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Characterisation of smallholders' goat production systems in the Fatick area, Senegal

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Abstract

Senegal, like the other Sahelian countries, remains an important livestock area, particularly for ruminants, with almost 36% of its livestock population was goat in 2016. The national herd increased from 2010 to 2016, from 3.32 to 3.54 million head of cattle, 5.6 to 6.68 million sheep and 4.8 to 5.7 million goats, i.e. annual growth rates of 1.1%, 3.2% and 3.13% respectively. Thus, due to diversification of local agricultural resources and the strengthening of goat breeding techniques in the Fatick area, a programme aiming to develop the local goat sector was set up in 2010. The programme focused on improving animal husbandry, providing new added values to goat products and structuring the goat sector. This study's aim is to better understand goat rearing systems in the area, in order to propose, together with the herders, ways of improving these systems, taking into account family and socio-cultural considerations. To better evaluate the diversity in different production systems, a survey of animal rearing practices was carried out. The survey involved 45 farmers in four localities. It revealed that the farmers were all agro-pastoralists practising a mixed farming system. The majority (93%) supplemented their animals with agricultural by-products, agro-forestry and kitchen leftovers. A multiple correspondence analysis identified three groups: cluster 1 (milk producers and processors into traditional curdled milk, selling animals for household needs), cluster 2 (milk processors into yoghurt and cheese) and cluster 3 (goat vendors in pastoral and the agro-pastoral system). The study of the objectives and contexts of goat farming in the Fatick will enable policy-makers to design strategies for the sustainable development of family goat farming in the area.

Keywords: Multivariate analysis, Meat, Milk, Production systems

Introduction

In developing countries, livestock farming is facing the challenge of an increasing demand for animal products, which is expected to double by 2050 (FAO 2011). At the same time, in the context of ongoing global changes (climate, demographics, pressure on resources, and urbanisation), there is a priority issue of vulnerability of

populations who relying on livestock. In Senegal, in the field of agricultural production, livestock is a strategic sector of the national economy, present in nearly 60% of farming households. Livestock accounts for 4.6% of the Gross Domestic Product and contributes nearly 0.2% to its growth, which was 4.3% in 2014 (ANSD 2017). Goat farming is a key agricultural sector in developing countries. Indeed, about 35% of the world's goat population is found in Africa (Skapetas and Bampidis 2016). According to FAOSTAT 2019, Senegal has more than 6,200,000 goats, representing 1.35% of the goat population in Africa. At present, goat breeding is increasingly the subject of special attention in programmes run by both the

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public authorities and veterinary research. According to Peacock (2008), goat farming, because of its productive potential and multi-functionality, can play a major role in the fight against poverty and food insecurity. Its economic role in pastoral areas, through its character of mobilisable savings, gives it an increasingly important place in sectors where women are strongly involved (De Vries 2008). Thus, in order to increase the level of productivity (milk and meat), a Goat Sector Improvement Programme (PAFC) was set up in 2010, as part of the decentralised cooperation between the regions of Fatick in Senegal and Poitou Charente in France. The programme aimed at helping populations to combat poverty in rural areas, focusing on improving livestock management, adding value to goat products and structuring the goat sector (Goetz 2011). Although the programme meets certain expectations of the actors (better valorisation of milk, reduction of child mortality, grouping in associations), but its approach has not in reality allowed to take into account the farmers' social and economic logics and imaginations as well as other needs that are indispensable for adoption of the proposed innovations. All the goat farmers, who preferred instead to introduce an improving buck into their farms, abandoned the practice of artificial insemination, which was the project's main innovation in reproduction. This programme intervened in an area that is dominated by a traditional goat-rearing system. This system depends on available natural resources, where several factors limit its development, including continuous exploitation of land under cultivation and a considerable reduction in available fodder (Coly et al. 2011). In order to contribute to the organisation of the goat sector, the traditional production system must be understood.

The present study thus aimed to characterise the goat production systems prevailing in the region, to identify gaps in order to inform uptake pathways, facilitate policy formulation and strengthen the capacity for improvement and investment in goat breeding development programmes.

Materials and methods

Study area

The Fatick area is centrally located at 14° 21.4836' N and 16° 35.1498' W. It covers an area of 6685 km², with a population of 714,389 inhabitants or 5.3% of the national population (ANSD 2017). The climate is Sudano-Sahelian, with rainfall ranging from 600 up to 700 mm. The average annual minimum temperature varies between 21 and 24 °C from December to the end of February, while the maximum temperature varies between 35 and 42 °C, particularly from March to June (ANSD 2017). The soil has a high salt content particularly high in fluorine, which makes nearly 266,500 ha hostile to

agriculture, i.e. 33.6% of the total area of the region. The vegetation, characteristic of the Sudanese zones, has undergone deep changes due to anthropic action and drought. This has shaped landscapes, possibly leading to the formation of mangroves and forests. Various mangrove species (*Avicennia nitida*, *Rhizophora racemosa* and *Langunculari* sp.) occupy the shores of the coastal inlets (Coly et al. 2011). The livestock population consists mainly of small ruminants, with approximately 755,000 animals representing 59% of the livestock in the Fatick area (Amadou Hamidine KANE 2019). Goats represent 52.38% of small ruminants in the Fatick area (Goetz 2011).

