

Full Length Research Paper

Characterization of goat production systems in two agro-ecological zones of Burkina Faso, West Africa

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Improving the management of goat in rural areas and enhancing its ability to alleviate smallholder poverty requires a better understanding of the existing production systems. This study has been undertaken to characterize the diversity of goat farming systems and identify major constraints and opportunities for their sustainability in two agro-ecological zones of Burkina Faso, namely Sudano-Sahelian and Sudanian, as input for community-based breeding programs. Therefore, data of 372 goat keepers and their herd characteristics were collected in a questionnaire. Two quantitative and 12 qualitative variables were used to perform multiple correspondence analysis and hierarchical cluster analysis. The results indicated that farmers were largely illiterate, with men slightly outnumbered by women. The surveys were divided into 3 clusters. The first 2 clusters were composed of sedentary agropastoral systems. These 2 clusters, which include over 85% of all respondents, represented subsistence crop and livestock productions. Livestock is reared for multiple purposes including income, meat, manure, saving and socio-cultural reasons. The third and smallest cluster (14.5%) was composed entirely of Fulani people in both areas Sudano-Sahelian (85%) and Sudanian (15%). This cluster was the only one containing transhumant production system, with 85% of these farmers practicing seasonal mobility of their herds. Fifteen constraints of goat production were identified, the main ones including conflicts, feed shortage, diseases, lack of workforce and abortions. Although our results showed diversity on goat farming systems among identified groups. Given the lack of formal breeding scheme and institutional support, community-based breeding approaches, which harness the indigenous knowledge and farmers' full commitment, should be explored to improve smallholder production system while conserving genetic diversity.

Key words: *Capra aegagrus hircus*, farming, agropastoral, transhumance.

INTRODUCTION

Goat farming is a key agricultural sector in developing countries (Sow et al., 2021). West Africa is an important area of goat production with 14.82% of the world goat population (Agossou et al., 2017). Goats are produced in a wide range of agro-ecological zones and management systems. However, extensive low-input systems still dominate and play important roles in ensuring food security and supporting rural livelihoods in arid and semi-arid areas where conditions for crop farming are limited (Pulina et al., 2017; Muigai et al., 2017; Alemayehu et al., 2021). In West Africa, goats are traditionally kept by more than 60 % of rural households, as the main or secondary livelihood activity, providing income and employment as well as a “living saving account” and insurance, and as such, contributing substantially to rural economies (Agossou et al., 2017; Desta, 2020; Monau et al., 2020).

In Burkina Faso, the goat population is estimated at 14 million animals, representing the first largest ruminant population in the country (MRAH, 2021; FAOSTAT, 2022). Goats have widely expanded in all regions and their breeding is dominated by the extensive farming system with low levels of inputs and with specific breeds adapted in varied herd sizes (Missohou et al., 2016). Indeed, each of the environmental areas of the country are assumed to be the habitat of different goat populations (Traoré et al., 2009, 2008). These populations include the Sahelian goat population, which is the Burkina Faso representative of the African long-legged goat group, spread throughout the Sahel region of West Africa; and the Djallonké population, located in the Sudanian area of Burkina Faso, which is a short-eared and small-horned goat also known as West African Dwarf goat; while in the Sudano-Sahelian area an intermediate type named the Mossi goat is found (Traoré et al., 2008, 2009, 2012). These main indigenous breeds are used for different purposes, including meat and milk production, play a major role in livelihoods of rural human populations, and also have a particular cultural importance due to their traditional use in rites and celebrations (Traoré et al., 2009). Under harsh environmental conditions and low management systems, goats have the ability to convert poor feed resources into good quality milk and meat and have, therefore, a high potential to contribute to the attainment of food security and environmental sustainability (Kwashirai and Mhike, 2019).

Despite this high potential, goat production in Burkina Faso is still challenging due to many constraints inducing low productivity, and consequently limiting its contribution

to people’s wealth and livelihoods (Solomon et al., 2014; Feldt et al., 2016). Indeed, lack of feed, poor nutritional status, high burden of disease, lack of good husbandry practices combined with lack of a genetic improvement and sustainable breeding strategy contribute to low productivity of most flocks (Haile et al., 2020).

Regarding its importance, improving goat management is a key for the improvement of the livelihood of rural populations in Burkina Faso. However, contrary to cattle, small ruminants in general and goats specifically are still neglected in the country in terms of genetic improvement. In this context, community-based breeding program (CBBP) which is known to be can be an approach adapted to extensive low-inputs systems is a good option for goat genetic improvement (Sölkner et al., 1998). Nevertheless, any improvement attempts could not long succeed without a deep understanding of the production environment (Mueller et al., 2015; Wurzinger et al., 2021). Therefore, the aim of this study was to analyse goat production systems and husbandry practices in different zones of Burkina Faso as an input for the implementation of CBBPs to support economic development and improve livelihoods of farmers.

MATERIALS AND METHODS

Study sites

This study was carried out simultaneously in two provinces of Burkina Faso, Namentenga and Poni (Figure 1). Namentenga province is geographically located in the north, while Poni province is situated in the southwest of the country. According to the agro-ecological area division of the country, climatically, Namentenga and Poni provinces belong to the Sudano-Sahelian and Sudanian zones, respectively.

The Sudano-Sahelian zone is located between 11°30' and 14° north latitude. The zone is characterized by a short rainy season from June to October (4-5 months), a long dry season (7-8 months), a variable rainfall with annual average of 750 mm. The temperatures vary from 20 to 42°C. In the Sudanian zone is located between 10° and 11°30' north latitude. The rainy season lasts from May to October (5–6 months) with annual rainfall is ranging between 900 and 1200 mm (Ganamé et al., 2019). The temperatures are relatively low in this area, varying from 17 to 35°C. Currently with the climate fluctuations, these characteristics have undergone deep changes. In both areas, farming systems are mainly dominated by subsistence mixed crop-livestock (Zoma-Traoré et al., 2020). Cattle, goats, and sheep are the main ruminants reared in the areas. Goat population was estimated about 1 440 000 head in the north and 697 000 heads in the southwest in 2018, representing 9% and 5% of the country population, respectively (MRAH, 2019). These 2 regions were selected for the implementation of goat CBBPs while the Sahel region despite its high potential in goat population is not targeted yet due to some practical constraints mainly linked to security issue.

