

RESEARCH ARTICLE

Characterization and typology of goat production systems in the Southern Highlands of Peru



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ABSTRACT

Background and Aim: Characterizing local animal production systems is crucial for sustainable livestock development. This study aimed to characterize the diversity of goat production systems in the Highlands of Chincha province, Ica, Peru.

Materials and Methods: A structured questionnaire was used to gather data from 82 goat breeders in three districts: San Juan de Yanac, San Pedro de Huacarpansa, and Chavín. Factor analysis of mixed data and hierarchical classification analysis were conducted to identify typologies of goat production systems using R version 4.4.2.

Results: Four distinct goat production types were identified, primarily differentiated by feeding location and deworming frequency. Type 2 (41.5%) was the most prevalent, characterized by grazing on breeders own land, minimal milk production (<1 liter/day, 91.2%), and a focus on cheese and goat kid sales (70.6%). Breeders were predominantly women, with limited resources and extensive management systems. Across all types, mixed breeding was common, and economic reliance on livestock and agriculture prevailed.

Conclusion: Despite their diversity, all goat production systems shared extensive management practices and resource constraints, resulting in low productivity. These findings highlight the need for targeted public policies to improve productivity and sustainability in goat farming within the Ica region.

Keywords: Chincha Highlands, extensive farming, goat production systems, multivariate analysis, Peru, typology.

INTRODUCTION

Locally available animal genetic resources are the basis for the productivity and adaptability of production systems [1]. Therefore, characterizing these systems and their diversity is the first step in establishing sustainable livestock development policies [2]. Goat production systems worldwide are mainly characterized by being resource-poor, extensive, and mixed [3, 4]. However, since domestication, the unique advantages of goats, particularly Creole goats, have been highlighted compared to other livestock species [5–7]. With their mobile upper lip and greater cellulose digestion efficiency, goats can forage from a wide variety of plants that neither sheep nor cattle can eat [1]. Therefore, they are more adapted to survive in adverse environments [8] and on a small scale [6]. Despite limited resources, goats

efficiently convert poor-quality animal feed into good-quality milk and meat [9].

Creole goats play a significant role in the rural economy by providing income, employment, and savings for small-scale breeders [10–14]. In addition to being considered more resilient to climate change [15], it has a high potential to contribute to the achievement of food security and sustainability [16–18]. Despite these competitive advantages, goats often receive less attention in national development programs [1], with policymakers typically focusing on improving cattle, sheep, and South American camelid farming to the detriment of goats [19]. In addition, few studies are available on goat production systems in Peru [20, 21]. In the current context in which poverty reduction and food security are the main challenges for developing

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countries, implementing public strategies to improve traditional goat farming would significantly benefit rural smallholders [9]. This requires a thorough understanding of the characteristics of local production systems [22]. In this sense, the typological approach, which utilizes multivariate statistical analysis, emerges as a valuable tool for understanding the diversity of livestock production systems and the role of zoogenetic resources within them [1, 23]. Such an approach helps evaluate the structural characteristics of these systems [24] and their ability to cope with changes in the biophysical and socioeconomic conditions in which they operate [25, 26] and to propose alternatives for improvements [9].

Therefore, this study aimed to characterize, through a typology, the diversity of goat production systems in the Highlands of Chinchá province, Ica region, Peru.

MATERIALS AND METHODS

Ethical approval and Informed consent

This study was based on interviews with goat breeders so ethical approval was not required. Before conducting the surveys, all volunteers signed an informed consent form.

Study period and location

The study was conducted from June to August 2023 in the districts of San Juan de Yanac (2533 masl, 13°12'39"S 75°47'13" W), San Pedro de Huacarpana (3776 masl, 13°02'56"S 75°38'52" W), and Chavín (3170 masl, 13°04'37"S 75°54'47" W), located in the mountains of Chinchá province, Ica region, Peru (Figure 1). According to the INEI [27], these districts are home to 60% of the goat population in Chinchá; predominantly Creole, are raised under an extensive system, and have a diet based mainly on stubble and natural grass.