Methods

Data collection

Structured individual interviews were conducted in August 2017 on 45 goat breeders (with 91% of women and 9% of men) affiliated to ARECAP member groups in 4 villages. The questionnaire (Table 1) consisted of open and closed questions and covered (i) socio-economic characteristics of the household, (ii) motivation for keeping goats, (iii) characteristics of the goat flock and (iv) method of breeding.

Statistical analysis

To establish a typology of the herds, we selected 12 variables from the questionnaire that address important herd characteristics and conducted a multiple correspondence analysis (MCA) followed by a hierarchical classification analysis (HCA) package. In each village, the entry point for our interviews was the group of breeders belonging to the goat breeders' association. This approach allowed investigators to work confidently with the goat farmers' FactoMineR, functions MCA and hierarchical clustering on principle components (Agro Campus Ouest, Rennes, France). The variables used for MCA and HCA are described in Table 1.

Chi-square or Fisher's exact tests were conducted to evaluate the dependence between clusters and categorical variables as well as between categorical variables, and the Kruskal-Wallis test was used to compare quantitative variables between clusters.

Multiple correspondence analysis is a method used to summarise a set of categorical variables into a small number of dimensions. We used these dimensions in the hierarchical classification analysis to group respondents according to the group to which they belong. Village, sex and ethnicity variables were used as an illustrative variable; it did not actively affect the construction of dimensions but projected on them to ease the interpretation of the generated clusters. Finally, we used chi-square and exact Fisher's tests to assess if these variables, socio-economic characteristics of households, motivation

Table 1 List of qualitative variables used in the MCA

Variables	Codes	Modalities
Educational level	Educ	Educ1 = literacy Educ2 = primary Educ3 = secondary Educ4 = quranic
Buck breed	Breed	Breed 1 = local Breed 2 = crossbred Breed 3 = exotic
Grazing modes	GrazMod	Mod 1 = mixed crop-livestock system Mod 2 = herding and tethering Mod 3 = free grazing
Animal housing	House	House 0 = homeless House 1 = shelters
Milk processing	Proc	Proc 0 = no process Proc 1 = curdled milk Proc 2 = cheese and yoghurt
Milking	milk	milk 0 = no milking Milk 1 = milking
Motivation to keeping goat	Motivation	Motivation 1 = cash income and self-consumption (milk and/or meat) Motivation 2 = milk Motivation 3 = both
Birth size	BSize	Single birth Double birth
Common diseases	Disease	Disease 1 = respiratory disease Disease 2 = digestive disease Disease 3 = skin disease Disease 4 = parasitic disease
Bovine keeping	Bov	Bov 0 = keep cattle? Bov 1 = no bovine
Sheep keeping	Sheep	Sheep 0 = keep sheep Sheep 1 = no sheep
Household size	HSize	Small, 1 to 5 members Medium, 6 to 10 members Large, > 10 members

for keeping goats, characteristics of the goat flock and method of breeding from sampled farmers, were significantly different among these clusters. For all analyses, p values were set at 1%. Graphical displays present the proximities between the subjects and show the associations between the categorical variables.

Results

Socio-economic characteristics

Descriptive analysis shows that the farmers interviewed were almost all women (91%) with only 4 men. The

main ethnic group was the Serrer (98%) with only one Peulh (2%). Three household levels were cited: small households with 1 to 5 members (11% responses), medium households with 6 to 10 members (51% responses) and large households with more than 10 members (38% responses). In terms of education, 69% of the herders had not attended school. Out of the 14 who did, 4 attended Quranic school, 6 primary school and 4 secondary school. All respondents were married. The majority (80% of responses) declared that they sold mainly male goats.

Characteristics of goat flock and method of breeding

In the study area, the goat breeders often kept multi-species holdings, mainly together with cattle and sheep (20% and 58% of respondents, respectively). The number of goats per herd varied from 3 to 30 heads, with a median value of 8. The proportion of adult female goats ranged from 25 to 92% with a median value of 57%. The majority of the farmers (80%) reported twin births. Only 4.4% of the breeders used a crossbred male as a genitor, while the others used a male from a local breed. Two methods of goat rearing were practised: (i) mixed crop-livestock mode mainly (93.3%) where animals graze natural pastures on common grazing or around the concessions (houses or homes) and are supplemented with preserved fodder or agro-forestry residues and kitchen leftovers and (ii) secondary grazing mode (7%) where the animals' diet depends mainly on natural pastures. Only 16% of the people surveyed kept animals in goat sheds, compared to the majority (84%) who housed their animals in open-air pens. The most frequently declared diseases were respiratory (58%), digestive (29%), dermatological (11%) and parasitic (2.2%). The selling age of male goats was between 6 and 48 months, with a median value of 13 months, and that of females was between 12 and 156 months, with a median value of 90 months. Thirty-eight goat breeders (84% of the respondents) gained incomes from the sale of goats, with a selling price per animal ranging from 15,000 to 40,000 FCFA (27,91 to 74,44\$) and a median value of 25,000 FCFA (46,52\$).

Motivation for keeping goats

There were three main motivations for keeping goats: cash income, milk and/or meat consumption and milk production in the majority (62%) holdings; cash income and meat consumption (29%); and finally milk production alone for income and/or home consumption (9%). Among the respondents, two-thirds processed milk either as curdled milk (60%) or as yoghurt and cheese (6.7%), while the rest did not process milk.