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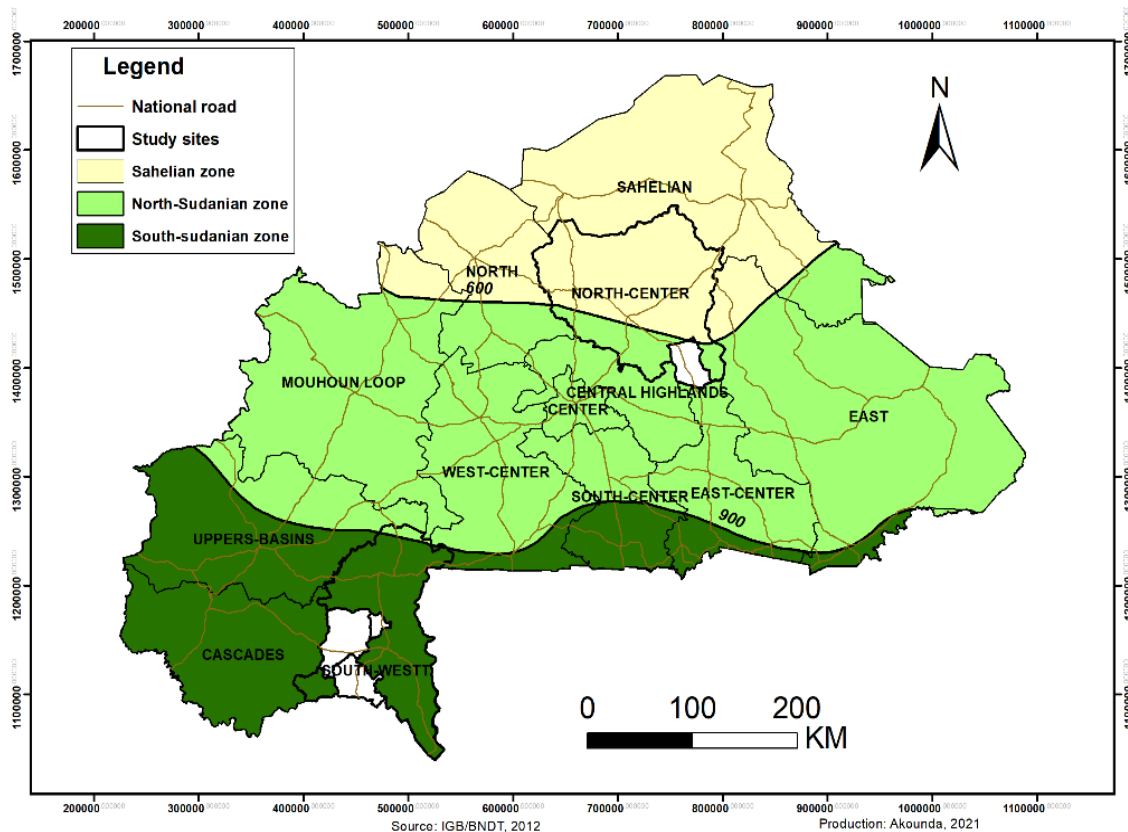


Figure 1. Map of Burkina Faso showing the sampling areas.

The study areas are assumed to be inhabited by Mossi goat and Djallonké goat populations in the Namentenga and Poni provinces, respectively. However, similar to taurine cattle (Barbato et al., 2020; Tapsoba et al., 2020), introgression of Sahelian breeds into Sudanian ones is occurring due to breeding practices and the migration and settlement of Fulani people with their herds from northern to southern regions (Álvarez et al., 2014; Traoré et al., 2009). Thus, both Sahelian and Mossi types are most likely to be found in the two areas.

Data collection

Informal discussions with stakeholders in each area including farmers' leaders and government extension workers were held from February to March 2021. The objectives were to raise awareness, to have a global view on goat production, and to select the potential villages for the study. These villages have been selected, based on the availability of goats and the willingness of the farmers to participate in the breeding program. Face-to-face individual interviews were conducted from April to June 2021, using a semi-structured questionnaire. The questionnaire has been designed by the research team based on its experience in similar previous studies. This questionnaire was pre-tested on 11 farmers to check whether questions were clear and whether respondents could understand them before being coded using Kobotoolbox (www.kobotoolbox.org). Smartphones were employed for digital data collection. The questionnaire consisted of closed- and open-ended questions and covered aspects like the socio-economic characteristics of the household, motivation of keeping goats, livestock species, characteristics of goat flock, flock management

including breeding, housing, feeding, and health. Specifically for breeding objectives and production constraints, farmers were asked to list the reasons for keeping goats and the main constraints faced in goat rearing, and to rank them from most to least important. Interviews were carried out by three experienced veterinary technicians from the provincial livestock extension offices in each area and one livestock expert from the research team.

The interviews were held in farmers local languages in each area. Farmers were met by appointment mostly in their homes and before starting, they were informed about the purpose of the study and the privacy of their information. Their oral informed consent was sought before their participation in the survey. A total of 372 goat farmers were selected and interviewed (Table 1).

Statistical analysis

Data were analyzed using R Version 4.0.2 (R Core Team, 2020). Descriptive statistics were first performed including means and standard deviations (SD) for quantitative data and proportions for qualitative data. Chi-square of Fischer's exact test was used to evaluate the dependence between the categorical variables and then Kruskal-Wallis test was employed to compare quantitative variables. The importance of the constraints and purposes of goat keeping, and their importance were assessed, by calculating meanrank scores.

To characterize the goat farming systems, Multiple Correspondence Analysis (MCA) was applied on 14 variables, out of 16 variables dedicated in the questionnaire to the goat farming system. The two unselected variables contributed very weakly to the inertia of the first two dimensions and were then removed to

Table 1. Distribution of the goat farmers by agro-ecological zone, site and sex.

Agro-ecological area	Site	Women	Men	Overall
Sudanian area	Bouroum-Bouroum	38	24	62
	Loropéni	44	26	70
	Kampti	29	32	61
Sudano-Sahelian area	Bangrin	30	30	60
	Koulikouga	30	30	60
	Napouguin	30	29	59
Overall		201	171	372

improve the total inertia on the 2 dimensions All variables selected for goat farming system characterization except age, were considered as active, i.e., determinant for the formation of factor axes. Each variable was coded in such a way as to divide it into two or three modalities with balanced numbers. Afterwards, multiple correspondence analysis (MCA) followed by hierarchical classification analysis (HCA, Ward's algorithm) were performed using the FactoMineR package (Lê et al., 2008).

