



Characterization and multivariate typology of goat farming systems in Kabylia region in the North of Algeria

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Abstract

To better understand the dynamics of goat breeding systems, a face-to-face survey was conducted with 48 goat farmers in different localities of Tizi-Ouzou province in the Kabylia region. The study aimed to characterize local production systems and assess how socioeconomic factors such as age, gender, education level, and breeding experience influence goat rearing practices. Relationships between farmer characteristics and husbandry practices were examined using multivariate analyses (multiple correspondence and cluster analysis) to identify farm features and classify them into farming typologies. More than half of the farmers had a secondary school level, 27% had post-secondary education, and 6% were university graduates, while only 10% were illiterate. Goat breeding was predominantly carried out by men (88%), and the average farmer age was about 40 years. For nearly half of the respondents (49%), goat farming represented the primary source of income, while also contributing to self-consumption and family celebrations. Mixed farming with goats and sheep was common (51%), with some farmers also keeping cattle, poultry, horses, or donkeys. Herd sizes were generally small, with 71% owning fewer than 25 goats. Cluster analysis identified four farming typologies. Cluster 1 (11 farmers) represented an extensive or pastoral system. Cluster 2 (14 farmers) reflected an improved traditional farming system. Cluster 3 (18 farmers) corresponded to an improved traditional livestock system. Cluster 4 (5 farmers) consisted of more intensive systems with larger herds. Differences among clusters were mainly related to land use, facilities and equipment, grazing practices, herd expansion and size, and preventive health programs. Overall, this study provides valuable insights into goat rearing practices, contributing to a better understanding of local production systems in the mountainous region of Kabylia.

Keywords Goat · Sustainable breeding practices · Socioeconomic characteristics · Multivariate typology · Clusters

Introduction

Goats (*Capra hircus*) are highly valued animals for their versatility including their ability to tolerate harsh climates, good drought recovery capacity, suitability for poor systems due to small size and grassland capacity. They are among the earliest small ruminants to be domesticated by humans

and used for many purposes as a source of meat, milk, fiber, leather and other valuable related services (Casey and Webb 2010). The domestication of goats had a profound impact on human history, making them an essential part of many societies and cultures around the world because of their ability to adapt wildly to diverse and harsh environmental conditions such as water and heat stress, and drought conditions thanks to their resilient metabolic properties and their ability to keep water (Usai et al. 2006; Salama et al. 2014). Goats are not only a valuable source of food and other products, but they are also known for their social roles (Miranda-de la Lama and Mattiello 2010). In recent years, worldwide goat production has seen a significant increase (Miller and Lu 2019), highlighting an economic importance. Therefore, goat farming has become increasingly important for national economies and a key factor in economic development, particularly in rural areas. Due to the acceleration of population growth, the application of new

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techniques and taking advantage of animals with zootechnical interests, such as goats, is more than needed (Chetroui et al. 2013; Kaumbata et al. 2021). Indeed, the livestock sector is characterized by different breeding systems that must well characterized, before promoting the implementation of a sustainable development policy (Rajala et al. 2021).

In Africa, small ruminants, particularly goats, have long been integral to animal production systems and are deeply embedded in the cultural practices of North African breeders (Anim-Jnr et al. 2023; Ndonga et al. 2024). They play a significant role in supporting sustainable livelihoods and alleviating poverty by contributing to increased household income (Gnanda et al. 2016; Djagba et al. 2020). In many African countries, goats are predominantly raised by smallholder farmers under extensive agroecological conditions within rural production systems.

In Algeria, goat farming represents one of the oldest forms of animal production. However, it has historically received limited scientific attention and remains relatively neglected. It is also increasingly marginalized by breeders (Ouchene-Khelifi et al. 2018), despite its important contribution to household income generation for goat keepers (Alary et al. 2011). Although goat farming offers numerous advantages, it is still largely perceived as an input-based livestock system. Nevertheless, traditional goat farming practices have been shown to support processes of ecological intensification (Ndonga et al. 2024).

According to the Food and Agriculture Organization (FAO) statistics from 2019, the goat population in Algeria reached approximately 5 million head, producing an average of 18.8 thousand tons of meat and 253 thousand tons of goat milk. Several indigenous goat breeds are distributed across different agroecological zones of the country. Among these, four major populations can be identified: *Arbia*, which represents the largest population and is mainly found in steppe regions; *Naine de Kabylie* located in the mountainous areas of Kabylia in northern Algeria; *M'zabite*, present in the northern Sahara and *Mekatia*, which predominates in transitional zones between steppe and Saharan regions (Ouchene-Khelifi et al. 2015; Lamri et al. 2023).

In recent years, however, there has been a notable increase in the introduction of imported breeds such as Saanen, Alpine, Murcia and Chami, along with their crossbreeds. These breeds are becoming increasingly prevalent and, in some areas, are replacing indigenous goats due to their high productivity and perceived economic advantages (Laouadi et al. 2018, 2020). Despite this shift, relatively few studies have focused on goat farming systems in Algeria. Existing research has primarily concentrated on morpho-biometric characterization, aiming to identify distinct breed populations within specific regions and to describe their phenotypic traits (Dekhili et al. 2013; Laouadi et al. 2020). These

studies have contributed to a better understanding of breed diversity and their potential implications for the development of the goat sector in Algeria.

Beyond simple descriptive characterization, livestock farm typologies are widely used worldwide to identify the diversity of production systems and to group farms according to structural, socioeconomic, and management similarities (Huber et al. 2024). Such approaches are particularly relevant in smallholder goat farming, where herd size, feeding strategies, breeding management, health care, and market orientation can vary considerably even within the same region (Oliveira et al. 2022; Zinsou et al. 2024; Adje et al. 2025; Sessarego et al. 2025). Typological analyses provide a robust framework for understanding this heterogeneity and are increasingly used to support the design of targeted development interventions, including breeding strategies, feeding improvement, disease prevention, advisory services, and resource management (Huber et al. 2024). In goat production systems, typologies have been successfully applied in different contexts, including Mediterranean and African environments, to distinguish extensive, semi-intensive, and intensive systems and to identify the constraints and opportunities specific to each group (Laouadi et al. 2020; Nguluma et al. 2022; Oliveira et al. 2022; Zinsou et al. 2024; Laroussi et al. 2026). Therefore, establishing a typology of goat farming systems in Kabylia is important not only for describing current practices but also for generating a decision-support basis for sustainable improvement programs adapted to local environmental and socioeconomic conditions. This study was therefore undertaken to shed light on the breeding systems in Algeria and provide valuable insights into the ways that would enhance goat production with a particular emphasis on Tizi-Ouzou region from the Kabylia region. Thus, this study aimed to achieve several objectives. First, to gather together all the basic information about the state of goat keeping and the diversity of breeding systems used. To profile and characterize the farms and the rearing practices applied by goat breeders along the production objectives and their contribution in household's livelihoods. We further aimed to identify the main breeds comprising the different goat herds and analyze the feeding and health care practices. Finally, we aim to understand the constraints and the challenges impeding goat productivity and the difficulties faced by farmers, to propose potential improvements for the future of goat farming in Kabylia region.