Typology of the goat production systems

Multiple correspondence analysis (MCA)

The amount of variation explained by each dimension of the MCA (inertia) is given in Fig. 1. From this, we retained only the first three dimensions (axis) (39.1% of the total variance) because each additional dimension contributed little to the total variance.

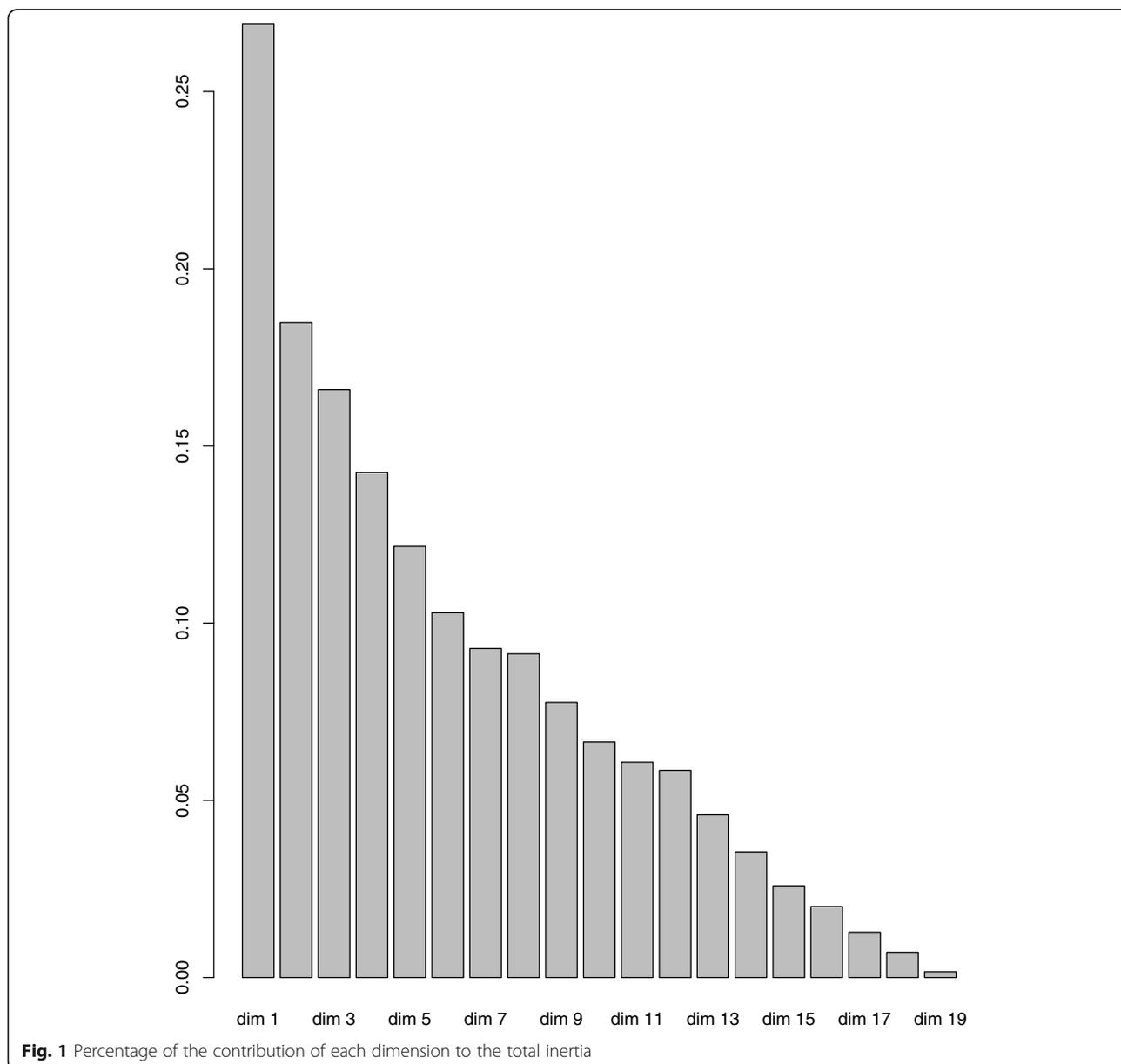
The multiple correspondence analysis was performed on 12 variables with 29 modalities, contributing to the formation of the first three axes.

The first axis (accounts for 17% of the total variation, Fig. 2) appears as opposing the grazing strategy practised by men to one of the mixed crop-livestock system practised by women. The second axis (11.7% of the total

variation) opposes mixed breeding (goat, sheep and cattle) to only goat breeding and is strongly associated with goat flock size ($p < 0.01$). The third axis (10.5% of the total variation, Fig. 3) separates herders who made yoghurt and cheese from those who made curdled milk.

Ascending hierarchical classification and group description

The hierarchical classification described three clusters (Fig. 4, Tables 2 and 3). The chi-square test showed a strongly statistically significant difference between the clusters ($p < 0.001$) for the variables ‘Milk processing’, ‘Education level’ and ‘Motivation to keep goat’, and a significant difference between the clusters for ‘Goat flock size’ ($p < 0.05$).