Data collection

Structured individual interviews were conducted with 82 goat breeders in different population centers in the selected districts, either in their local dialect or with the support of a translator. For the choice of breeders, the possibilities of geographical access, support from public institutions for their identification and location, predisposition of breeders, and availability of transport were considered. The questionnaire included open and closed questions that considered socioeconomic aspects of the family unit, herd composition, zootechnical management, selection criteria, and commercialization.

Statistical analysis

All statistical analyses were conducted using R Studio 4.4.2 software to ensure comprehensive evaluation and reproducibility of results. Descriptive statistics, including means, standard deviations, and frequencies, were used to summarize the socioeconomic and management characteristics of goat breeders. To explore the diversity of goat production

systems, a factor analysis of mixed data (FAMD) was applied to integrate both qualitative and quantitative variables, reducing dimensionality while preserving variability [28, 29]. The process of typifying goat farms is outlined in Figure 2, which illustrates the analytical flow from data reduction to cluster formation. The principal components derived from FAMD were subjected to hierarchical clustering analysis using Ward's method to identify distinct typologies of goat herds [30, 31].

Differences among typologies were assessed using a one-way analysis of variance for continuous variables and the Kruskal-Wallis test, where assumptions of normality were violated. Chi-square tests were applied to categorical variables to identify significant associations with typologies.

The variables used in the multivariate statistical analysis are detailed in Table 1, highlighting their importance in characterizing the goat production systems. Statistical significance was determined at $p < 0.05$, and results are presented using publication-quality tables and visualizations.

RESULTS

Socioeconomic characteristics of goat breeders

It was found that 56.1% of the interviewees were men. Similarly, of the total number of respondents, 6.1% were illiterate, 85.4% had completed elementary or secondary school, and only 8.5% had a higher degree. The ages ranged from 24 to 83 years, with a median age of 53. The fathers and mothers of the households made the decisions regarding the upbringing of their goats in 64.6% of agricultural units. 65.9% of breeders have their primary economic income from livestock and agriculture. Of the goat breeders, 73.2% had been breeding for more than 20 years, 65.9% were breeding for milk and meat, and 31.7% were solely focused on producing dairy products, primarily cheeses.

Management and production characteristics of goatherds

In the Highlands of Chinchá, most goat breeders (89.0%) carried out mixed breeding, mainly with sheep, followed by cattle. In the same way, about 90% of the respondents mentioned that they practiced grazing, either with cultivated or natural pastures; the remaining respondents engaged in grazing combined with stubble. The breeders had an average population of 61.4 goats (range = 12 to 367, median = 35), of which 36.1% were goats in production. Their goats yielded milk for 4.1 months on average (median = 4, range = 3 to 6), with 73.2% of the producers reporting that their goats produced less than 1 L of milk per day.

Typology of goat production systems

Mixed data factor analysis yielded 29 principal orthogonal components, of which the first 10 explain 62.0% of the total variability observed in the study (Figure 3). However, for the purposes of this study, an explanation will focus on the first two dimensions.