Materials and methods

Ethical considerations

This study was based on non-invasive face-to-face interviews with goat farmers. Prior to each interview, the objectives of the study were clearly explained, and all participants were informed that their participation was entirely voluntary. Informed consent was obtained from all respondents before data collection. Participants were free to decline answering any question or to withdraw from the survey at any stage. No personal identifiers were included in the analytical dataset, and all responses were treated confidentially and analyzed anonymously.

Study area

The study was carried out in Tizi-Ouzou province, the central region of Kabylia. This coastal region is situated in the northern central part of Algeria, with a latitude of 36° 43' 00"N and a longitude of 4° 3' 00" E. The average altitude of the region is approximately 550 m, and it is situated approximately 100 km east of the capital city, Algiers. The province boasts a 70-kilometre coastline along the Mediterranean Sea. Tizi-Ouzou province covers an area of 2,994 square kilometers, with a low population density of 32%. Rugged mountainous areas characterize the region called the Djurdjura Mountains, which comprise 82% of its

territory. Despite its mountainous areas, the region presents a high agricultural potential, which makes it an excellent place to hold small ruminants such as goats (Ouahiba and Arezki 2010; Lamri et al. 2022, 2023).

Our field study was conducted in multiple localities in Tizi-Ouzou province. In collaboration with the local Agricultural Services (DSA), an initial list of goat farms operating in Tizi-Ouzou province was established. Farmers were eligible for inclusion if they were actively raising goats during the survey period and agreed to participate in the study. The final sample included 48 goat farmers distributed across 12 major localities, selected to cover the diversity of production situations in the study area. Farm selection sought broad geographic representation while also considering practical field constraints such as accessibility of farms, availability of respondents, and the feasibility of conducting face-to-face interviews during the survey period. Our study was carried out from December 2018 to July 2019 in the study area to characterize and identify the different breeding systems, as highlighted in (Fig. 1). Because a complete and validated census of all goat production units in the study area was not available in a form suitable for rigorous sampling inference at the time of the survey, we state that the survey was not intended to be a statistically exhaustive census but rather an exploratory cross-sectional field study designed to capture the diversity of goat production situations in the region.

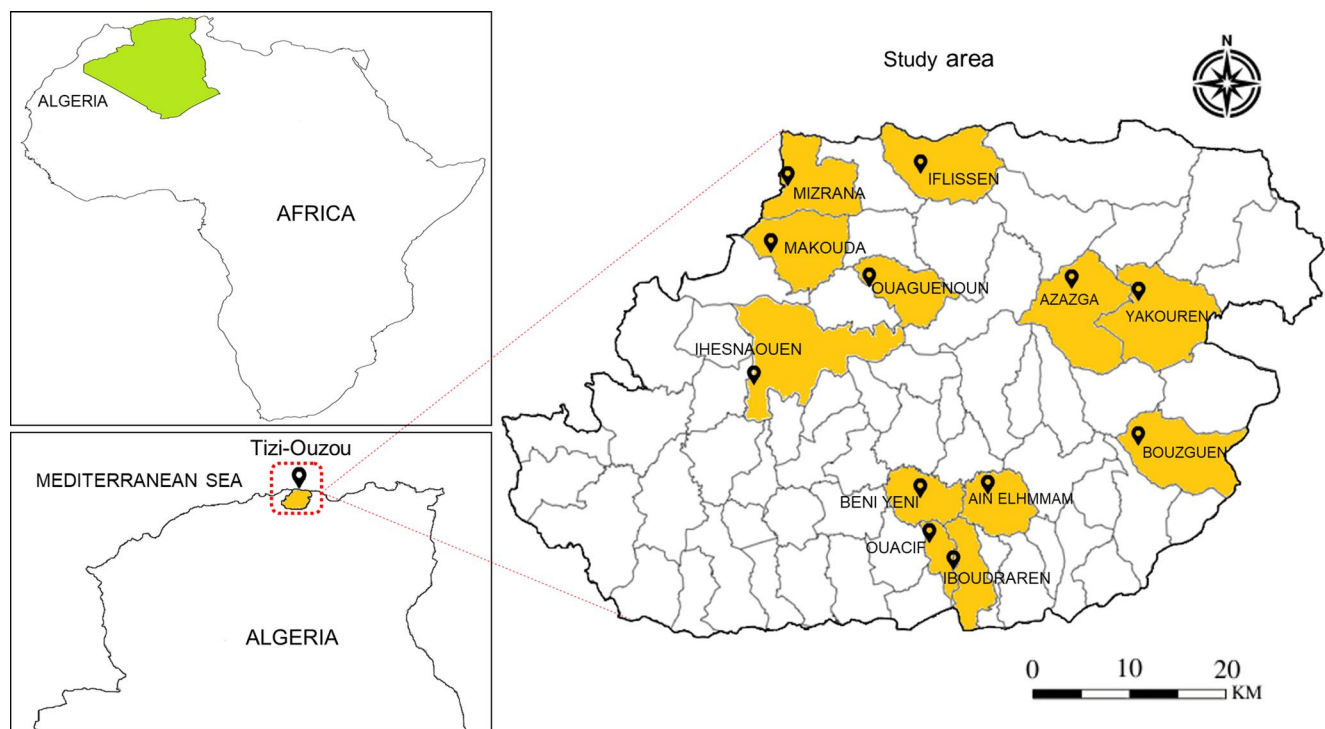


Fig. 1 Map of the study area in Tizi-Ouzou province of Kabylia region

Data collection

Data were collected through a structured questionnaire administered during face-to-face visits to each farm. The questionnaire was not conducted online. All interviews were conducted by the first author, which ensured consistency in the administration of the questionnaire and reduced interviewer-related variability. The interviewer was a PhD student at the time of the survey and was previously briefed on the objectives of the study, the interpretation of the questionnaire items, and the standardized recording of responses. Furthermore, the interviewer led the preparation of the survey under the supervision of the last author and conducted the interviews with the native language of the farmers (Amazigh language), while accurately filling the survey. The questionnaire combined closed-ended and open-ended questions and was organized into six thematic sections: (i) socio-demographic characteristics of the farmer and general farm features; (ii) herd composition and animal management; (iii) feeding practices, grazing systems, and health care; (iv) productive and reproductive management; (v) commercialization channels and consumer preferences; and (vi) major constraints faced by farmers and prospects for improving goat production. Before the survey, the questionnaire was pre-tested on 3 goat farms not included in the final sample to ensure clarity and feasibility, and minor wording adjustments were made accordingly. Each interview lasted approximately 60–80 min, depending on herd size and the level of detail provided by the respondent. All the data collected served to the creation of a large database about the goat farming situation in the study area and used for subsequent qualitative and quantitative statistical analyses.

Statistical analyses

All survey responses, being quantitative or qualitative, were entered into a database in Microsoft Excel (spreadsheet file), then checked for completeness, consistency, and possible data entry errors. They were further coded before statistical analysis. The analyses were performed using R software (version 3.3.1). Descriptive statistics were first generated to summarize the socio-economic characteristics of farmers, herd composition, management practices, and production objectives. Categorical variables were summarized as frequencies and percentages, whereas quantitative variables were summarized as means $\pm$ standard deviations, as appropriate.