RESULTS

Socio-economic characteristics of goat keepers

The overall characteristics of the farmers surveyed in the study areas are presented in Table 2. Women represented 54.03% of the overall respondents. Most of them were illiterate in both areas. Globally, farmers belonged mostly to the Mossi ethnic group (45.7%), but this depends on the survey location. According to the survey, 56.9% of households in the Sudano-Sahelian area consisted of 10 to 20 people, whereas a high proportion (48.7%) of households in the Sudanian area had fewer than 10 people. The majority of respondents rely on crop production as the main activity (71.24% of all respondents) followed by Livestock rearing (23.39%). These two activities are most often associated with small trade. Except for sex, both areas were significantly different ($P < 0.05$) for household size, education, and main activities.

Characteristics of goat flocks and management

In the study areas, goats were simultaneously kept with other livestock species, including cattle and sheep as ruminants, pigs, donkeys and birds including chicken, guinea fowl and duck. The average goat flock size varied from 12.9 in the Sudano-Sahelian area to 15.7 in the Sudanian one, with the big flocks counting up to 140 animals (Table 3). Flock size was significantly ($P < 0.05$) different among the two sites.

The majority of goat farmers in the Sudano-Sahelian area (54%) did not house their goats, as opposed to 41.45% in the Sudanian area. About 40.41 and 20.11% in the Sudano-Sahelian and Sudanian zones, respectively,

were using bench building houses for their goats (Table 4). The other types of houses found in the two sites were houses build with permanent and semi-permanent material, sheds and chain link fences. The two areas were significantly different ($P < 0.05$) in the housing system.

While goats freely graze during dry season, different herding systems occur in the two areas during the rainy season. Indeed, 83.80% and 77.72% of farmers in Sudano-Sahelian and Sudanian areas keep their animals during the rainy season, respectively (Figure 2). On the contrary, up to 15 and 22.28% in both respective areas acknowledged that their animals freely graze even in the rainy season. Only two farmers in the Sudano-Sahelian area mentioned that they tether their animals in the rainy season. Both sites were significantly different ($P < 0.05$) regarding the herding system.

Purpose of keeping goats

Farmer's reasons for keeping goats in the study areas are presented in Table 5. There were several motivations for keeping goats. In general, cash income was the main reason of goat keeping, followed by manure, meat, and socio-cultural reasons in the two areas. The importance of these reasons however varied according to the agro-ecological zone (Table 5). According to the mean scores, the Sudano-Sahelian area is highlighted income (1.12), manure (2.27), and meat (2.31) as first reason in the ranking. In the Sudanian zone, income (1.14), meat (2.19) and manure (2.40) were the top three ranked reasons. The purposes with low mean scores are considered to be the most important. The other reasons provided were socio-cultural, wealth status and skin. Saving was mentioned in the Sudanian zone.

Production Constraints

Table 6 summarises the goat production constraints recognized by the interviewed farmers. Overall, diseases, conflicts with crop producers, and feed shortage were the top three ranked constraints. The importance of these constraints varied according to the areas. Conflicts (1)

Table 2. Socio-economic characteristics of goat farmers in the Sudanian and the Sudano-sahelian areas of Burkina Faso.

Variable	Modalities	Total (n=372)	Sudanian (n=193)	Sudano-Sahelian (n=179)	P-value
Sex	Men	45.97	42.49	49.72	NS
	Women	54.03	57.51	42.49	NS
Education level	Illiterate	79.57	78.24	84.92	NS
	Informal	06.72	04.15	04.47	NS
	Formal	13.71	17.62	10.61	NS
Ethnics group	Mossi	45.70	19.17 ^a	84.36 ^b	***
	Fulani	14.52	04.66 ^a	09.50 ^b	***
	Lobi	35.75	68.91 ^a	00.00 ^b	*
	Others	04.03	07.25 ^a	06.15 ^a	NS
Main activities	Crop production	71.24	55.96 ^a	85.47 ^b	***
	Livestock breeding	23.39	31.61 ^a	14.53 ^b	***
	Trading	04.03	10.36 ^a	00.00 ^b	***
	Others	01.34	02.07 ^a	00.00 ^a	NS
Household size	Small (≤ 10 people)	34.41	18.99 ^a	48.70 ^b	***
	Medium (10 - 20 people)	45.97	56.87 ^a	36.79 ^b	**
	Large (≥ 20 people)	19.62	25.14 ^a	14.51 ^a	NS
Age (years)	Young: <30	15.76	07.19 ^a	14.81 ^a	NS
	Middle: 30 - 50	54.55	37.25 ^a	55.56 ^b	***
	Senior: >50	29.70	55.56 ^a	29.63 ^b	***
Number of years farming goats	Little (≤ 10 years)	47.58	61.66 ^a	32.40 ^b	**
	Medium (10- 20 years)	25.27	19.17 ^a	31.84 ^a	NS
	High (more than 20 years)	27.15	19.17 ^a	35.75 ^b	**
Mode of Farming	Sedentary	87.64	92.18 ^a	83.42 ^b	*
	Transhumant	12.37	07.82 ^a	16.58 ^b	**

^{a,b,c} values with the same letters on the same line are not significantly different at $P < 0.05$; n: number of goat keepers ; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; NS: not significant).

feed shortage (1.72) and diseases (1.73) were the three main constraints for Sudano-Sahelian goat farmers. Meanwhile diseases (1.26), lack of workforce (2) and abortion (2) were notable concerns in the Sudanian farms. Similar to goat keeping purpose, constraints with lower mean scores are considered are the main ones. Some constraints like low access to veterinary services, cost of concentrated feed for supplementation, abortions and accidents as mentioned in the Sudanian areas were not cited in the Sudano-Sahelian zones.

Characterization of goat production systems

Multiple correspondence analysis (MCA)

The Multiple Correspondence Analysis (MCA) was performed on 14 variables with 39 modalities. Only the

first two dimensions, which strongly contributed (26.2%) to the total variance, were retained. The bidimensional map, constructed using the surveyed individuals, revealed two distinct clusters representing each of the two population samples (as shown in Figure 3). The first axis, accounting for 15.8% of the total variation (as depicted in Figure 4), effectively differentiated farmers from the Sudano-Sahelian region from those in the Sudanian area. The second axis, contributing 11.7% of the total variation, separated farmers practicing transhumance from sedentary farmers.

Ascending hierarchical classification and group description

The hierarchical ascending classification performed on all variables defined three groups. Figure 5 shows the

Table 3. Distribution of livestock species by zone in the two agro-ecological zones.

