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A typological characterization of rural goat production systems of Benin prior to their sustainability assessment

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SUMMARY

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 therefore been undertaken to characterize the diversity of goat farming systems and identify major constraints and opportunities for their sustainability in different agro-ecological zones of Benin. Data collected on 478 rural goat herds kept in four districts in Benin were subjected to Categorical Principal Component Analysis and Two-step cluster analysis. Four different goat farm types were identified using the housing mode practiced, the number of reproductive females in the flock, and farmer's resource endowment as discriminating variables. Seasonal confinement includes goat tethering (group 1, n=203, 47%) or housing in enclosure (group 4, n=29, 5%) during the day in the rainy season. In free roaming system, goats were allowed to wander all year round and kept in small herds (group 2, n=222, 47%) or large herds (group 3, n=24, 5%). The relationship between farmers' socio-economics characteristics, location constraints and management practices in each farm type highlight the impact of poor interest and investment of farmers, lack of resources and access for education and training mainly by women on the poor management of goats.

Typologie des systèmes d'élevage caprin en milieu rural au Bénin en vue d'une étude ultérieure de leur durabilité

Mots clés supplémentaires
Diversité des exploitations.
Intégration agriculture-élevage.
Petits ruminants.
Systèmes d'élevage.

RESUMÉ

Cette étude a été entreprise afin de caractériser la diversité des systèmes d'élevage caprin et identifier les principales contraintes et opportunités pour leur durabilité dans les différentes zones agro-écologiques du Bénin. Les données collectées sur 478 troupeaux caprins ruraux élevés dans quatre communes du Bénin ont été soumises à une analyse en composantes principales catégorielles et à l'algorithme de classification "two-step" du logiciel statistique IBM®-SPSS®. Quatre différents types d'élevages caprins ont été identifiés en utilisant le mode de logement pratiqué, le nombre de femelles reproductrices dans le troupeau et la disponibilité en ressources des producteurs comme variables discriminantes. La claustration saisonnière comprend l'attache des caprins au piquet (groupe 1, n = 203, 47%) ou la mise en enclos (groupe 4, n = 29, 5%) durant la journée pendant la saison des pluies. Dans le système de divagation totale, les caprins erraient toute l'année en de petits troupeaux (groupe 2, n = 222, 47%) ou de grands troupeaux (groupe 3, n = 24, 5%). La relation entre les caractéristiques socio-économiques des agriculteurs, les contraintes du milieu et les pratiques de gestion dans chaque type d'exploitation met en évidence l'impact du faible investissement des producteurs, du manque de ressources alimentaires, d'accès à l'éducation et à la formation principalement par les femmes sur la mauvaise gestion des élevages de caprins. En outre, une meilleure gestion du logement et de l'alimentation des caprins ainsi que le développement de marchés de caprins sont essentiels pour le développement de l'élevage caprin villageois.

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INTRODUCTION

Since its domestication thousands of years ago, the importance and special attributes of goats compared with other farm animal species have been reported and discussed by many authors worldwide (Skapetas & Bampidis 2016; Badenhorst 2018; Darcan & Silanikove 2018; Dubeuf et al. 2018; dos Santos Souza et al. 2019; Kwashirai & Mhike 2019 and Mazhangara et al. 2019). Goats sustain the livelihoods of smallholders in several rural areas across Africa. They are traditionally kept by more than 60 % of the rural populations in West Africa, either as the main or secondary livelihood's activity (Agossou et al. 2017). They are an important source of income and employment as well as living savings account and insurance and make a substantial contribution to the rural economy of poor farmers (Madsen et al. 2007; Alex et al. 2010; Monau et al. 2020 and Desta et al. 2020). Under harsh environmental conditions and low management systems, goats have the abilities to convert poor feed resources into good quality of milk and meat and have therefore a high potential to contribute to the attainment of food security and environmental sustainability (Capote 2017 and Kwashirai & Mhike 2019).

In Benin, goats are owned by the majority of rural people, mainly women and vulnerable people, in mi-

xed farming system and are considered as investment and insurance (Dossa et al. 2008). The national goat population was estimated at around 2504000 head in 2019 (FAOSTAT 2019). Unfortunately, despite its high potential for poverty alleviation, goats are barely considered in scientific research and breeding improvement programs in Benin. Information on their performances and production systems are scanty. In the present context where poverty reduction and food security constitute some major challenges in developing countries, implementing strategies to improve traditional goat production must benefit rural farmers in supporting and enhancing their wellbeing. Adequate development policies to sustain smallholder goat farming require an effective understanding and exploitation of the diversity of production systems, each farming system having its specific set of limitations, constraints and potentials for achieving food security (Waha et al. 2018).

Typologies have been extensively used to explore and describe the diversity of farming systems (Dossa et al. 2011; Kuivanen et al. 2016 and Alvarez et al. 2018), assess their structural characteristics (Gelasakis et al. 2017 and Blanco-Penedo et al. 2019) as well as their capacity to cope with stress and changes in the bio-physical and socio-economic conditions in which they evolve (Maleksaeidi et al. 2016; Ibidhi et al. 2018; Friedman et al. 2019 and Tittonell et al. 2020) in order to develop relevant recommendations for their improvement. This study aims therefore to characterize, through a typology, the diversity of rural goat farming systems across different agro-ecological zones of Benin, and identify key entry points to enhance their potentials to sustain rural food security.

