barley); while in the north of Peru, in addition to natural grasslands and crop by-products, it was common practice to supplement with concentrate (Temoche, 2019). In these areas, the flocks grazed freely, with or without the shepherd, while others practiced tying their goats (Nampanzira et al., 2015; Sow et al., 2021) to optimize the use of natural pastures and crop by-products (Nampanzira et al., 2015; Sarria et al., 2015). Proper design of feeding programs is essential to guarantee the profitability of the sector, according to each production model and different realities (Morales-Jerrett et al., 2022).

Reproductive and genetic management

The breeders mentioned that genetic improvement is one of the management priorities of their herds. Replacement breeders were chosen from their herds based on specific selection criteria. Males were selected according to body conformation, size, and live weight, while females were chosen for their prolificacy and milk production (Laouadi et al., 2018). Similar reproductive management has been

reported in northern Peru (Temoche, 2019), and Senegal (Sow et al., 2021). However, in Ecuador, the selection of broodstock was carried out according to hardiness, resistance, and ease of handling (Villacres Matias et al., 2017). These differences in reproductive management would be subject to the purpose of breeding (milk, meat, or fiber), where the producer determines his selection criteria to choose the future parents of the herd.

Categorizing the herd is essential to carry out good reproductive management, avoiding the repercussions on its growth and productive performance in the future (Sarria et al., 2015; Villanueva, 2008). Proper mating management in herds guarantees proper use of genetic material, avoiding indiscriminate inbreeding, which is a main factor in the deterioration of productive parameters (Nguluma et al., 2020).

Field records management

Records management is fundamental in a productive unit, being a tool that stores important information and helps in making decisions about the herd. In this study, there was no evidence of any use of records (health, reproductive, sale, milk production) by breeders, unlike producers from northern Peru which handled inventory records as part of the control of their animals (Temoche, 2019). Many reasons could explain the less use of field records as the lack of financial resources, there was no motivation to improve their husbandry, or low size herds.

Health management

Antiparasitic controls are little or not practiced in the study area, with a high prevalence of gastrointestinal parasites (Mendoza, 2023). In contrast, breeders from Northern Peru (Temoche, 2019), Ecuador (Villacres Matias et al., 2017), and other countries such as Algeria and Tanzania (Laouadi et al., 2018; Nguluma et al., 2022) dewormed and vaccinated their herds. These differences were possibly due to agrarian policies, ancestral traditions, and a lack of knowledge of sanitary management by producers in the sector. Goats are predisposed to acquire diseases of bacterial, viral, fungal, and parasitic origin (Kardjadj, 2017; Sow et al., 2021; Tumusiime et al., 2022). Herds must have a defined sanitary calendar, considering geographical conditions, parasite prevalence, and life cycle (Dismas et al., 2014).

Economic characterization

Animal husbandry is a tool for cash flow in a family economy so in other parts of the world it is considered “saving” life security (Missohou et al., 2016; Manirakiza et al., 2020). In this study, it was recorded that few breeders have a defined market for the sale of their products, as well as in Ecuador (Villacres Matias et al., 2017). These reports differ from those of northern Peru, where breeders know about the economic value of goat breeding (Temoche, 2019), as well as in Spain and Argelia (Morales-Jerrett et al., 2022; Laouadi et al., 2018). In these areas, goat-derived products continue to be traditional, with a short production chain that is related to a weak organization of the actors involved in designing the policies of the sector (Camara et al., 2019; Sow et al., 2021) that results in an unnoticed competitiveness in the regional and national market (Laouadi et al., 2018).

Typification of the production system

Using multivariate analysis (MCA), the breeders were grouped into three groups. This typification in groups of goat breeders is differentiated by variables such as total unit area, income source, production objective, irrigation system, sources of water, and deworming period.

The breeders in Group 1 were part of family infra-subsistence farming, the cultivation of cereals in the sector was their primary activity. The harvesting of crops covered all their family’s expenses, including food, education, and clothing. Goat breeding was done solely to ensure food security. Because they have areas of less than 0.5 hectares of land, breeders are limit themselves to livestock, putting more interest in growing cereals in the sector (corn, peas, wheat, beans, wheat, and barley). The breeders mostly carried out technified irrigation due to the geographical conditions (ravines and slopes) or the type of economic activity (agriculture or fruit production). Herds that took advantage of the natural pastures of communal lands preferred to consume vegetables from shrub and arboreal strata rather than herbaceous ones, these preferences are related to the feeding behavior of the goats (browsing).