Because the farm typology was based mainly on categorical management and structural variables, multiple correspondence analysis (MCA) was used as the main exploratory multivariate method. A total of 16 variables judged to be the most informative for discriminating goat

production systems were selected as active variables (Table 1). These variables described farm structure, herd management, feeding practices, breeding practices, and health-related management. Prior to MCA, categorical modalities were checked for consistency and recoded where necessary to ensure interpretability (Table 1). The MCA was performed using the FactoMineR package (Lê et al. 2008). The first factorial dimensions were retained based on their contribution to total inertia, the interpretability of the factorial planes, and the relative contribution of variables and modalities to axis construction. Variables contributing most strongly to each retained dimension were identified using their contribution values and *v*-test statistics. Furthermore, because MCA is designed for categorical variables and can tolerate associations among modalities to some extent, the objective was not to eliminate all correlation as in a predictive regression framework, but rather to avoid redundant or near-duplicate variables that would artificially overweight a single management domain. Therefore, prior to final selection, variables were screened for redundancy based on biological meaning, overlap of information content, and distribution of modalities. Highly sparse or weakly informative variables, and variables judged redundant with more interpretable alternatives, were excluded from the active set. The final number of 16 variables was therefore determined by a balance between (i) preserving the major dimensions of farm management heterogeneity, (ii) avoiding overparameterization relative to the sample size, and (iii) maintaining interpretability of the factorial space and the resulting clusters.

To establish the farm typology, hierarchical clustering analysis (HCA) was then applied to the individual farm coordinates obtained from the retained MCA dimensions. Clustering was performed using Ward's minimum variance method and Euclidean distance, which is commonly used for typology construction from factorial coordinates. The final number of clusters was determined based on the dendrogram structure, the relative gain in between-cluster inertia, and the biological/agronomic interpretability of the resulting groups. Since the clustering was based on MCA coordinates, standardization of the original variables was not required at the clustering stage, since the factorial coordinates are dimensionless synthetic scores derived from the MCA space.

To further describe and compare the clusters, associations between cluster membership and categorical variables were assessed using the chi-square test or Fisher's exact test when expected cell counts were small. For quantitative variables, normality was evaluated using the Shapiro–Wilk test. A significance threshold of $P < 0.05$ was used, and $P < 0.10$ was considered a tendency.

Table 1 Variables and modalities codes used in the multiple correspondence analysis (MCA)

Variables	Codes	Modalities
House holding surface	HSEsfc	HSEsfc1: 100–500 HSEsfc2: >500 HSEsfc3: <5
House holding Age	HSEage	HSEage1: <5 HSEage2: 5–10 HSEage3: 11–15 HSEage4: 16–20 HSEage5: 21–25 HSEage6: >25
Animal litter	Animlitr	Animlitr1: None Animlitr2: Straw Animlitr3: Others
Disinfection	Disinfect	DisinfectNo: No DisinfectYes: Yes
Disinfection frequency	Disinfectfreq	Disinfectfreq1: Never Disinfectfreq2: Once per day Disinfectfreq3: Once per month Disinfectfreq4: Once per year Disinfectfreq5: 2–5 per year
Herd size	HerdSz	HerdSz1: <25 HerdSz2: 25–50 HerdSz3: 51–100 HerdSz4: >100
Livestock specialization	LivestSpec	LivestSpecNo: No LivestSpecYes: Yes
Cohabitation	Cohab	CohabNo: No CohabYes: Yes
Male changing frequency	MaleChng	MaleChng1: 1–2 year MaleChng2: 2–3 year MaleChng3: Reform MaleChng4: No male
Controlled mating	ContMat	ContMatNo: No ContMatYes: Yes
Crossbreeding	Xbreed	XbreedNo: No XbreedYes: Yes
Feeding system	FedSys	FedSys1: Free grazing FedSys2: Free grazing and supplement FedSys3: Through feed
Grazing (year)	Graz	GrazNo: No GrazYes: Yes
Dietary supplementation	Suppl	SupplNo: No SupplYes: Yes
Deworming	Deworm	DewormNo: No DewormYes: Yes
Vaccination	Vacc	VaccNo: No VaccYes: Yes

Results and discussion

Background characterization of the surveyed farms/farmers

The variables related to the socio-economic characterization

of the goat keepers are presented in Table 2. Out of the 48 interviewed farmers (goat keepers), all of the respondents revealed owning their farms. Almost all the farms of different localities of the study area were headed by men (88%), and only (12%) were female. This could be due to the fact that animal farming is generally an activity attributed to

Table 2 The socio-economic characterization of the respondents (farmers)

Variables	Modalities	(%) of Respondents
Gender	Male	88
	Female	12
Age (years)	<30	4
	30–39	33
	40–49	31
	50–59	24
	>60	8
Level of education /Literacy	No formal education	10
	Primary school	6
	Secondary school	51
	Post-Secondary school	27
	University	6
Breeding experience (years)	<5	29
	5–10	22
	10–15	14
	15–20	12
	20–25	10
	≥25	12
Breeding knowledge	Legacy	80
	Specialized training	4
	Other sources	16
Other sources of income	No	51
	Yes	49
Purpose of goat keeping	Income	69
	Milk Production	51
	Meat Production	27
	Traditional Activity	39
Goat keeping responsibility	Owner	61
	Family labor	35
	Workers	4

men, especially in the mountainous rural areas but women still contribute reasonably to this activity. The masculine predominance was similarly reported in earlier studies from the Kabylia region (Kadi et al. 2014; Moula et al. 2017). Previous other studies from Cuba and Mozambique about the characterization of different smallholders (goats) production systems reported a male predominance (Gispert Muñoz et al. 2019). Unlike other studies that convened a dominance of females in goat breeding (Dossech et al. 2021), this involvement could be related to the sharing responsibilities among the family members (Fikru and Gebeyew 2015).

Age range was found to be variable (Table 2). A total of 63% of the farmers are aged more than 40 years old and 33% were in their thirties, while a minority (4%) were under 30 years. This variation of age is not related to the distribution of the breeders in the study area. The fact that the majority are above their 40s reflects experience in animal production, with or without training, while the low percentage of young people under 30 years of age may be due to the orientation of young people to other more remunerative jobs

than animal production, as reported in other studies (Khelifi and Ouchene 2021). In general, it is known that the farmers more involved in goat breeding are likely to be the middle aged farmers (Dossa et al. 2015).

In the case of our study area, the education level of the farmers was concentrated between farmers who have a level between secondary and post-secondary school (78%). Few attained a primary school (6%) or a university level (6%), while the others (10%) were illiterate. The proportion of illiterates is lower compared to those reported in the Algerian steppic regions: in Laghouat by 44.3% (Laouadi et al. 2018) and M'Sila by 60% (Hadbaoui 2013). It is obvious that the education level of the farmers is a significant parameter in the production systems as it impacts directly farmers behaviors and knowledge towards the different breeding practices (Rahadi et al. 2020). Another study reported the low level of education of the farmers in Tunisia (Nafti et al. 2021). Generally, the farming knowledge of the farmers is gained from their own experience or from their parents. The majority of them consider it as a legacy (80%) and a traditional practice that is not allowing them to be productive; and only a few of them had specialized training (4%), generally organized by the local management of agricultural services of each region, and they target to secure with livestock farming their unique income. The possible causes of the low productivity problem can be attributed to several issues, for instance to the low level of education in the sector. Nevertheless, several other factors may also be at the origin of the low productivity of livestock, such as bad weather conditions – Livestock dependence on rainwater has often negatively affected the production of animal products –, lack of modernization in the sector, and diseases (Abdallah et al. 2019; Kdidi et al. 2021). Moreover, limited grazing land and scarcity of feed resources, disease outbreaks resulting in high mortality and poor housing can be other factors reported for goat farming in Africa (Dossa et al. 2007).