Species	Sudano-Sahelian (n=179)			Sudanian (n=193)			P-value
	Mean±SD	Median	Range	Mean±SD	Median	Range	
Cattle	04.13±06.98 ^b	02.00	00-50	07.66±21.64 ^a	00.00	0-200	0.032
Sheep	09.24±09.14 ^a	06.00	00-50	06.31±10.47 ^b	02.00	00-58	0.004
Goats	12.93±13.72 ^a	10.00	1-140	15.68±13.76 ^a	12.00	2-100	0.054
Pigs	00.01±00.08 ^b	00.00	00-10	05.22±07.21 ^a	01.00	00-40	0.000
Donkeys	01.41±01.83 ^a	01.00	00-10	00.02±00.16 ^b	00.00	00-02	0.000
Poultry	14.31±13.48 ^b	10.00	00-90	23.77±30.79 ^a	15.00	0-202	0.000
Guinea fowl	04.18±07.37 ^b	00.00	00-40	07.38±12.79 ^a	00.00	00-98	0.003

Significant difference at $P < 0.05$ tested by Wilcoxon. Test comparison by production system is indicated with different letters. SD: Standard Deviation.

Table 4. Goat flock management by agro-ecological zones.

Parameter	Modalities	Total (n=372)	Sudanian (n=193)	Sudano-Sahelian (n=179)	P-value
Goat health management	No treatment	51.88	13.99 ^a	92.74 ^b	0.000
	Self-treatment	47.58	84.97 ^a	07.26 ^b	0.000
	Veterinary treatment	00.54	01.04 ^a	00.00 ^b	0.512
Goat supplementation	Yes	23.39	10.88 ^a	36.87 ^b	0.000
	No	76.61	89.12 ^a	63.13 ^b	0.000
Animal housing	Yes	52.69	58.55	46.37	0.025
	No	47.31	41.45	53.63	0.025
Grazing mode in rainy season	Herding in pasture	80.65	77.72	83.80	0.177
	Free grazing	18.82	22.28	15.00	0.101
	Tethering	00.54	00.00	01.20	0.445

^{a,b,c} values with the same letters on the same line are not significantly different at $P < 0.05$.

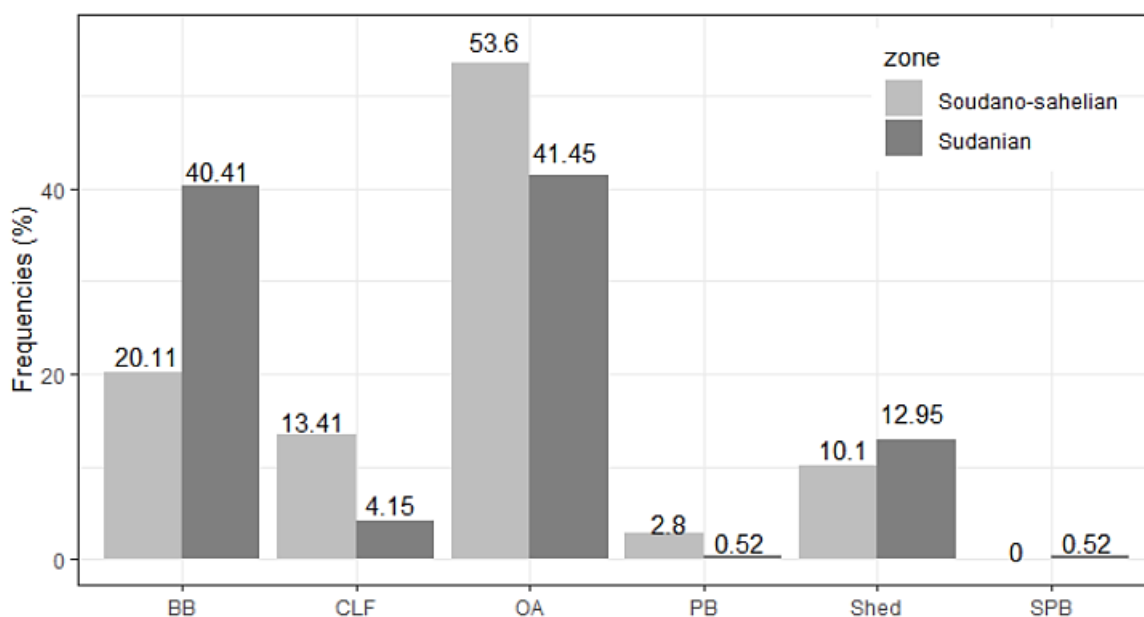
**Figure 2.** Frequencies of farmers per goat housing types in the study areas.

Table 5. Mean scores of the reasons of keeping goats in the Sudanian and Sudano-sahelian areas of Burkina Faso.

Purpose	Overall	Sudano-sahelian	Sudanian
	Mean score	Mean score	Mean score
Income	01.12	01.10	01.14
Manure	02.27	02.18	02.40
Socio-cultural	02.63	02.83	02.41
Meat	02.31	02.50	02.19
Savings	03.00	-	03.00
Wealth status	02.73	02.50	02.78
Skin	02.56	02.33	03.00

The lower the mean score, the more important the constraint is.

Table 6. Mean scores of the constraints of goat production reported by farmers in the two agro-ecological zones.

Constraint	Overall	Sudano-sahelian	Sudanian
	Mean score	Mean score	Mean score
Diseases and parasites	01.46	01.73	01.26
Feed shortage	01.95	01.72	02.47
Housing problems	02.53	02.76	02.32
Water shortage	02.10	02.04	02.21
Theft	02.72	03.00	02.45
Lack of extension service	02.57	02.57	02.57
Lack of workforce	02.26	02.37	02.00
Low access to veterinary service	02.62	-	02.62
Lack of grazing area	02.78	02.33	03.00
Cost of concentrate feed	02.00	-	02.00
Accident	02.50	-	02.50
Abortion	02.00	-	02.00
Market	02.80	02.60	03.00
Predators	02.50	02.00	03.00
Conflict with crop farmers	01.86	01.00	02.00

The lower the mean score, the more important the constraint is.

clusters and Table 7 presents the distribution of goat farmers in these clusters by variables and modalities.

Group 1

This group was represented by 164 farmers (44.09% of total surveyed). Farmers in this group came almost exclusively from the Sudano-Sahelian area (97.56%), belonging to the Mossi ethnic group (96.34%) and almost half were women (51.22%). The majority were adult (56.10%), illiterate (85.37%) and managing medium-size households (55.49%) (Table 7). They were sedentary (100%) and mostly involved in crop production (92.68%). These farmers had small goat flocks (62.80%) and were diversified in terms of experience in goat rearing. The

majority of their flocks were herded in the rainy season and 51.83% reported that they did not house their animals. A total of 60.37% reported that their animals did not benefit from feed supplementation, and none of them provided veterinary treatment.