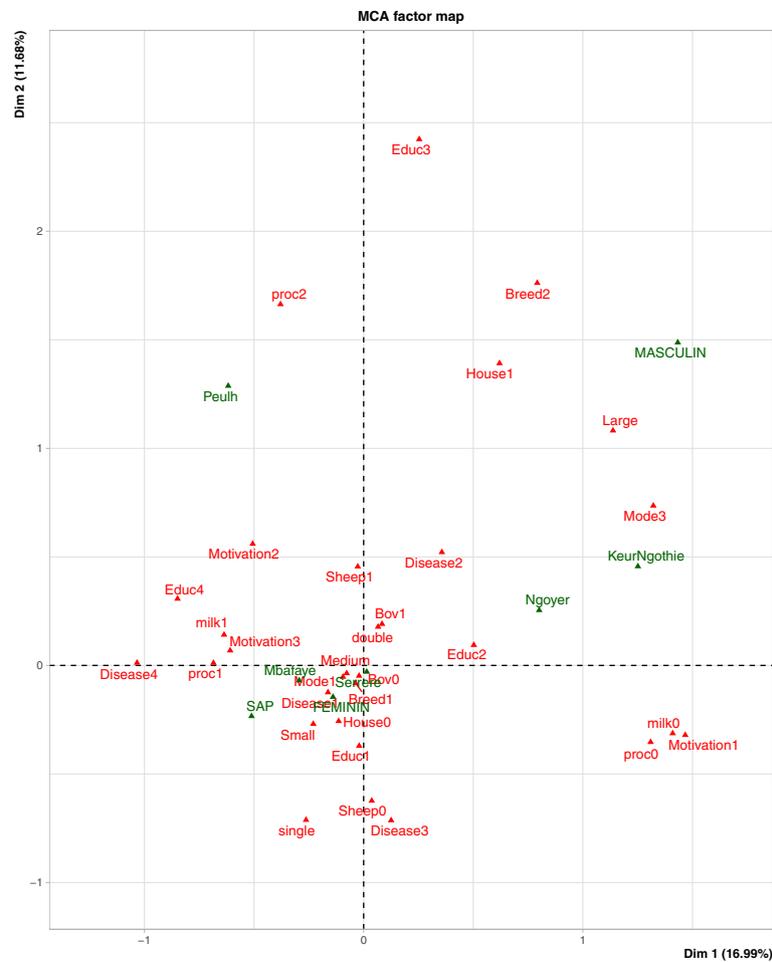


Fig. 2 Modalities associated to axes 1 and 2 of MCA applied to the typology of goat production systems in the Fatick region, Senegal (see Table 1 for the signification of codes)

Group 1 ($n = 28$; 62.2% of the total surveyed breeders) could be considered as belonging to milk-producing breeders, running a mixed crop-livestock system (96.4% of respondents). In this group, breeders were almost all women (96.4%). This group mainly comprised small (42.9%) or medium size households (50%). They owned from 3 to 30 goats, with a median value of 8 goats (mean \pm sd 10.5 ± 6.7). The majority of these breeders (96.4%) held local breed bucks in the flock for mating. The majority of births were twins (77.4%). The majority of farmers (2/3) combined goat with sheep rearing, while only 6 combined goat rearing with cattle. Almost all farmers (89%) in this group kept their animals in open-air pens. This practice was significantly associated to the prevalence of diseases reported. Respiratory diseases were the most commonly declared ones (68%), followed by digestive diseases (18%), while dermatosis and parasitosis were the least cited, with 3 and 1 respondents, respectively. The vast majority of farmers were illiterate (75% of farmers in this group). Among them, 7 were

enrolled in school, 4 attended Quranic school and 3 primary school. Their motivations for raising goats were milk production and income from the sale of animals or self-consumption (89%). The farmers produced (100%) and processed (92.9%) milk into curdled milk for self-consumption. Sales were dictated by the needs of the household or farm at an average price per animal of 25.200 ± 5.400 FCFA ($46,95 \pm 10,06$ \$). The average male and female goat selling age was 18 ± 9.5 months and 87 ± 26 months, respectively.

Group 2 ($n = 4$; 8.9% of the total surveyed breeders) could be qualified as innovators-breeders. They all combined sheep with goat farming. In contrast to group 1, farmers in group 2 had a secondary level of education and processed milk into yoghurt and cheese. They belonged to middle-sized households (50% of respondents). They owned larger goat flocks ranging from 9 to 24 goats, with a median value of 18 animals (mean \pm sd 17 ± 6.6). All farmers in this group reported twin births in their goat flocks. The average selling age of males and