For a better understanding of the importance of goat production in generating income, our survey revealed that goat breeding represents the primary source of income for 49% of them and 51% had parallel activity in private or public sectors (Table 2). Thus, for this second category of breeders, income from goat breeding is complementary. In addition, the farmers highlighted many purposes of holding goats, and among the most reported we mention milk sale (51%) and/or meat (27%) but also often by selling the live animals or their kids to make income. The contribution of goat production in the alleviation of the livelihood and food security of these farmers was already reported by various studies (Peacock 2005; Ouchene-Khelifi et al. 2015). While, 39% of the respondents consider goat breeding an ancient tradition that should always be preserved for future generations, our results are in agreement with other findings, for instance

from rural areas of the Nile Delta in Egypt (Abdallah et al. 2019). For this group of breeders, goat breeding is exclusively planned for self-consumption (meat and milk), family celebrations and for economic purposes. Because of their small size, slaughtered goats are entirely consumed in few days by all family members, without the risk of deterioration due to the lack of refrigeration facilities. Always in the same idea, the top-ten countries producing goat meat are all in developing countries located in Africa and Asia; indicating the importance of goat meat to people in resource-poor zones, of which the majority is produced and consumed locally within households (Dubeuf et al. 2004; Aziz 2010).

The survey revealed that 61% of goat farmers are taking the householding responsibility alone, while 35% of them shared this responsibility with the family members and 4% use outside labor. In fact, the implication of family members needing laborers depends on the herds' sizes. Goats have the potential to reduce poverty in various countries of the world due to the role they play in food security (Peacock 2005), and in some communities the goat farming is considered as a sign of wealth (Saico and Abul 2007; Hadjigeorgiou 2011).

Table 3 The factors characterizing the animal feeding and health care applied by the farmers

Variables	Modalities	(%) of respondents
Cohabitation housing	No	49
	Yes	51
Herd size	<25	71
	25–50	18
	51–100	4
	> 100	6
Grazing all year	No	35
	Yes	65
Feeding system	Free grazing	6
	Free grazing and Supplement	90
	Through feed	4
Water analysis routine	No	94
	Yes	4
Udder washing frequency	Before milking	86
	After milking	4
	Irregular	6
	Rarely	6
	Never milking	2
Controlled mating	No	59
	Yes	41
Crossbreeding	No	65
	Yes	35
Vaccination	No	35
	Yes	65

Background characterization of the goat flocks

In Algeria, goats are the third most important livestock species after sheep and cattle. Over 95% of the world's goat population is kept in developing countries, of which 64% are found in rural arid and semi-arid agro-ecological areas (Rumosa Gwaze et al. 2008). Globally, and over the past decade, there had been an increase in goat production and there are currently over a billion goats, and Africa contributes approximately by 36% of global production (Mazhangara et al. 2019). This study revealed that 51% of the breeders has opted for mixed breeding with the presence of sheep, cattle, poultry, and sometimes even with horses and donkeys, while the others (49%) prefer keeping only goats (Table 3). Generally, goat husbandry mixed with sheep is the widely used practice in traditional farming systems (Caroprese et al. 2015; Simões et al. 2021; Al-Barakeh et al. 2024), which is also a common practice in Kabylia region (Ouchene-Khefifi et al. 2015). Overall, our results are higher to the 35% of breeders reported in other studies that exclusively raises goats in their farms (Madani et al. 2013; Moula et al. 2017). The mixed crop-livestock system is also used in Algeria and more particularly in Hoggar and Tassili. This system is characterized by the breeding of livestock (cattle, poultry, rabbit, and sheep). All the animals provide the manure necessary for the fertilization of agricultural soils while the animals in return benefit the farmer during the period of food shortage.

The main goat breeds or populations reared by the farmers were variables. Previous studies showed some interactions between breed and rearing system on products quality (Ripoll et al. 2021). Researchers suggest that livestock breeders focus on the choice of breed and breeding system to produce the quality carcasses demanded by a competitive market in the case of meat (Peacock et al. 2011; Mohlatlole et al. 2015; Daskiran et al. 2018; Marsoner et al. 2018). In Algeria and Kabylia region, the purpose of use is mostly for milk production. Generally speaking, the Algerian goat herd presents a good level of genetic diversity (Tefiel et al. 2018) and often associated with diversity of breeding methods, however, and to the best of our knowledge very few descriptions of their populations and genetics have been provided to date. Within the surveyed farmers, the herd represents few local goat breeds such as the *Arbia*, the *Naine de Kabylie* or the *Makatia*. A significant number of them were imported European breeds represented mainly by Saanen and to a lesser extent Alpine, known for their high milk yields. We can also observe a mixed group of uncontrolled or controlled crossbreeding local breeds with imported breeds. This is due to the fact that the *Naine de kabylie* breed is not profitable in terms of productivity for both meat and milk, so the breeders have this tendency to crossbreed for genetic amelioration (Kadi et al. 2014; Moula

et al. 2017). This is in fact alarming in terms of the loss of the local animal genetic resources.

Our results showed that the number of goats per herd varies according to the breeders (Table 3), and the majority of the breeders (71%) have less than 25 heads. The other minor parts are characterized by medium flock size ranging 25 to 100 heads (22%) and 6% of the farmers that had largest flocks composed of more than 100 heads. In addition, and as represented in Fig. 2, there are less than ten breeders who have a homogeneous composition of their herds with high effective of all the categories of goats. However, there is a remarkable dominance of Does (Goats > 6 months) even in the smallest flocks, unlike the bucks, which are generally absent or minor in the small flocks. This is mainly related to the use of bucks for insemination. Therefore, some of the farmers prefer using buck services from their neighbors which is consistent with earlier results reported in an Ethiopian study (Abraham et al. 2017). This indicates that the Does remains in the flock for reproduction and milk production purposes, while the male is generally directed to meat production. One of the other reasons for the weak presence

of large flocks is due to the Peste des petits ruminant (PPR) disease considered as goat plague, which is the most fatal infectious viral disease for small ruminants, which unfortunately touched the animals in the period of our study. Thus, the size of the flocks have been significantly reduced. Generally, the genetic erosion of the national herd and the lack of information on the genetic and phenotypic characteristics of the goat breeds, mainly due to cross-breeding with imported European and commercial breeds, with the possibility of low resistance or less resilient compared to the autochthonous breeds and the emergence of destructive diseases. The main abortive diseases in goats in Algeria are brucellosis and toxoplasmosis, among others (Gabli et al. 2015; Haif et al. 2021). For example, authors found that the Toxoplasmosis, due to *Toxoplasma gondii*, is one of the major parasitic causes of reproductive failure associated with abortion in female goats in Tebessa, northeastern Algeria (Ait Issad et al. 2020). Taking into consideration that some of these diseases are zoonoses, breeders must take imperative precautionary hygiene measures to reduce the prevalence of these