The majority of Group 2 breeders belonged to subsistence family farming. The breeders of this group consider livestock and agriculture as their main activities, which would be related to the extensions of their lands due to the geographical conditions (accessible and wide valleys). Between March and June, breeders had higher incomes due to the calving and the great availability of pastures. The use of pressurized irrigation in this group would be related to the existing agricultural and fruit activity in the sectors, however, flood irrigation still prevails. Regarding parasitic control, most breeders did not comply with the deworming schedule, reporting a higher prevalence of gastrointestinal parasites (Eimeria spp., Strongyloides, Trichuris spp.). (Mendoza, 2023). The lack of sanitary management in these herds is attributed to the absence of entities and professionals that provide technical assistance and training.

The majority of the producers in group 3 belonged to subsistence family farming. In this group, goat breeding was the primary activity for breeders, driven by strong market demand for cheese and standing kids. To support this, they practiced transhumance, moving their herds throughout the year to ensure adequate feeding, unlike the sedentary lifestyle of the other two groups. The breeders also had a long-standing tradition of effective herd health management, passed down through generations. However, there is a need to enhance the production chain in the sector.

Group 1, includes mainly producers from the districts of Santillana and Chuschi; Group 2, producers from the districts of Pacaycasa and Accomarca; and Group 3, producers from the districts of Ocaña, concluding that there are differences between the districts. Group 1 concentrates on producers who are mainly dedicated to agriculture, most of them, being subsistence category. Group 2 concentrates on producers who give importance to both livestock and agriculture, most of them, being subsistence categories. On the other hand, group 3 concentrates on producers who are dedicated only to goat activity, where almost all of them are subsistence categories. Thus, the producers in Group 1 raise goats for self-consumption, Group 2 for consumption and sale of surpluses, and Group 3 to market their products. The producers in Group 1 have smaller land extensions (<0.5 hectares) than those in Group 2 (0.5–2 hectares) and Group 3 (>2 hectares).

The Ayacucho region is divided into three ecosystems by the Andes Mountains: the southern highlands, the center of the abrupt mountains, and the northeast of the tropical forest, with altitudes ranging between 500 and 5,000 m.a.s.l. It is characterized by a rugged geography, a variety of microclimates, with a diversity of ecological sites, where there are scattered natural resources. These geographical characteristics have influenced the nature of human settlements and socio-economic articulations, attributing to agro-ecological diversity among the populations of the region (Torres, 2001). These geographical and agroecological characteristics, in addition to social, cultural, and economic factors, would be influencing the different agricultural and livestock production processes, resulting in grouping producers into 3 groups.

Group 1 concentrates producers in the subsistence category (58%) because goat farmers in the sectors do not cover their basic needs and have land <0.5 hectares, so they opt for other sources of income other than agriculture and livestock. Group 2 concentrates producers in the subsistence category (58%), where goat farmers can cover their basic needs, with land between 0.5 and 2 hectares, however, they do not have enough savings capacity. Group 3 concentrates on producers in the subsistence category (88%), where goat farmers can save their income and have the opportunity to improve their quality of life. The classification of PAFs is based on socioeconomic and ecological characteristics (land, water, and biodiversity), which have a strong impact on agricultural production systems (Fonseca-Carreño, 2019), and requires a highly disaggregated vision (Maletta, 2017).

Conclusion

In the southeast of Peru, it was evident that goat breeding is one of the main livestock activities that are practiced in inhospitable, forgotten areas that are difficult to access, where other production species (cattle, sheep, and camelids) were not evident. In these sectors, goat activity plays a very important role for the inhabitants, being a direct source of food for all families and as economic support for certain producers. However, it is revealed that it lacks good management practices in breeding, without genetic improvement strategies, with free grazing management that takes a long time in communal lands, where local authorities do not put interest to consider in their productive development plans. Three groups of goat breeding were typified; the first where breeders are characterized by producing only to cover food security; the second where they seek to market surplus production (milk, cheese, and meat); and the third where goats as their main source of income. This study will also contribute to the design of strategies to develop sustainable goat farming within the region. Further research on improvement proposals is required, to establish sustainable and profitable livestock systems for the producer.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

WP: Conceptualization and design of the experiment, data analysis and interpretation, statistical analysis, manuscript writing. DG: Conceptualization and design of the experiment, manuscript writing, and editing. JH: Data collection, experiment development. ES: Data analysis and interpretation. FT: Statistical analysis, manuscript review, and editing. JC: Conceptualization and design of the experiment, and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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