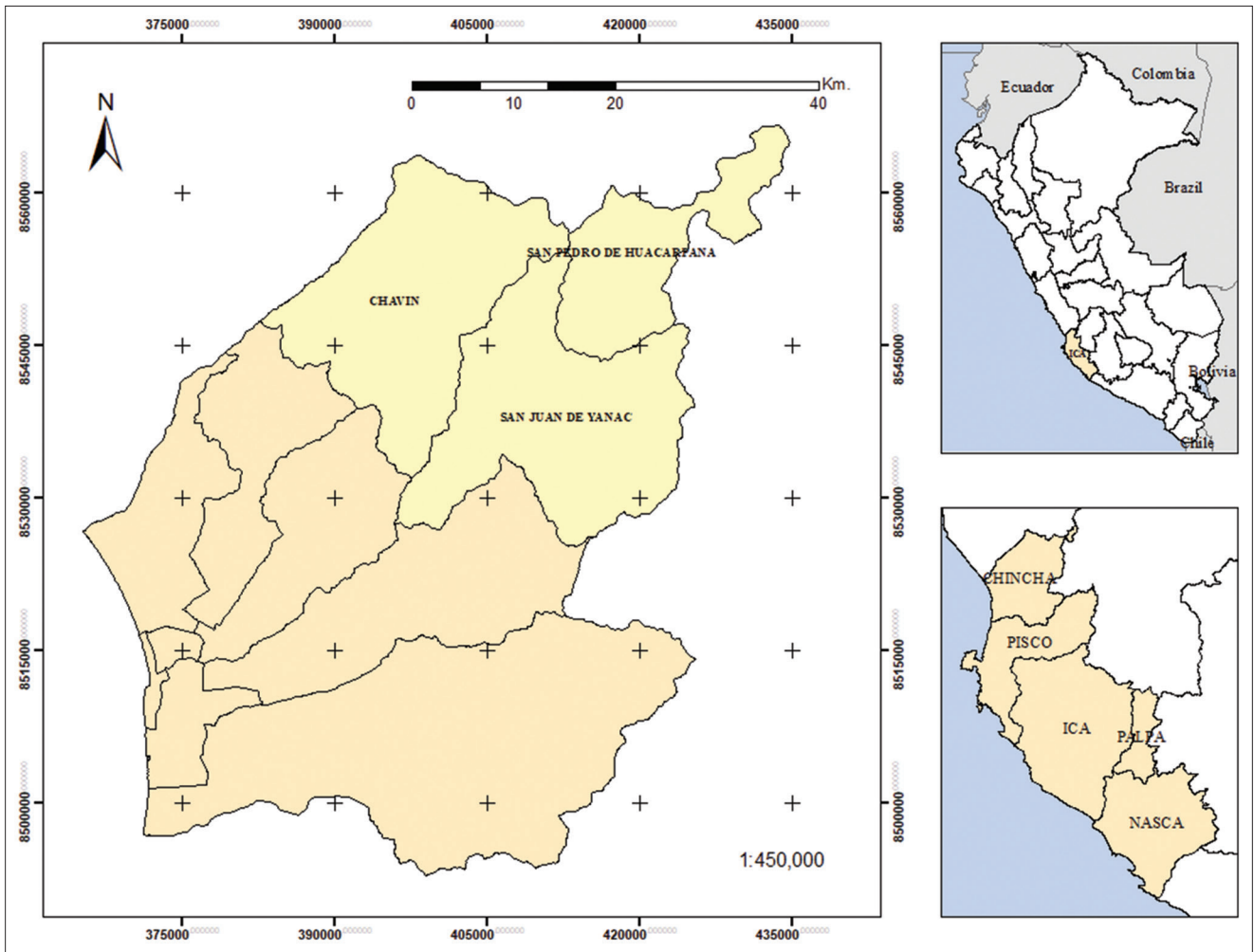


Figure 1: Location of Ica region in Peru country (above right); subdivision of Ica region (below right) and evaluated districts (cream) in Chincha province (left) [Source: The map was generated with ArcGIS 10.8].