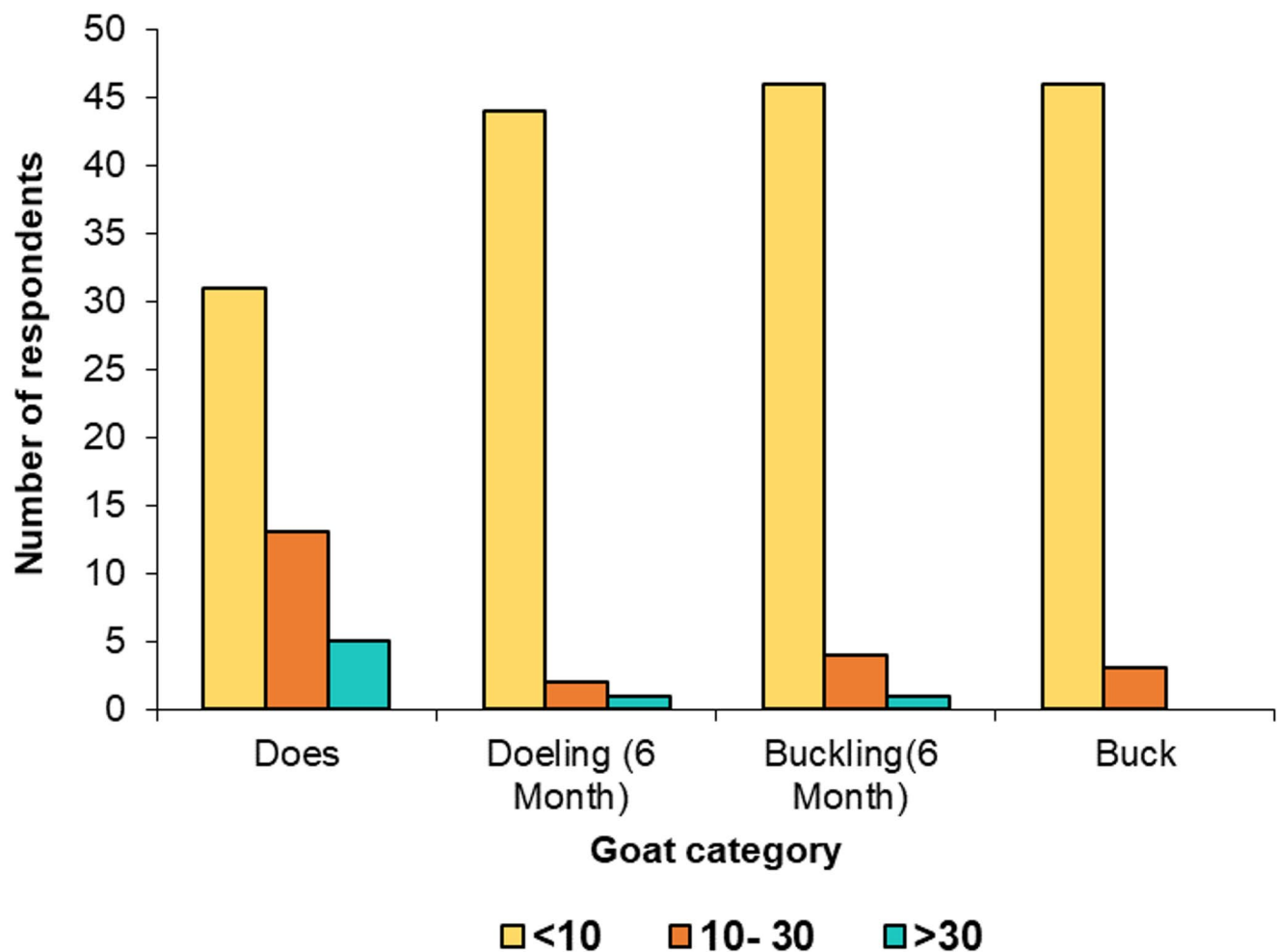


Fig. 2 Goat herd composition by age categories

infections and, therefore, diminish economic loss and may cause public health risks in Algeria.

Background characterization of the feeding, health and breeding practices

As reported in Table 3, the majority of the farmers (90%) feed their goats on pasture, with traditional supplementary feeding. This type of feeding is widely practiced in Algeria (Kadi et al. 2014; Moula et al. 2017; Laouadi et al. 2018). This sustainable practice reduces production costs and allows farmers to rationalize their resources. The supplements mainly comprise fodder, hay, straw, organic kitchen waste, tree leaves, and crop residues. Few farmers use commercial feeds or certain cereals such as wheat and barley. Feeding may be one of the largest expenses of any goat operation. The farmers revealed major feeding constraints, which were the lack of forage and the high cost of animal feed, fiber and concentrates. The manner how goats are reared in Kabylia region is shown in few pictures reported in Fig. 3. They highlight the diversity of practices applied by the farmers from extensive to intensive productions systems, with sometimes a mix of both depending on their facilities, capacities and means.

As stated above, goats, despite being strong, they can be sensitive to certain diseases (Kitching 2003; Kardjadj 2017; Dudek et al. 2022), the most common ones in goat farming in Algeria are diarrheal diseases, pneumonia, abortive diseases (brucellosis, toxoplasmosis, chlamydia, Encephalitis Virus (SGEV), Q fever, Rift Valley fever, and blue tongue), parasites (external and internal) and skin diseases. The Algerian authorities have carried out a large-scale vaccination campaign against the main diseases of small ruminants such as goat. As shown in Table 3, most of the farmers deworm and vaccinate their goats. It should be noted that the Algerian government subsidizes a national vaccination campaign for small ruminants against PPR. According to our results, around 35% of breeders are reluctant to receive this vaccination even though it is taken in charge by the government veterinary services.

Typology of goat farming systems in Kabylia region

Multiple correspondence analysis was applied to the 16 most important categorical variables with modalities (Table 1; Fig. 4). Table 4 summarizes the main active variables contributing to the construction of the first three MCA dimensions, together with the corresponding eigenvalues and percentages of inertia explained by each retained axis. The first three dimensions accounted for 30.04% of the total inertia (12.13%, 9.31%, and 8.60%, respectively), which is considered acceptable in an exploratory MCA applied

to heterogeneous categorical variables, where the inertia is often distributed across several dimensions. The interpretation of the factorial space was therefore based primarily on the variables showing the highest contributions to axis construction rather than on formal hypothesis-testing criteria (Fig. 4). Thus, Table 4 presents the degree of association (η^2) between the active categorical variables and the first three retained MCA dimensions, allowing identification of the variables that most strongly structured the factorial space. Based on the adopted threshold ($\eta^2 \geq 0.20$), the variables most strongly associated with Dimension 1 were house holding surface, animal litter, disinfection, disinfection frequency, herd size, livestock specialization, cohabitation, and deworming. Dimension 2 was mainly associated with house holding age, disinfection frequency, herd size, male changing frequency, and dietary supplementation, whereas Dimension 3 was primarily structured by house holding surface, animal litter, herd size, male changing frequency, and vaccination. Notably, herd size showed consistent and relatively high η^2 values across all three dimensions, indicating that it was an important discriminating variable in the construction of the typology. Overall, the MCA dimensions suggest that differences among goat production units were mainly related to farm structure, herd size, hygiene and health management, reproductive management, and feeding practices, which together formed the basis for the subsequent hierarchical clustering of farms.

The hierarchical classification led to the identification of four clusters characterizing the typologies of goat farming in Kabylia region (Fig. 5; Tables 5 and 6). Further details of the distribution of the farmers in the four clusters by modalities are given in the Supplementary Table 1.