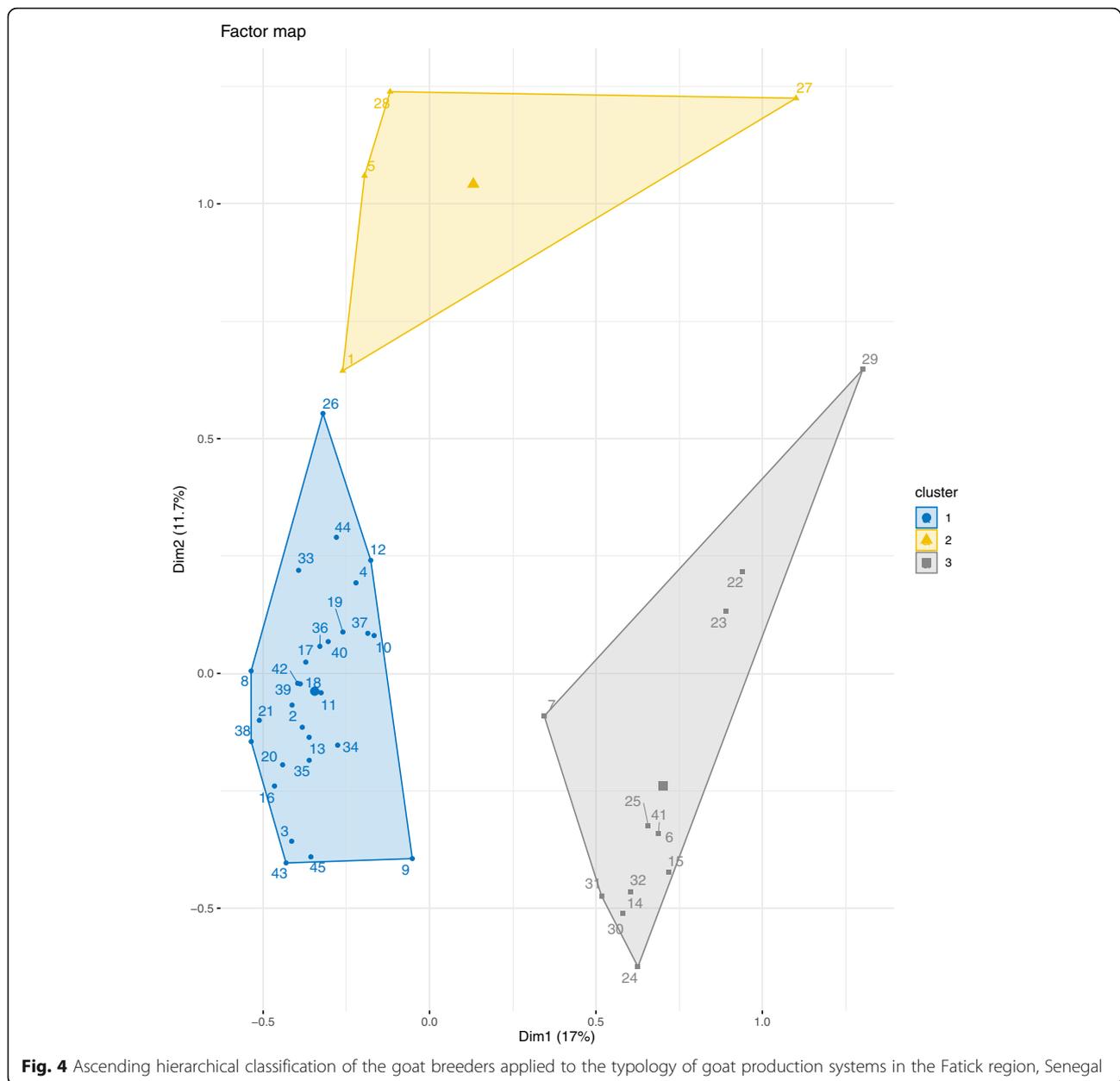


Fig. 4 Ascending hierarchical classification of the goat breeders applied to the typology of goat production systems in the Fatick region, Senegal

same area (63.4%). This could be ascribed to the traditional and cultural background of goat production systems in the Serere area and highlight the important role that women play in the socio-economic balance of rural households in Senegal (Missouhou et al. 2004). The proportion of herders without formal education (68.9%) is high in this study. This low level of literacy among pastoralists is one of the factors that could impede the sector (Agossou et al. 2017). According to Thiolye (2015), poverty and the early marriage of women (under 18 years of age) accentuate the low level of schooling in rural areas.

Characteristics of the goat flock, breeding mode and goat production system

Almost all goat breeders practised agro-pastoral systems. According to Agossou et al. (2017), there is an extensive sedentary system where animals are grazed on fallow land and natural vegetation zones in the cropping season and then brought back to the cultivated areas after harvesting in the dry season. The presence of other species (sheep and cattle), especially sheep kept by the majority of respondents, indicates the interest of farmers in mixed farming of small ruminants in the study area. The common association of sheep (27.3%) and cattle (24.6%)

Table 2 Distribution of responders per categories for the three clusters identified by the hierarchical classification analysis

Variables and categories	Cluster 1	Cluster 2	Cluster 3	Total	p value
Educational level					***
Literacy education	21	0	10	31	
Primary education	3	0	3	6	
Secondary education	0	4	0	4	
Quranic education	4	0	0	4	
Buck breed					NS
Local breed mating	27	3	13	43	
Crossbreeding	1	1	0	2	
Grazing mode					NS
Mixed crop-livestock system	27	4	11	42	
Free grazing	1	0	2	3	
Animal housing					NS
Unsheltered	25	2	11	38	
Sheltered	3	2	2	7	
Milk process					***
No milk processing	1	1	13	15	
Milk curdling	26	1	0	27	
Cheese and yoghurt processing	1	2	0	3	
Milking					***
No milking	0	1	13	14	
Milking	28	3	0	31	
Motivation of keeping goat					***
Cash income and self-consumption	0	1	12	13	
Milk	3	1	0	4	
Cash income and self-consumption and milking	25	2	1	28	
Birth size					NS
Single births	7	0	2	9	
Twin births	21	4	11	36	
Common diseases					*
Respiratory disease	19	1	6	26	
Digestive disease	5	3	5	13	
Dermatosis disease	3	0	2	5	
Parasitosis disease	1	0	0	1	
Bovine					NS
No bovine keeping	22	3	11	36	
Bovine keeping	6	1	2	9	
Sheep					NS
No sheep keeping	12	0	7	19	
Sheep keeping	16	4	6	26	
Household size					NS
Small household, 1 to 5 members	12	1	4	17	
Medium household, 6 to 10 members	14	2	7	23	
Large household, > 10 members	2	1	2	5	