Group 2

With 158 farmers (42.47% of the total sample), this group came almost exclusively from the Sudanian area (96.84%). Majority of farmers were women (55.70%) and came from Lobi ethnic group (82.91%). They were illiterate (74.05%), sedentary (100%) and had crop production as a main activity (70.25%). In this group, half of farmers were more than 50 years old (56.33%) with

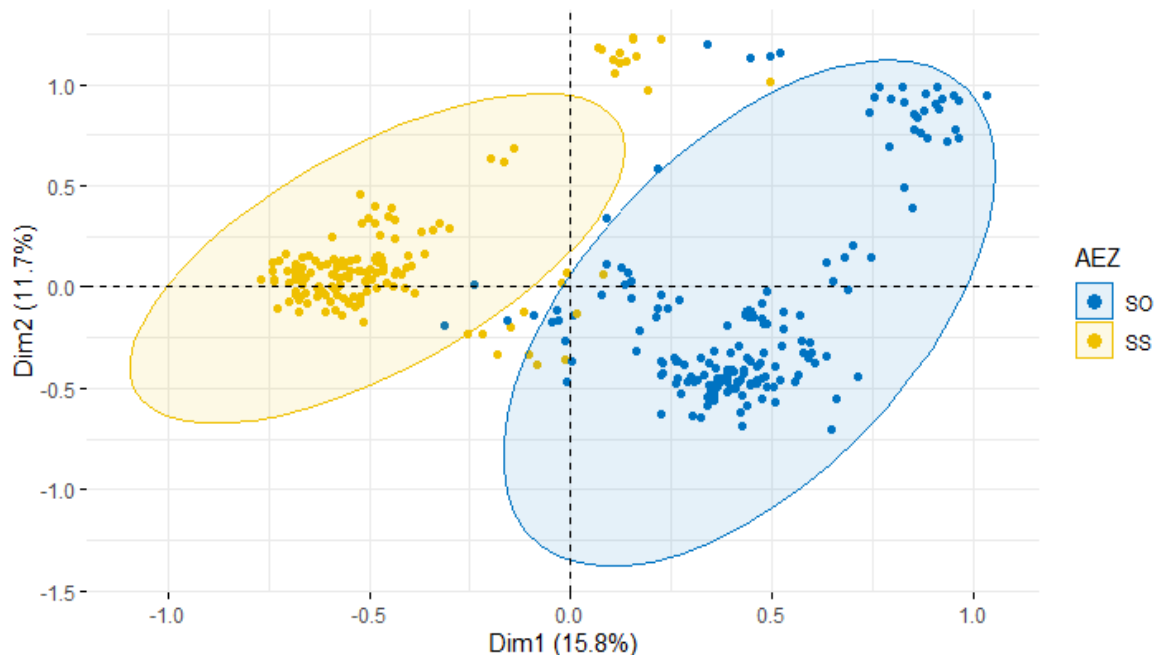


Figure 3. Distribution of farmers surveyed in the MCA two-dimensional plane based on 14 variables and 39 modalities in the two agro-ecological zones. AEZ: Agro-ecological zone; Dim: Dimension; MCA: Multiple correspondence analysis; So: Sudanian; SS: Sudano-Sahelian.

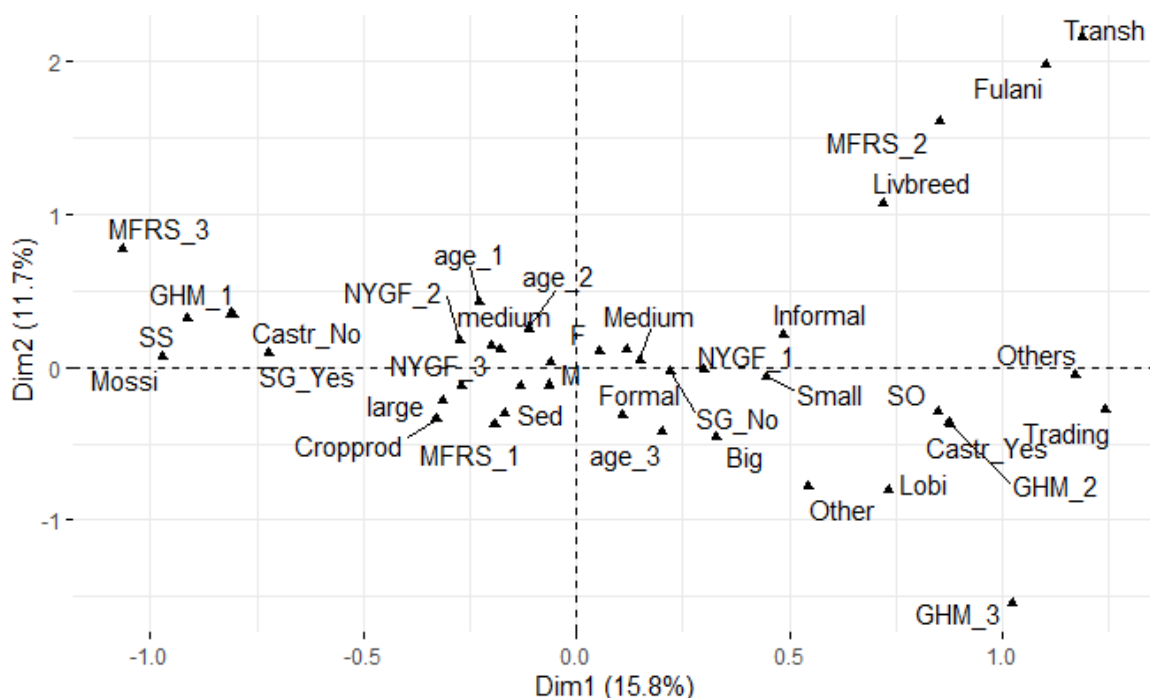


Figure 4. Distribution of the variability of Multiple Correspondence Analysis (MCA) of goat farmers in the two agro-ecological zones. Castr: Castration; Big: Big number of goats; Cropprod: Crop production; F: Female; Formal: formal education; GHM: Goat health management; Informal: informal education; large: large household size; Lobi: Lobi ethnic group; Livbreed: Livestock breeder; M: Male ; medium: medium household size; Medium: medium number of goats; MFRS: Mode of farming in rainy season [1:Herding in pasture, 2:Free grazing, 3:Tethering]; Mossi: Mossi ethnic group; NYGF: Number of year in goat farming [1: Little, 2: Medium, 3: High]; SG: Supplementation of goat [1:Yes, 2: No]; So: Sudanian; Sed: Sédentary; SS: Sudano-Sahelian; Transh: Transhumant ; small: small goat number, Small: Small household size.