The cluster 1 grouped 11 farmers (22% of the total). It is characterized as “extensive goat production system or pastoral system”. The absence of investment and inputs is the main characteristic of this production system (practice typology). For most breeders in this group (8/11), feeding is based on grazing/pasture and a limited supplementation with organic waste (i.e., kitchen, crop residues, and leaves of some trees such as elm, ash, and olive trees). Worthy to mention that two breeders in this group feed their goats exclusively on pasture. The goats are driven to the fields, often by children or elderly people (a common practice in rural regions like Kabylia). The selective and opportunistic grazing behavior of goats allows them to meet their food needs in the complex soil and climate conditions of Kabylia. Earlier studies reported that goats are usually associated with traditional production systems with low externalities (Alexandre and Mandonnet 2005). Ten of the eleven farmers have a house-holding area of 100 to 500 m², and all the farmers have less than 25 goats, and 8/11 of them and in addition to their goats, raise other animal species (sheep and poultry).

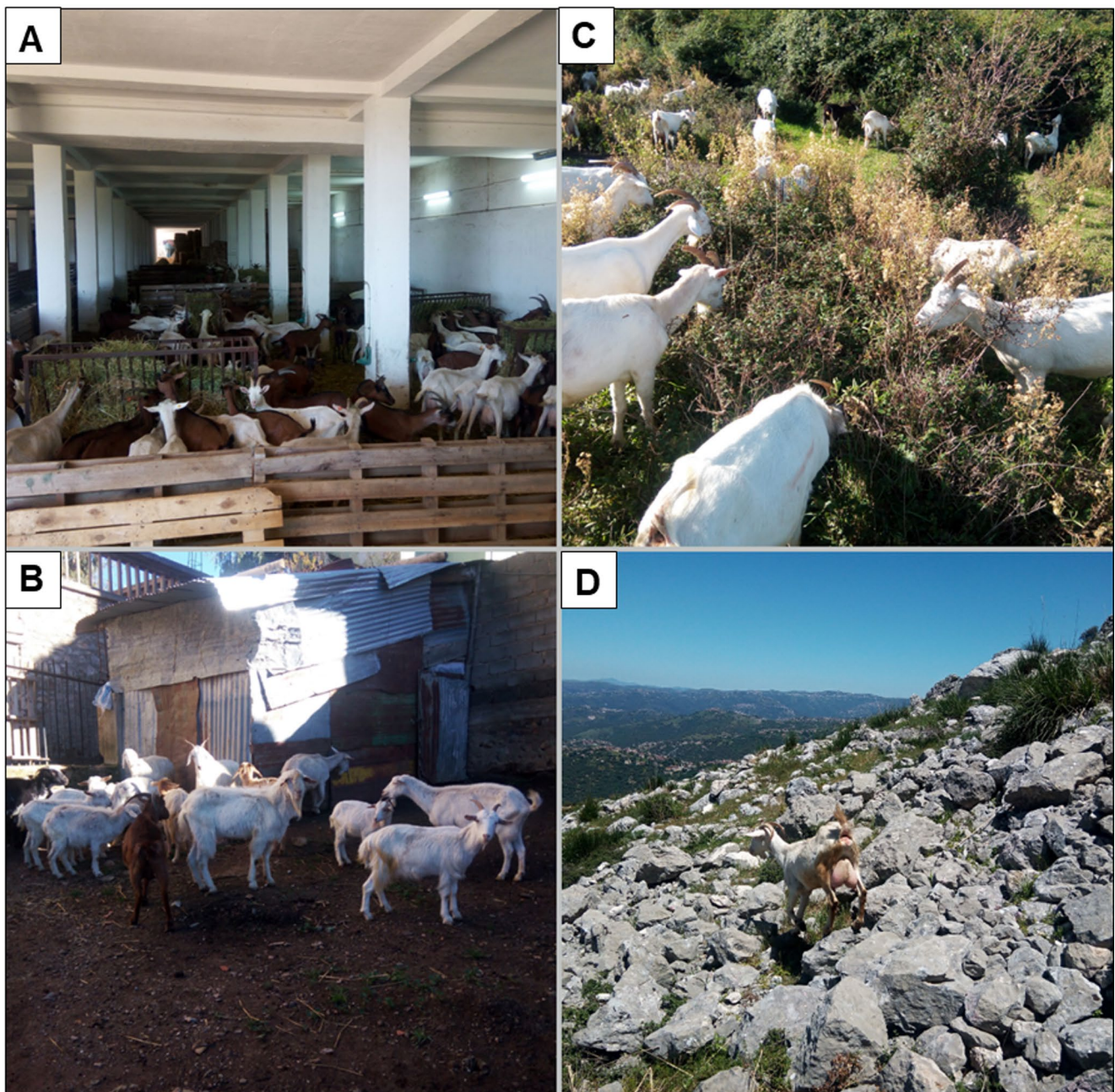


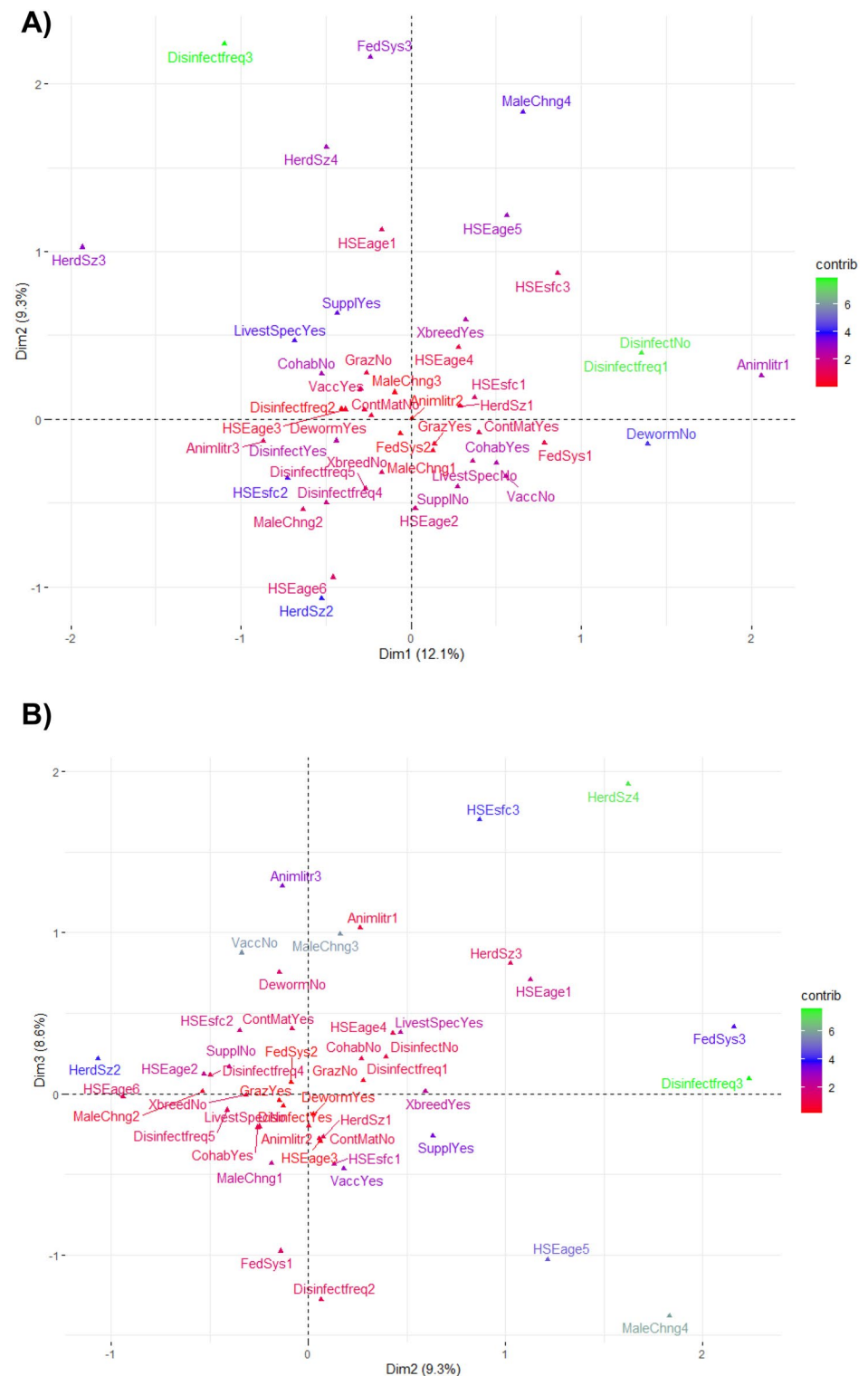
Fig. 3 Diversity of rearing practices applied for goat breeding by farmers in Kabylia region, standing from extensive to intensive production, with sometimes a mixture of both. **(A)** Goats reared exclusively under modern breeding practices under intensive production; **(B)** A mixture