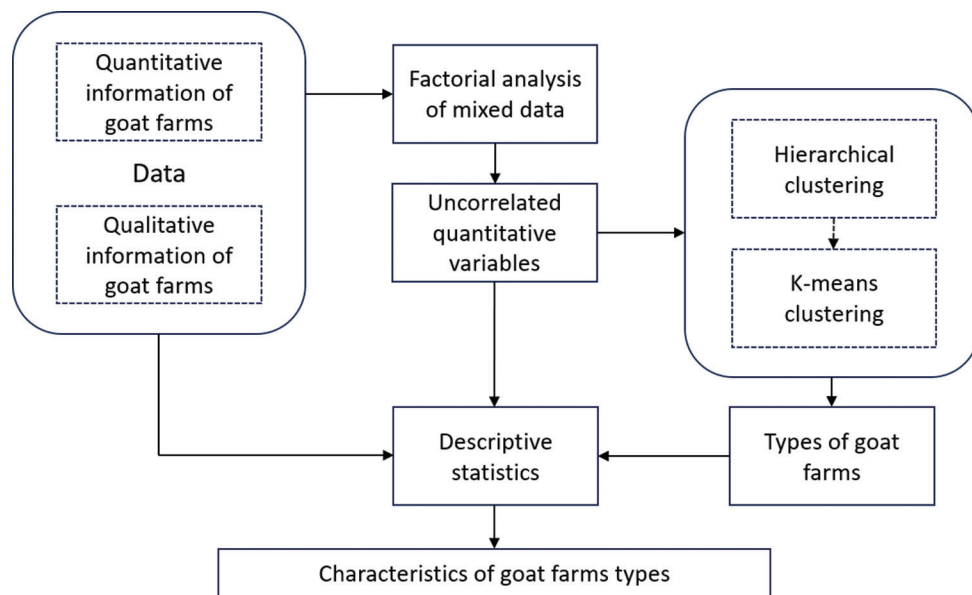


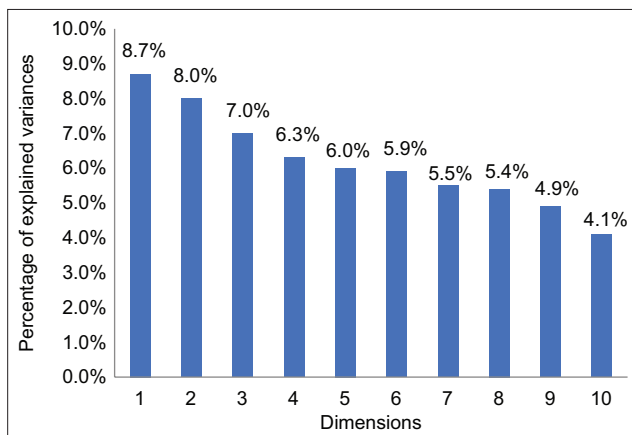
Figure 2: Process of goat farm typification.

The findings of the factor analysis of the quantitative and qualitative data on goatherds are shown in Figure 4. The first axis (dimension 1) retained 8.7% of the accumulated inertia and showed a high

positive correlation with the variable feeding place of the goats. In this sense, it can be mentioned that breeders who have between 5 and 10 years of experience in the breeding of goats have their own feeding area (mainly

Table 1: Variables used in the multivariate statistical analysis of the goat production system in the Highlands of Chincha.

No.	Variable	Code	Category and/or value
1	District	DIST	(1) San Juan de Yanac, (2) San Pedro de Huacarpana, (3) Chavín
2	Educational level	GRADO_INSTR	(1) No studies, (2) Prim. Incomplete, (3) Prim. Complete, (4) Sect. Incomplete, (5) Sec. Complete, (6) Sup. Incomplete, (7) Sup. Complete
3	Breeding decisions	DECIS_CRIA	(1) Father, (2) Mother, (3) Both, (4) Other
4	Years of animal husbandry	AÑO_CRIA	(1) <5 years, (2) 5–10 years, (3) 10–20 years, (4) >20 years
5	Main sources of income	FUENT_INGR	(1) Agriculture (2) Livestock, (3) Agriculture and livestock.
6	The main objective of husbandry	OBJE_CRIA	(1) Milk, (2) Dairy Products, (3) Dual Purpose
7	Time dedicated to husbandry	DEDIC_CRIA	(1) 3–6 h, (2) 6–9 h, (3) >9 h
8	Mixed husbandry	CRIA_MIX	(1) Yes, (2) No
9	Goat Feeding	ALIM_CABRA	(1) Grazing, (2) Grazing and Foraging
10	Goat feeding place	LUGAR_ALIM	(1) Own, (2) Communal, (3) Lease, (4) Own and Communal, (5) Own and Lease
11	Number of offspring per delivery	CRIS_PARTO	(1) Single, (2) Double, (3) Triple
12	Production per goat per day	PROD_CABRA	(1) <1 L, (2) 1–2 L
13	Deworming frequency per year	FREC_DESPARAS	(1) 3 times a year; (2) 2 times a year; (3) 1 time a year; (4) No deworming
14	Sale of milk and/or dairy products	LECHE_DERIV	(1) Cheese, (2) Milk and cheese, (6) Cheese and butter
15	Sale of meat and/or meat derivatives	CARNE_DERIV	(1) Culled goats, (2) Weaned goat kids, (3) Culled goats and weaned goat kids, (4) did not sell
16	Age of the breeder	PROD_AGE	---
17	Percentage of goats that milked	PORCENT_ORDEÑO	---
18	Months of milk production	MESES_PROD	---
19	The goat population in the herd	CABE_CAPRIN	---