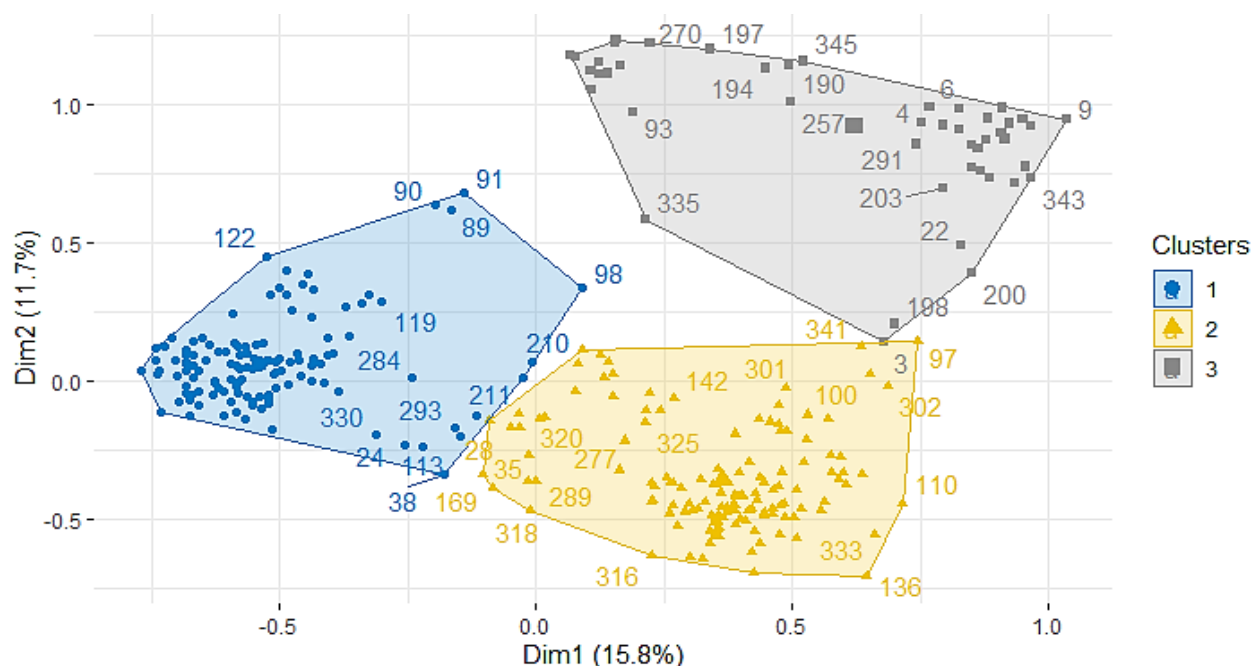


Figure 5. Clusters on axis 1 and 2 representing goat farming systems in the two agro-ecological zones (the numbers correspond to breeders' identifiers).

small household size (48.68%). About 48% of farmers in this group owned small flocks and unlike the previous groups, the majority (60.13%) had little experience in goat farming. The majority of flocks in this group freely grazed in rainy season and 47.47% of them were not housed. A majority of farmers (90.51%) in this group did not provide feed supplementation and self-treated their animals (87.30%).

Group 3

A total of 50 farmers representing 13.44% of all surveyed belonged to this cluster. Farmers in this group were from the Fulani ethnic group (100%) and about 72% were found in the Sudanian area. They were illiterate (78%), mostly middle aged (30-50 years old) (56%) and their households were predominantly medium (46%) to small (40%). They had livestock rearing as main activity, combining goat and cattle farming and practicing herd mobility (98%). These farmers were less experienced in goat rearing with 54% of these farmers having ≤ 10 years of experience raising goats and their flocks were in majority small (50%) with a relative high proportion of medium flock size (38%). Unlike the previous two groups, all farmers of this group freely grazed their animals in rainy season and a high proportion (68%) not housing their goats. Like the other groups, animals did not benefit from feed supplementation (86%) and similarly to group 2 many (64%) used self-treatment for animal health management.

DISCUSSION

Socio-economic and demographic characteristics of goat farmers

In the two study areas of the Sudanian and Sudano-Saharan zones, goat breeding is predominantly practiced by women (54%). This observation confirms previous reports by M'Bareck et al. (2021), who stated that the predominance of women in goat breeding is linked to their involvement in income-generating activities. Thus, regarding their high involvement in goat farming, CBBPs in the study areas should encourage strong participation of women. Also, women are often involved in income-Saharan zones, goat breeding is predominantly practiced by women (54%). This observation confirms previous reports by M'Bareck et al. (2021), who stated that the predominance of women in goat breeding is linked to their involvement in income-generating activities. Thus, regarding their high involvement in goat farming, CBBPs in the study areas should encourage strong participation of women. Also, women are often involved in income-generating activities by non-governmental organizations and governments; their participation in CBBPs could improve their access to resources and economic empowerment. Improvement of goat production in Burkina Faso is a promising option to improve rural women livelihoods and reduce poverty. Unlike large ruminants like cattle that are usually handled by men, small ruminants are managed by women. Specifically, the goat is considered a woman's animal in most traditional farms

Table 7. Hierarchical classification of goat farmers based on the selected variables.

Variable	Categorie	Cluster 1	Cluster 2	Cluster 3	P-value
		n=164 (44.09%)	n=158 (42.47%)	n=50 (13.44%)	
Agro-ecological zone	Sudanian	02.44	96.84	72.00	***
	Sudano-Sahelian	97.56	03.16	28.00	
Sex	Men	48.78	44.30	42.00	NS
	Women	51.22	55.70	58.00	
Ethnics group	Mossi	96.34	07.59	00.00	***
	Fulani	01.83	00.63	100.0	
	Lobi	01.22	82.91	00.00	
	Other	00.61	08.86	00.00	
Educational level	Illiterate	85.37	74.05	78.00	NS
	Informal	04.27	06.96	14.00	
	Formal	10.37	18.99	08.00	
Age	Young: ≤30 years	15.85	7.59	14.00	***
	Middle: 30 - 50 years	56.10	36.08	56.00	
	Senior: > 50 years	28.05	56.33	30.00	
Main activities	Crop production	92.68	70.25	04.00	***
	Livestock breeding	07.32	20.89	84.00	
	Trading	00.00	06.96	08.00	
	Others	00.00	01.90	04.00	
Mode of farming	Sedentary	100.0	100.00	2.00	***
	Transhumant	00.00	00.00	98.00	
Household size	Small (≤ 10 people)	19.51	48.10	40.00	***
	Medium (10 – 20 people)	55.49	36.08	46.00	
	Large (≥ 20 people)	25.00	15.82	14.00	
Number of goats	Small (≤ 10)	62.80	46.20	50.00	NS
	Medium (10 –20)	28.05	29.75	38.00	
	Big (> 20)	09.15	24.05	12.00	
Number of years faming goats	Little (≤ 10 years)	33.54	60.13	54.00	***
	Medium (10- 20 years)	32.93	18.35	22.00	
	High (> 20 years)	35.54	21.52	24.00	
Grazing mode in rainy season	Herding in pasture	90.85	95.57	00.00	***
	Free grazing	07.93	04.43	100.00	
	Tethering	01.22	00.00	00.00	
Animal housing	Yes	48.17	52.53	32.00	*
	No	51.83	47.47	68.00	
Goat supplementation	Yes	39.63	9.49	12.96	NS
	No	60.37	90.51	86.00	
Goat health management	No treatment	95.73	11.39	36.00	***
	Self-treatment	04.27	87.30	64.00	
	Veterinary treatment	00.00	01.27	00.00	