of intensive production but less elaborated practices, **(C)** Extensive production but with an overlap with intensive practices; **(D)** Extensive and pastoralism production type in the mountains

The majority (10/11) of the breeders interviewed confirmed that their breeding is not specialized. For some time now, the trend in Kabylia region has shown a renewed interest in systems that combine plant and animal production. Polyculture-livestock farming is therefore seen as a method of technical intensification to improve the income of the agropastoralists by limiting the purchase of inputs (Jayet et al. 2020). Concerning the prevention of pathologies, 10/11 of

the breeders never disinfect the breeding installations, and only six vaccinate their animals. This group practicing traditional husbandry corresponds to the practices described in previous studies for the majority of goat farms in the Kabylia region (Moula et al. 2017). Small flocks are often raised with sheep whose breeding objective is mixed, producing kids for sale and milk for self-consumption.

Fig. 4 Modalities graphic representation on the three first axis of the multiple correspondence analysis (for the meaning of the codification refer to Table 1). **(A)** Dimension 1 and 2 and **(B)** Dimension 2 and 3



The cluster 2 grouped 14 farmers (29% of the total). This cluster represents an “improved traditional farming system”. For most farmers of this typology, grazing is the primary feed source for their goats. However, as in the first group, farmers supplement their goats with feed. The animals’ house holding surface in this group varies from 100 to

500 m². The average number of goats per farm is also less than 25 and most farmers raise other animal species (9/14), and the goat products is mixed (milk and kids). Compared to the first group, the improvements made by the farmers are mainly related to better practices of vaccination (14/14),

Table 4 Degree of association (η^2) between the studied categorical variables and the first three MCA dimensions

Variables	Dimension 1	Dimension 2	Dimension 3
House holding surface	0.32	0.101	0.342
House holding Age	0.093	0.445	0.186
Animal litter	0.25	0.005	0.248
Disinfection	0.595	0.05	0.017
Disinfection frequency	0.643	0.573	0.087
Herd size	0.278	0.418	0.312
Livestock specialization	0.249	0.117	0.078
Cohabitation	0.264	0.07	0.045
Male changing frequency	0.087	0.267	0.512
Controlled mating	0.109	0.005	0.112
Cross breeding	0.055	0.187	0
Feeding system	0.056	0.199	0.089
Grazing (year)	0.036	0.041	0.004
Dietary supplementation	0.118	0.253	0.044
Deworming	0.322	0.004	0.095
Vaccination	0.165	0.061	0.407

η^2 values indicate the strength of association between each categorical variable and the MCA dimensions. Higher η^2 values indicate stronger relationships. Bold values indicate the strongest associations ($\eta^2 \geq 0.20$)

disinfection of the installations (14/14) with a frequency of 2 to 5 per year in 10/14 breeders.

The cluster 3 grouped 18 farmers (37% of the total). This typology (group) has few similarities to the former clusters, but characterized as an “improved traditional livestock system”. As with the two previous clusters, feeding is based on grazing and supplementation using organic kitchen waste, leaves from specific trees found in Kabylia, fodder, and agricultural by-products. The surface area of livestock buildings in this group is greater ($> 500 \text{ m}^2$) for 11/18 farmers. In this group, disinfection is practiced by 17/18 farmers, with frequencies varying from 1 to 5 times per year. Half of the farmers of this cluster vaccinate their animals. The average herd size in this group varies from 25 to 50 heads, a higher number than the previous clusters.

The cluster 4 grouped few farmers ($n=5$; 12% of the total). This cluster is characterized as an “intensive goat production system”. This group is composed of farmers aged between 40 and 49 years and they possess large housing units ($> 500 \text{ m}^2$, for 4/5 farmers). In contrast to the others, these farmers use bedding rather than straw, and disinfect more frequently than clusters 2 and 3. The average size of their herd is more than 50 heads, which means that the farmers exclusively raise goats. The goats’ diet is based on pasture and a more adapted supplementation all the other groups. The majority of the farmers in this cluster vaccinate their goats. The main activity of this group is goat breeding.

Conclusion

This study established an exploratory typology of goat production systems in the Kabylia region based on survey data collected from 48 goat farmers from Tizi-Ouzou province. Using multiple correspondence analysis combined with hierarchical clustering, four distinct farm typologies were identified, ranging from extensive/pastoral systems to improved traditional systems and a smaller group of more intensive farms. The main factors differentiating these typologies were herd size, housing characteristics, sanitary management (disinfection, disinfection frequency, deworming, and vaccination), feeding and grazing practices, dietary supplementation, and reproductive management variables. Overall, the results show that goat farming in the study area is heterogeneous and is mainly structured by differences in management intensity and the use of external inputs. This typology provides a first analytical framework for describing the diversity of goat production systems in Kabylia. However, given the exploratory nature of the study, the limited number of surveyed farms, and the regional scale of the sampling, the proposed classification should be considered preliminary and would benefit from validation through broader surveys including a larger number of production units and additional districts.