**Figure 3:** Contribution of the top 10 dimensions to total inertia.

stubble), and at certain times of the year, they rent to carry out grazing and thus be able to maintain the production of cheeses in their majority, followed by few breeders who also make butter.

On the other hand, dimension 2 (which retains 8% of the total variability) has a high correlation with the variables for the commercialization of meat and/or dairy products and the frequency of deworming. In this regard, it should be noted that breeders who work with goats for 6–9 h a day mostly make their living from livestock. In the same way, breeders who do not perform mixed breeding focus more on the sale of culled goats and weaned goats and, therefore, try to select goats that have more calves at birth.

Subsequently, four distinct goatherd types were identified in the Highlands of Chincha using the breeder's coordinates on the main axes for cluster analysis (Figures 5 and 6). It is worth noting that the variables "Feeding place" and "Deworming frequency" are the ones that most characterized the partition into the four groups. The proportions of different types of goatherds are shown in Figure 7.

In the first group ($n = 19$), 57.9% were San Juan de Yanac breeders, followed by 31.6% from San Pedro de Huacarpana. The majority had a full elementary school (36.8%), and both the mother and father of the household made decisions about goat breeding (94.7%). Their main income came from livestock (63.2%), they grazed (100%) on their own and communal land (57.9%), they deworm their goats generally once a year (74.7%), they dedicate 6–9 h to their goats (68.4%), and they produce between 1 and 2 L/day (57.9%) to manufacture, mainly dairy products (73.7%).

In the second group ($n = 34$), 52.9% were San Pedro de Huacarpana breeders, followed by 32.4% from Chavín. The majority had completed secondary school (32.4%), and the wife was the one who made the decisions about raising goats (50%). Their main economic income came from agriculture and livestock (85.3%); they carried out only grazing (100%); on their land (67.6%), they dewormed their goats generally twice a year (52.9%); and they dedicate 3–6 h to their goats (67.6%) and produce <1 L/day (91.2%), with a tendency to double purpose (70.6%).

Table 2: Quantitative variables by goatherd type in the Highlands of Chinchá.

Variable	Type of goat farm				p-value
	1	2	3	4	
Age of breeder (years)	56.0 ± 15.0 ^a	53.8 ± 12.5 ^a	56.3 ± 13.2 ^a	46.8 ± 10.6 ^a	0.1707
Number of goats (unit)	75.5 ± 56.0 ^{ab}	41.5 ± 47.7 ^b	53.8 ± 48.3 ^{ab}	98.9 ± 94.3 ^a	0.0192
Percentage of milking (%)	33.9 ± 15.5 ^{ab}	36.4 ± 12.5 ^{ab}	30.1 ± 13.6 ^b	44.5 ± 15.4 ^a	0.0462
Production time (months)	3.9 ± 0.8 ^a	4.0 ± 0.8 ^a	4.1 ± 0.9 ^a	4.5 ± 0.9 ^a	0.2575

Different superscripts in each row mean statistically significant differences ($p < 0.05$).

than 9 h to their goats (71.4%), and produce equitably between <1 L and 1–2 L/day, with the aim of double purpose (92.9%).