NS not significant

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 3 Quantitative variables' characteristics of goat farms for the three clusters identified by the hierarchical classification analysis

Variables	Cluster 1	Cluster 2	Cluster 3	p value
TotalGoat: median (mean, sd)	8 (10.5 ± 6.7) ab	18 (17 ± 6.6) a	8 (8 ± 3) b	*
Femaladult. (%): median (mean, sd)	56.5 (54.3 ± 13.0)	62 (60.8 ± 10.7)	50 (56.9 ± 19.43)	NS
Age.s.sale.Male (months): median (mean, sd)	17 (17.6 ± 9.5)	15.1 (19.6 ± 11.47)	18.2 (19.2 ± 8.4)	NS
Age.s.sale.Female (months): median (mean, sd)	85.5 (86.5 ± 25.9)	85.5 (103.1 ± 32.3)	85.5 (77.9 ± 19.2)	NS
Sale.s.price.goat (FCFA): median (mean, sd)	25,000 (25,200 ± 5400)	23,500 (23,100 ± 1760)	24,700 (24,100 ± 4660)	NS

Treatments with the same letter are not significantly different between clusters

NS not significant, sd standard deviation

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

with goat farming was previously reported in the area (Djakba 2007). In these rural areas, goats are generally used to meet the daily needs of the household in milk and meat, while sheep meat is more expensive and therefore kept for sale or important ceremonies such as Tabaski, the Muslim festival (Festival of Abraham) where sheep were sacrificed. Male goats were sold much earlier than those females. Our results showed that male goats are kept for cash income or socio-cultural ceremonies, while females are kept for milking and their reproductive careers. According to Kosgey et al. (2008), males are sold before the age of reproduction in small-holders' goat production systems. The low numbers of goats (10 ± 6.1) per livestock keepers classified as small family farms highlight their role in managing household emergencies. Manirakiza et al. (2020) in a study in Burundi described the role of small family goat farms as 'wallet'. Our study underlines the close link between goat rearing and traditional practices which is dominated by the mixed crop-livestock system. According to Alexandre and Mandonnet (2005), Ahuya et al. (2009) and Iñiguez (2011), goats are usually associated with traditional production systems with low levels of external inputs. Local goats, despite their hardiness (Sow et al. 2020), are susceptible to certain diseases. The most cited by farmers were digestive, respiratory, dermatological and parasitic diseases. Djakba (2007) and Diouf (2012) reported similar findings in the same area. Almost all of the goat breeders surveyed (95.6% of respondents) used a local buck as a genitor. While crossbred goats grow faster, local goats are more resistant to harsh conditions as previously reported (Tindano et al. 2015). However, no reproductive management was applied with animals of all categories being mixed all year round and mating was uncontrolled. Culling and renewal of breeding stock was therefore not reasoned according to individual performance.

Farmers' motivations on the goat production system

In the study area, the primary motives for goat keeping were self-consumption and sale and secondary motives were only sale for cash income. According to Laouadi et al. (2018), goats may be a source of income throughout the year and contribute to the satisfaction of family

needs for milk and meat. They are also a tool for cash flow, through their role as a 'moneybox', subsistence and security of agrarian systems in the front-line (Dieye et al. 2000; Ruiz et al. 2008 and Missohou et al. 2016). Management systems in which goats are generally free to roam support the latter motivation. This allows them to make reserves of feed until the critical lean period (Agossou et al. 2017). The low rate of farmers motivated by milk production showed that milk product sales were not a priority, but rather intended for self-consumption by the family and the children for their growth. Moreover, dairy goats, unlike cattle, receive only weak public support policies. In general, dairy goats were neglected in milk production improvement schemes (Missohou et al. 2004). The use of goat dairy products remains largely traditional and based on a short circuit. This might be due to the weak organisation of the policy-makers towards the sector in the study area (Camara et al. 2018), thus promoting a lack of competitiveness in the market (Udo et al. 2011; Ayao Missohou et al. (2016) and Laouadi et al., 2018). According to Sanon (2007); Sangaré (2009) and Agossou and al. (2017), the limited resources of small farmers limit their ability to adopt modern animal husbandry technologies, which require a certain amount of monetary and technical support.

Typology and goat production system

The findings that the use of goat farming was different across the groups of farmers, derived from the multivariate analyses, reveal two opposing groups as well as an intermediate one, showing innovation in terms of milk processing into yoghurt and cheese.

The first group was more invested in milk production and processing into curdled milk. The goat flocks were smaller when compared to group 2, and farmers kept their animals in open-air pens. The majority of goat breeders held local breed bucks in the flock for mating. In this group, goat breeding is a subsistence farming based on the use of local breeds and available natural resources. According to Agossou et al. (2017), the West African region contains a wide range of indigenous goat breeds well-adapted to harsh environmental and

precarious husbandry conditions, which nevertheless have low genetic potential for meat and milk production.

The second group of farmers, in contrast to the previous group, was more motivated by processing milk into yoghurt and cheese. Goat flocks were larger and kept in goat sheds. The farmers had a higher education level (secondary education) and lived in villages equipped with milk-processing units. This suggests a possible direct impact of education on adoption of innovations or on improved living standards (Tindano et al. 2015).