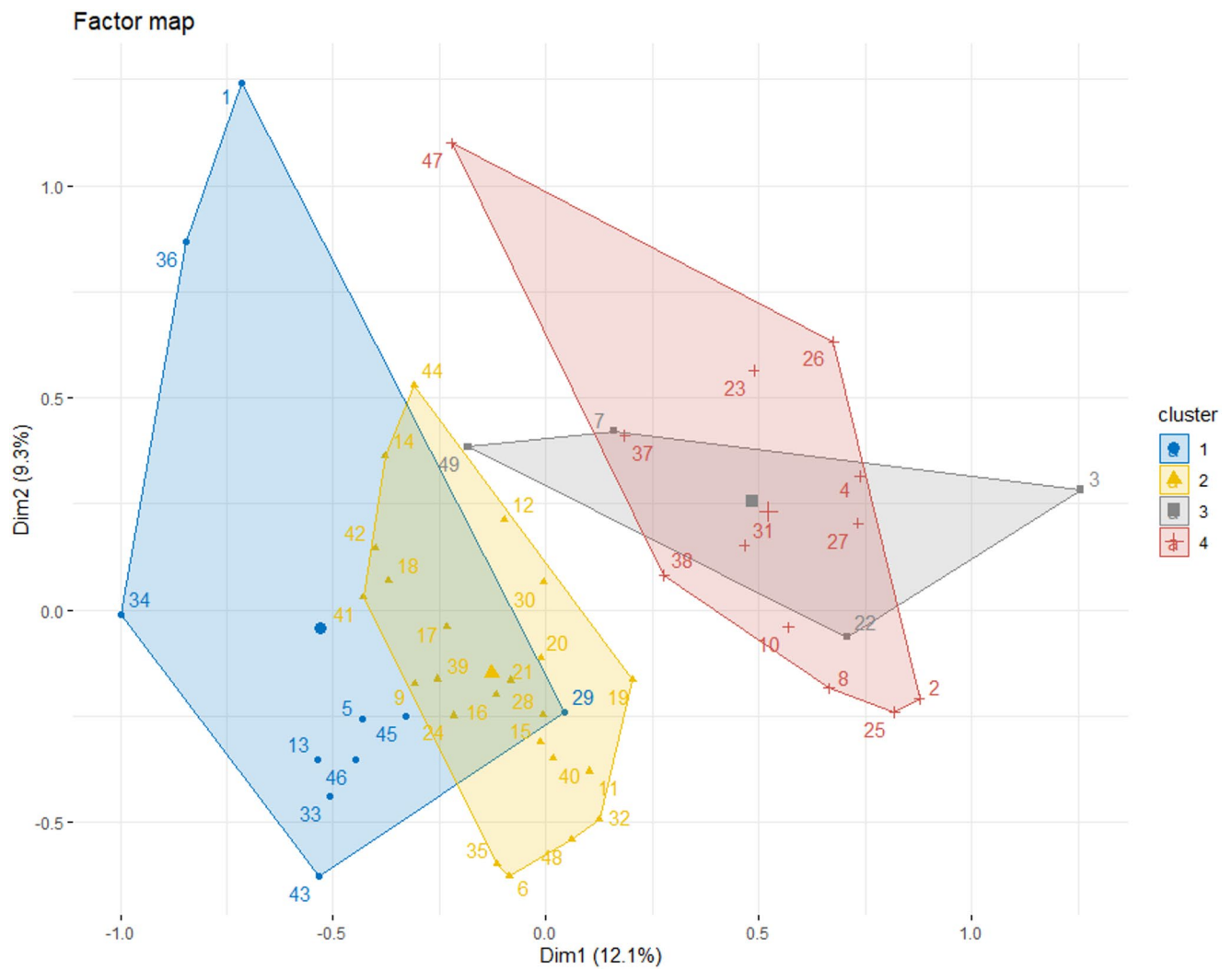


Fig. 5 Clustering analyses highlighting the four clusters identified in this study based on the multiple correspondence analysis. The numbers correspond to the codification of each respondent

Table 5 Distribution of the farmers (in percentages, %) in the different clusters¹ for the most relevant and significant modalities retained in this study as having a minimum of 50% contribution within a cluster

Modalities ²	Cluster 1 (n = 11)	Cluster 2 (n = 14)	Cluster 3 (n = 18)	Cluster 4 (n = 5)
HSEsfc2	- ³	11.76	64.71	23.53
HSEage1	-	-	100	-
HSEage2	26.32	15.79	52.63	5.26
HSEage3	11.11	55.6	11.11	22.22
HSEage5	40	60	-	-
HSEage6	-	-	100	-
Animltr1	100	-	-	-
Animltr3	-	-	40	60
DisinfectNo	83.33	-	8.33	8.33
Disinfectfreq1	83.33	-	8.33	8.33
Disinfectfreq2	-	50	50	-
Disinfectfreq3	-	66.67	-	33.33
Disinfectfreq4	8.33	8.33	66.67	16.67
Disinfectfreq5	-	52.63	42.11	5.26
HerdSz2	-	11.11	88.89	-
HerdSz3	-	-	-	100
HerdSz4	-	-	-	100
MaleChang2	-	16.67	66.67	16.67
MaleChang4	66.67	33.33	-	-
FedSys1	50	-	50	-
FedSys3	100	-	-	-
GrazNo	12.50	56.25	25	6.25
SupplNo	30	6.67	60	3.33
SupplYes	11.11	66.67	-	22.22
DewormNo	71.43	14.29	14.29	-
VaccNo	35.29	-	52.94	11.76

¹**Cluster 1:** extensive goat production system or pastoral system; **Cluster 2:** improved traditional farming system; **Cluster 3:** improved traditional livestock system; **Cluster 4:** intensive goat production system

² The abbreviations of the modalities are described in Table 1

³ “-” indicates no significant distribution of the variable in that cluster. The modalities in bold are those that are the major contributors within each cluster (> 50%)

Table 6 Distribution of the farmers in the four clusters by modalities

Modalities	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Total
HSEsfc1	10	11	7	0	28
HSEsfc2	0	2	11	4	17
HSEsfc3	1	1	0	1	3
HSEage1	0	0	2	0	2
HSEage2	5	3	10	1	19
HSEage3	1	5	1	2	9
HSEage4	3	3	1	2	9
HSEage5	2	3	0	0	5
HSEage6	0	0	4	0	4
Animltr1	2	0	0	0	2
Animltr2	9	14	16	2	41
Animltr3	0	0	2	3	5
DisinfecNo	10	0	1	1	12
DisinfecYes	1	14	17	4	36
Disinfectfreq1	10	0	1	1	12
Disinfectfreq2	0	1	1	0	2
Disinfectfreq3	0	2	0	1	3
Disinfectfreq4	1	1	8	2	12
Disinfectfreq5	0	10	8	1	19
HerdSz1	11	13	10	1	35
HerdSz2	0	1	8	0	9
HerdSz3	0	0	0	2	2
HerdSz4	0	0	0	2	2
LivestSpecNo	10	9	11	2	32
LivestSpecYes	1	5	7	3	16
CohabNo	3	5	10	5	23
CohabYes	8	9	8	0	25
MaleChng1	5	10	8	2	25
MaleChng2	0	1	4	1	6
MaleChng3	4	2	6	2	14
MaleChng4	2	1	0	0	3
ContMatNo	6	9	10	4	29
ContMatYes	5	5	8	1	19
XbreedNo	5	11	14	1	31
XbreedYes	6	3	4	4	17
FedSys1	2	0	2	0	4
FedSys2	8	14	16	5	43
FedSys3	1	0	0	0	1
GrazNo	2	9	4	1	16
GrazYes	9	5	14	4	32
SupplNo	9	2	18	1	30
SupplYes	2	12	0	4	18
DewormNo	5	1	1	0	7
DewormYes	6	13	17	5	41
VaccNo	6	0	9	2	17
VaccYes	5	14	9	3	31

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable.

Declarations

Conflict of interest The authors declare that they have no conflicts of interest that could have influenced the results or interpretation of the study.

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