Chi-square used to test for significance differences (*P < 0.05; **P < 0.01; ***P < 0.001; NS: not significant).

in Africa (Alary et al., 2011). Our results, however, contrast with those obtained by Laoubi et al. (2011), Kadi et al. (2014) and Laouadi et al. (2018) in Algeria where 86,2-100% of the respondents were men. This difference is maybe due to the difference of cultures in the 2 countries.

A high proportion of farmers in this study did not have formal education. This high illiteracy in accordance with the global education level in the country supports the findings of previous studies in Burkina Faso, and in similar contexts (Agossou et al., 2017; Ouédraogo et al., 2020; Zoma-Traoré et al., 2020). In developing countries in general, women have less access to education due to social and cultural constraints. Indeed, factors such as early marriage of women (under 18 years of age) accentuate the low level of schooling in rural areas (Thioye, 2015). This low level of literacy in rural areas would imply a difficulty to access technological innovations (Agossou et al., 2017; Sow et al., 2021).

However, unlike the conventional breeding approach which required well educated farmers, CBBP is more likely to be adapted for farmers with low level of education, like the majority of goat keepers in the study areas (Sölkner et al., 1998).

Crop and livestock production constituted the main livelihood activities of the households that participated in this study, which is consistent with the results of previous studies (Ouédraogo et al., 2020; Zoma-Traoré et al., 2020). This observation reflects the fact that in Burkina Faso, the majority of the population live in rural areas and rely on subsistence crop production and livestock breeding for their livelihoods. Indeed, the dependency of rural livelihoods on crop and livestock production is widespread in developing countries (Okeno et al., 2012; Osei-Amponsah et al., 2011). In both areas, crop production is conspired by a high proportion of farmers as their main activity. The relative high proportion of farmers in the Sudanian area having livestock rearing as main activity could be explained by the proportion of Fulani people among the surveyed in this area. Ouédraogo et al. (2020) reported that in Southwestern Burkina Faso, sedentary people depend primarily on crop production while Fulani pastoralist depends on livestock as primary sources of income. However, Fulani always have both activities attesting the diversification of sources of incomes and integration of crop and livestock. According to Onzima et al. (2018), the low income level and the subsistence nature of the smallholder farmers, may have influenced the choice of main livelihood activity. Diversification of source of incomes as mentioned in our study is reported as a strategy of smallholder farmers to cope with the global environmental and socio-economic changes. Crop-livestock integration aim to capture the advantages of each activity (Ayantunde et al., 2014; Haile et al., 2020; Zampaligré et al., 2014). These findings corroborate that of Kosgey et al. (2008), Guangul (2014) and Sow et al. (2021) respectively in Kenya, Ethiopia and

Senegal. This observation is consistent with results reported from studies in similar context in Algeria (Ouchene-Khelifi et al., 2021), Brazil (Guilherme et al., 2017) and Mexico (Hernández et al., 2011). In the Sudano-Sahelian and Sudanian areas of Burkina Faso, the advantages of crop-livestock integration could be used to enhance goat productivity in CBBPs context by using crop residues to improve animal feeding conditions.

Characteristics of goat flocks and management

In the study areas, goats are jointly kept with other livestock species. In both areas, goat flocks by household were on average higher compared to other ruminants like sheep and cattle, confirming the national ruminant population distribution trend. Indeed, the recent statistics reported that goats represent the largest ruminant population in Burkina Faso (MRAH, 2019, 2021; FAOSTAT, 2022). This relatively big goat flocks' size is an asset for genetic improvement in these areas because it could provide a large breeding stock. Indeed, small flock size is one of the characteristics limiting the implementation of effective improvement programs in many developing countries (Sölkner et al., 1998).

The diversity of reasons for keeping goats in this study confirms the multifunctionality of livestock for rural smallholder farmers. The different reasons reported in this study are in accordance with previous studies in West Africa (Ouédraogo et al., 2020; Traoré et al., 2017; Yakubu et al., 2020). In both areas, income was ranked first confirming the importance of goats in generating incomes for rural households (Kosgey et al., 2008; Semakula et al., 2010, Okeno et al., 2012; Laouadi et al., 2018). Subsistence crop production fulfils the needs of households in food, whereas livestock in general and small ruminants in particular, such as goat is source of cash for farmers to support education of children, access to health services and other basic needs. Manure was another important reason mentioned by farmers and this resource is consistent with crop-livestock integration. Similarly, earlier studies with smallholder farmers have also ranked manure highly (Kosgey et al., 2008). Goat manure is generally considered useful in enhancing soil fertility for vegetable production (Onzima et al., 2018). According to Nziku et al. (2016), mineralization of goats manure results in organic nitrogen and phosphorous, and is therefore a cheap source of organic fertilizer. Meat for household consumption was also an important reason for keeping goats. Even if meat is not usually part of rural household daily diet, farm animals are usually slaughtered during celebrations and socio-cultural ceremonies. However, milk, which is another important product for household consumption, was not cited in this study meaning that goats are not milked. This is probably due to the type of goat kept in both areas (Mossi and Djallonke breeds). In Burkina Faso, only Sahelian goat

breeds are known to perform well in milk production. Regarding the proportion of women keeping goats, goat milk consumption should be encouraged because it can contribute to improve nutritional conditions of children (Sow et al., 2021).

Implementation of breeding programs in these areas should consider these needs of farmers. Furthermore, breeding objectives and traits to be improved should be defined accordingly in participatory way as required by CBBP approach (Mueller et al., 2015; Wurzinger et al., 2021).