The third group of farmers was more motivated by meat production. Farmers did not consume or process milk. Goat flocks were small and farmers kept their animals in open-air pens. This might be due to their motivation of keeping goats as cash for income and self-consumption. Farmers in this group were more likely than group 1 to report that their motivation for goat rearing was for the market and self-consumption, which is supported by Manirakiza et al. (2020). They proposed that goat breeding, in addition to a nutritional role, has a socio-economic dimension through income generation. According to Missohou et al. (2016), goat breeding allowed social promotion through the acquisition of species considered more high status and noble, like sheep and bovine.

Conclusion

Goat rearing in the Fatick area is an exclusively female activity in a serere environment, and mixed flocks of sheep and goats are common. The processing of milk into various by-products such as yoghurt and cheese other than traditional curdled milk is emerging but highlights the possibilities for innovation in goat-rearing in the region.

Recommendations

The objectives of ARECAF and its development partners, which are the improvement of breeding management, the sale of goat products and the structuring of the goat sector, are highly relevant in the context of the local economy. Nevertheless, the current situation of the sector does not allow these goals to be achieved. Thus, for sustainable prospects, two requirements must be met:

- 1) Increasing productivity by intensifying the use of land, using locally available resources and improving animal performance;
- 2) Adopting techniques that guarantee the three pillars of sustainability: environmental, economic and social.

Abbreviations

NASD: National Agency for Statistics and Demography; MCA: Multiple correspondence analysis; ARECAF: Regional Association of Caprine Breeders of Fatick; AHC: Ascending hierarchical classification; CIHEAM: International Centre for Advanced Mediterranean Agronomic Studies; FAO: Food and Agriculture Organization of the United Nations; FCFA: African Financial Community Franc; ISRA: Senegalese Agricultural Research Institute; PAFC: Goat Sector Improvement Programme; WAAPP: West African Agriculture of Productivity Program

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Authors' contributions

F.S. collected the data, ran the statistical analyses and wrote the manuscript; Y.C. contributed to the original draft preparation; E.H.T. provided resources; N.A.M., J.F.C. and A.M. helped with data editing; J.L.-H., N.M. and Y.C. supervised the analyses and contributed to the draft of the manuscript and interpretation of the results. All authors have read and agreed to the published version of the manuscript.

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Availability of data and materials

Please contact the corresponding author for data requests.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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References

- Agossou, D.J., Dougba, T.D., Koluman, N. (2017) Recent Developments in Goat Farming and Perspectives for a Sustainable Production in Western Africa. *International Journal of Environment, Agriculture and Biotechnology* 2(4): 2047-2051. <https://doi.org/10.22161/ijeab/2.4.62>.
- ANSD. 2017. "Situation Economique et Sociale Du Sénégal Ed. 2016." Dakar, Sénégal. www.ansd.sn.
- Ahuya, C.O., J.M.K. Ojango, R.O. Mosi, C.P. Peacock, and A.M. Okeyo. 2009. *Performance of Toggenburg Dairy Goats in Smallholder Production Systems of the Eastern Highlands of Kenya*. Vol. 83, 7–13. <https://doi.org/10.1016/j.smaillrumres.2008.11.012>.
- Alexandre, G., and N. Mandonnet. 2005. Goat Meat Production in Harsh Environments. *Small Ruminant Research* 60 (1-2 SPEC. ISS): 53–66. <https://doi.org/10.1016/j.smaillrumres.2005.06.005>.
- Amadou Hamidine KANE. 2019. "Analyse Du Rôle de l'assurance Dans La Résilience Des Populations Vulnérables Aux Chocs Climatiques et à