Table 2 presents the means ± standard deviations of the quantitative variables considered in the FAMD according to the type of goatherd. In this sense, it can be seen that there were no significant differences between the age of the breeders and the production time of the goats according to the types of herds that were found. On the other hand, type 2 had the fewest goat heads, and type 3 had the lowest percentage of goats being milked.

DISCUSSION

This study aimed to understand the diversity of goat production systems in the Highlands of Chinchá. The findings revealed significant heterogeneity among goatherds in the study region. In this regard, on the central coast of Peru, goat breeding is based on stubble, with reduced herd sizes, low milk production, and low-value meat [20].

A notable observation is the slight majority of male respondents (56.1%) in this study, contrasting sharply with findings from other regions where goat farming characteristics predominantly feature male participants. For instance, in the state of Paraíba in Brazil, 96.8% of the respondents were men [32]; in the Laghouat area of southern Algeria, 99.1% of the respondents were men [1]; and in the Huerter–Norte region of Costa Rica, 83.25% of the respondents were men [33]. This disparity is attributed to traditional gender roles that have historically limited women's participation in interviews and meetings, a trend that is evolving in Peru. In the same way, the proportion of breeders without formal education in the current study (6.1%) contrasts significantly with rates reported in Algeria, where 44.3% of breeders were illiterate [1]. On the other hand, only 8.5% of the breeders in this study had access to university studies, mainly due to the location of the evaluated districts from the Chinchá coast and limited transportation options.

Another common characteristic among breeders is their advanced age, averaging 53.6 years with a median of 53, consistent with typical demographics in goat production systems [34].

Based on the FAMD, the study identified four types of goatherds, three oriented toward dual purposes, highlighting cheese sales, culled goats, and weaned

goats. The remaining type (Type 1) primarily focuses on dairy product sales as its main economic activity, prioritizing cultivated pastures, particularly alfalfa, and achieving goat milk production of 1–2 L/day. It should be emphasized that it is difficult to fully capture the diversity of low-resource livestock production systems, which is a limitation of the present typology [30]. However, extensive goat farming remains predominant and economically significant in mountainous areas [35].

Similarly, small breeders' manual production methods are limited in output but provide significant benefits in terms of lower production costs [36]. The basis of goat feeding in these systems is grasses and stubble, without the inclusion of grain-based feed [37], with the disadvantage of not controlling mating since the animals are released to graze or stubble during the day [38].

In this context, implementing conservation and genetic improvement programs is crucial, yet their sustainability in low-resource production systems with local breeds depends largely on breeder interest shaped by the socioeconomic context [39]. However, based on the participatory interview, it is very likely that breeders will respond favorably [40]. To this end, it should be noted that the use of exotic breeds in this type of production system is not recommended by Husson *et al.* [30], mainly because of their higher nutritional demand, poor adaptability, and low production efficiency [41].

CONCLUSION

This typological study has delineated four distinct types of goatherds based on their feeding locations and deworming practices. Despite their diversity, these herds share common features, such as reliance on grazing, livestock, and agriculture as primary income sources, coupled with mixed breeding methods. Notably, cheese production and sale of goat kids are the principal economic activities underscored by traditional management practices. The herds are of moderate size, with a significant proportion of goats that milk <1 L of milk daily. These findings provide valuable insights into the heterogeneous nature of goat production systems in the Highlands of Chinchá, offering a foundation for targeted interventions to enhance sustainability and productivity.

AUTHORS' CONTRIBUTIONS

DJG: Planned and designed the study and revised the manuscript. EAS: Sampling, analyzed the results,

and drafted and revised the manuscript. FCT, WPG, JAC: Analyzed the results and revised the manuscript. All authors have read and approved the final manuscript.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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