Goats are mainly fed in natural pasture following different herding systems in the two areas. Free grazing is commonly used in the dry season, during the rainy season goats are herded in pasture, tethered and exceptionally freely grazing in some cases. In Burkina Faso, whatever the area, small ruminants (sheep and goat) are free in the dry season (Kaboré et al., 2011). The practice of herding versus tethering depends on many factors such as flock size and workforce availability. When the flock is big, animals are usually kept by children in pasture during the day. However, when there is lack of children for herding, animals were tethered. Even if forage is relatively available in the rainy season, during the dry season dried forage contains low nutritive value and cannot provide the goat's requirements, which in turn leads to loss of productivity (Lamini and Ologbosé, 2014). However, the majority of goat farmers in this study do not provide feed supplementation to their animals. According to Missohou et al. (2016), goats receive less supplementation than other animals because farmers deem them more robust and perhaps less valuable. Furthermore, goats are not provided with adapted housing system on most farms. The herding and housing systems in the study areas could be limitations for the successful implementation of goat CBBPs. Indeed, free grazing for example is a constraint for animals' performance recording and mating control. Lack of appropriate feeding and housing strategy can raise the issue of animal welfare and consequently strongly impact their productivity. Sustainable goat production calls to raise farmers' awareness of animal welfare and its implications.

Several problems are encountered in goat farming in Sudano-Sahelian and Sudanian areas of Burkina Faso. The most important ones among others are conflict, feed shortage, water shortage, and lack of workforce. Constraints reported in this study are consistent with previous reports in Southwestern Burkina Faso (Zoma-Traoré et al., 2020).

Reduction of productivity of land is a direct impact of climate change and demographic growth in the country because of increased competition for land and conflict between crop producers and livestock keepers. The lack of workforce results from recent socio-economic changes in rural societies of Burkina Faso, marked by rural exodus and the emergence of gold panning activities that attract

more young people.

Most common goat diseases reported are parasitosis, diarrhoea and plague of small ruminants. Local goats, despite their hardiness are susceptible to certain diseases (Sow et al., 2021). Despite the importance of diseases, there is limited access to veterinary service in the areas. Consequently, many farmers do not treat their animals or frequently resort to self-medication using inappropriate drugs and more often medicinal plants. Previous study emphasized the role and importance of plants in animal diseases treatment in Burkina Faso and particularly in the Southwest (Traoré et al., 2020). CBBPs could not be successfully sustainably implemented and generate genetic gain in the Sudano-Sahelian and Sudanian zones of Burkina Faso without overcoming the major constraints faced by goat keepers. For this, farmer's capacities should be strengthened in goat feeding strategies and they should be provided with facilities in animal health care. According to De Vries (2008) factors such as education, training of farmers and providing them with extension services are critical for the success of goat development programs.

Characterization of goat production systems

The results of this study suggested that goat farmers practiced different modes of farming depending on the agro-ecological zone they are in. Multivariate analysis, indeed, allowed the discrimination of three groups of farmers regarding their characteristics and their practices. On one hand, the sedentary agropastoral goat farmers were different from transhumant pastoral farmers when considering mobility, and on the other hand, the sedentary farming type was split considering ethnic groups: Lobi in the Sudanian zone and Mossi in the Sudano-Sahelian area.

The first group of identified herders is represented by the sedentary agropastoral goat farming system located in the Sudano-Sahelian zone. In this system, herders manage small herds grazed in pastures, and a relative proportion of them provide feed supplements to their animals. Men slightly dominate this group, and they are more involved in crop production than in livestock. The second group consists of sedentary agropastoral goat farming systems located in the Sudanian zone, which are run by Lobi women. Unlike the previous group, these farmers do not tend to supplement their animals' diet. These findings are consistent with Ouédraogo et al. (2020) and Zoma-Traoré et al. (2020), who described sedentary agropastoral cattle production system involving Lobi and Mossi people in Southwestern Burkina Faso.

According to Worogo et al. (2020), the association of livestock with agricultural activities could still be justified by the fact that farmers want to increase their production by benefiting from manure. These results are corroborated by Ba et al. (2011), who opined that the

majority of production systems are mixed (agropastoral), and agriculture is largely dominant.

The third group consists of pastoral goat farming systems located in the Sudano-Sahelian zone, mainly involving Fulani herders. These farmers are mainly involved in livestock, combining goats with cattle and practicing transhumance, a seasonal mobile herd search for pastures. Similar system involving Fulani was also identified in previous studies (Ouédraogo et al., 2020; Zoma-Traoré et al., 2020). This observation is consistent with the assertions of Ayantunde et al. (2011) and Houessou et al. (2019), who argue that the practice of transhumance remains the domain of Fulani people.

These results suggest that goat herders adapt to their agro-ecological environment, and their practices are influenced by the availability of pasture, water and feed resources for their livestock. Most production systems are mixed (agropastoral), showing a strong interaction between agriculture and livestock in the regions. The results of this study could help design more tailored development strategies for each group of herders, taking into account their specificities and needs related to the agro-ecological environment in which they operate.

Development of genetic improvement programs for small ruminants will only be successful when accompanied by a good understanding of the different farming systems and when simultaneously addressing several constraints such as feeding, health control, general management, availability of credit and marketing infrastructure (Kosgey et al., 2008).

Globally, the results of this study provide an in-depth understanding of goat production systems in different zones of Burkina Faso, including husbandry practices, flock sizes, housing and grazing systems, as well as differences between the zones. This knowledge is crucial for the implementation of effective and location-specific community-based breeding programs (CBBP), taking into account existing husbandry practices and the needs of local farmers (Haile et al., 2020).

Additionally, the results have shown that Fulani breeders practice transhumance, which may require different pasture management approaches compared to those who practice sedentary farming. CBBPs based on this local knowledge can be more effective and have a greater chance of improving the livelihoods of farmers and supporting economic development in these areas.

Conclusion

This study was carried out to understand the diversity of goat farming practices in Burkina Faso in preparation of a potential CBBP implementation. It provided a detailed analysis of the diversity of goat farming systems in Burkina Faso, particularly in the Sudano-Sahelian and Sudanian zones, which is essential to understand current farming practices. The results of this study provided important information for the implementation of CBBP in

the context of goat farming in Burkina Faso. Goat improvement strategy, CBBP approach should consider this diversity of goat farming systems and needs. The results of this study can be used to improve livelihoods of farmers and support economic development in these zones.

Therefore, Community-Based Goat Breeding Programs (CBBPs) designed and implemented based on the results of this study are more likely to improve the livelihoods of farmers and support economic development in these zones.

CONFLICT OF INTERESTS

The authors declared any conflict of interests.

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