- l'insécurité Alimentaire: Cas de La Région de Région de Fatick Au Sénégal." Université Catholique de Louvain. <https://matheo.uliege.be>.
- Camara, Y., N. Moula, F. Sow, M.M. Sissokho, and N. Antoine-Moussiaux. 2018. Analysing Innovations among Cattle Smallholders to Evaluate the Adequacy of Breeding Programs. *Animal*: 1–10 <https://doi.org/10.1017/S1751731118001544>.
- De Vries, James. 2008. Goats for the Poor: Some Keys to Successful Promotion of Goat Production among the Poor. *Small Ruminant Research* 77 (2–3): 221–224. <https://doi.org/10.1016/j.smallrumres.2008.03.006>.
- Dieye, Papa Nouhine, C R Z Kolda, Papa Nouhine Dieye, Guillaume Duteurtre, and Cheikh Ly. 2000. "Synthèse Bibliographique Sur Les Filières Laitières Au Sénégal." 1. Dakar, Sénégal. www.repol.sn.
- Diouf, Mor Bigue. 2012. "Alimentation Des Caprins Dans La Région de Fatick (Sénégal) : Pratiques, Ressources, Compléments Disponibles et Possibilités d'amélioration." thèse vétérinaire. Université Cheikh Anta DIOP de Dakar-Sénégal. Ecole Inter-Etats des Sciences et Médecine Vétérinaires (EISMV). N°30, p.138.
- Djakba, Akroé. 2007. Evaluation Des Parametres De Reproduction Chez La Chevre Du Sahel Inseminee Artificiellement Dans La Region De Fatick. *Thèse vétérinaire. Université Cheikh Anta DIOP, Dakar-Sénégal. Ecole Inter-Etats Des Sciences Et Medecine Veterinaires (E.I.S.M.V.)* N°39, p. 109.
- Goetz, Vincent. 2011. "Le Projet d' Amélioration de La Filière Caprine de Fatick (Ou PAFC) Au Sénégal."
- FAO. 2011. "World Livestock 2011-Livestock in Food Security." Rome. 130p.
- FAOSTAT (2019). (<http://www.fao.org/faostat/fr/#data/QA>, , consulté le 26 janvier 2021)
- I Coly, F Diome, H Dacosta, R Malou, LE Akpo, (2011) Typologie des exploitations agropastorales du terroir de la NEMA (Sénégal, West Africa). *International Journal of Biological and Chemical Sciences* 5(5):1941
- Kosgey, I.S., G.J. Rowlands, J.A.M. van Arendonk, and R.L. Baker. 2008. Small Ruminant Production in Smallholder and Pastoral/Extensive Farming Systems in Kenya. *Small Ruminant Research* 77 (1): 11–24 <https://doi.org/10.1016/j.smaillrumres.2008.02.005>.
- Laouadi, Mourad, Safia Tennah, Nacereddine Kafidi, Nicolas Antoine-moussiaux, and Nassim Moula. 2018. A Basic Characterization of Small-Holders' Goat Production Systems in Laghouat Area, Algeria. *Pastoralism: Research, Policy and Practice* 24: 8 <https://doi.org/10.1186/s13570-018-0131-7>.
- Luis Iniguez, (2011) The challenges of research and development of small ruminant production in dry areas. *Small Ruminant Research* 98(1-3):12-20
- Manirakiza, Josiane, Gilbert Hatungumukama, Badi Besbes, and Johann Detilleux. 2020. Characteristics of Smallholders' Goat Production Systems and Effect of Boer Crossbreeding on Body Measurements of Goats in Burundi. *Pastoralism: Research, Policy and Practice* 10 (2): 11 <https://doi.org/10.1186/s13570-019-0157-5>.
- Missouhou, A., L. Diouf, R.S. Sow, and C.B.A. Wollny. 2004. Goat Milk Production and Processing in the NIAYES in Senegal. *South African Journal of Animal Science* 34 April 2015.
- Missouhou, Ayao, Grégoire Nahimana, Simplicio Bosco, and Ayssiwede Mbacké. 2016. Elevage Caprin En Afrique de l' Ouest: Une Synthèse. *Revue d'élevage et de Médecine Vétérinaire des Pays Tropicaux* 69 (1): 3–18 Goat Breeding in West Africa: A Review [in French].
- Peacock C. 2008. "Dairy Goat Development in East Africa: A Replicable Model for Smallholders?" *Small Ruminant Research* 77 (2–3): 225–238. <https://doi.org/10.1016/j.smaillrumres.2008.03.005>.
- Ruiz, F.A., J.M. Castel, Y. Mena, J. Camúñez, and P. González-Redondo. 2008. Application of the Technico-Economic Analysis for Characterizing, Making Diagnoses and Improving Pastoral Dairy Goat Systems in Andalusia (Spain). *Small Ruminant Research* 77 (2–3): 208–220. <https://doi.org/10.1016/j.smaillrumres.2008.03.007>.
- Sangaré, M. 2009. Intérêts et Limites de l' Élevage Caprin Dans Les Écosystèmes Fragiles et Propositions d' Amélioration: Cas Des Systèmes d' Élevage Sahélien Du Mali. *CIHEAM / DRAP-Norte / FAO* 156 (91): 151–156.
- Sanon, Hadja Oumou. 2007. *The Importance of Some Sahelian Browse Species as Feed for Goats* (Thesis). Swedish University of Agricultural Sciences. Department of Animal Nutrition and Management Uppsala. p.72.
- Skapetas, B., and V. Bampidis. 2016. Goat Production in the World: Present Situation and Trends. *Livestock Research for Rural Development* 28 (11): 7.
- Sow, Fafa, Khady Niang, Younouss Camara, El Hadji, and Nassim Moula. 2020. Comparative Study of Intake, Apparent Digestibility and Energy and Nitrogen Uses in Sahelian and Majorera Dairy Goats Fed Hay of Vigna Unguiculata. *Animals* 10: 1–11 <https://doi.org/10.3390/ani10050861>.
- Thioye, Ndeye Titine. 2015. *La Scolarisation Des Filles à l' Ère Des Reformes Éducatives Au Sénégal*. Thèse en Science politique. Université Paris 1 – Panthéon- Sorbonne <https://dumas.ccsd.cnrs.fr/dumas-01294503>. p.121.
- Tindano, K., N. Moula, A. Traoré, and P. Leroy. 2015. Characteristics and Typology of Sheep Herding Systems in the Suburban Area of Ouagadougou (Burkina Faso). *Archives Animal Breeding* 58: 415–423 <https://doi.org/10.5194/aab-58-415-2015>.
- Udo, H.M.J., H.A. Aklilu, L.T. Phong, R.H. Bosma, I.G.S. Budisatria, B.R. Patil, T. Samdup, and B.O. Bebe. 2011. Impact of Intensification of Different Types of Livestock Production in Smallholder Crop-Livestock Systems. *Livestock Science* 139(1–2):22–29. <https://doi.org/10.1016/j.livsci.2011.03.020>.

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