MATERIAL AND METHODS

Study locations

The study was conducted in four agro-ecological zones along the gradient South-North in Benin, West Africa (**Figure 1**). In each agro-ecological zone, a location, where goat farming is well developed and farmers relatively accessible was selected.

Kpomassè (between 6°21′ to 6°42′ N and 2°13′ to 2°25′ E) is located in the Guineo-Congolese agro-ecological zone in Southern Benin at between 22 and 41 m above sea level (Dossou-Guedegbe & Quenum 2010). It is characterized by a bimodal rainfall regime (two dry seasons and two wet seasons) with annual precipitations varying from 1300 to 1500 mm. The soils are predominantly deep ferralitic (Neuenschwander et al. 2011) and covered by a shrubby vegetation dominated by palm trees. Crop farming is the most important economic activities, followed by fishing, animal husbandry and petty trade. The main food crops are maize, cowpea, cassava, tomato and groundnut. Pigs, poultry and small ruminants are the main livestock species raised.

Glazoué (7°58′25″ N and 2°14′24″ E) is located in the Sudano-Guinean agro-ecological zone at an average altitude of 200 m. The soils are tropical ferruginous, covered by natural vegetation (riparian forests, gallery forests, dense forests, dry, clear forests, tree and shrub

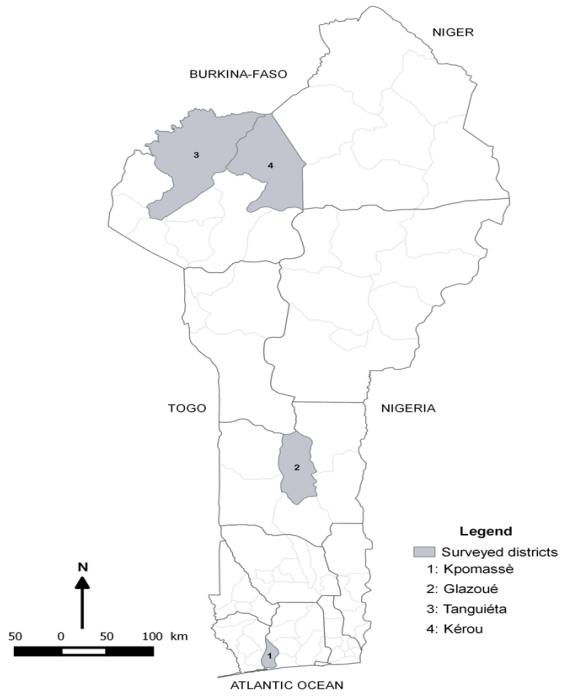

Figure 1. Map of Benin indicating the four districts surveyed (Carte du Bénin indiquant les quatre communes enquêtées).

wooded savannas and saxicolous savannas) and teak plantations (Adam & Boko 1993). Annual rainfall ranges from 960 mm to 1256 mm. The main economic activities include rainfed agriculture, animal husbandry, small-scale processing of agricultural products, and commerce. Maize, rice, sorghum, cassava, yam, sweet potato, cowpea, bambara bean, soy and tomato are the main crops. The livestock species raised include cattle, small ruminants, pig and poultry.

Kérou and Tanguieta belong to two distinct agro-ecological zones (Sinsin & Kampmann 2010) in the Sudanian vegetation zone characterized by a dry tropical climate with one single rainy season and a ferruginous soil.

Kérou lies at an average altitude of 300 m in the Borgou-Nord agro-ecological zone characterized by an annual precipitation varying between 1000 and 1150 mm, and a humidity index of 1.9 with a vegetation largely dominated by savannas with continuous grassy groundcover. The economic activities in Kérou are similar to those in Glazoué. Main cultivated crops include maize, sorghum, cotton, yam, cowpea, bambara bean, soya bean and tomato and livestock species include cattle, goats, sheep, pigs and poultry. The population of ruminant species is relatively greater than in Glazoué. Tanguiéta belongs to the "Chaîne de l'Atacora" agro-ecological zone which contrasts with the previous by its high altitude (500 m), poorly developed soils, higher humidity index (2.1) and the presence of pockets of dense and light forests. In addition to rainfed agriculture and animal husbandry, hunting, handicraft and tourism are important economic activities.

Sampling procedure and data collection

In each of the four locations, data were collected in four randomly selected villages. First, a focus group discussion was hold in each village to explain the objectives of the study and obtain the prior-informed consent of the goat farmers to participate. A list of goat farmers willing to participate was drawn. Subsequently, thirty (30) farmers were randomly sampled per village, except in one village of Glazoué where 28 goat breeders were surveyed, for individual interviews. Using a semi-structured questionnaire, a data collection strategy and a research method (McIntosh & Morse 2015) which allows the interviewees to freely express their opinions and thoughts (Horton et al. 2004), information was collected from the heads of households or their representatives and included *inter alia* the socio-economic characteristics of households, their resources endowment, goat herd characteristics, management practices and constraints to production.

Statistical analyses

All statistical analyses were performed using the IBM®-SPSS® software version 20 (IBM Corp. 2011). Descriptive statistics included means and standard deviations for quantitative data and frequencies for qualitative data. Kruskal-Wallis tests were performed to compare means among locations.

Variables that showed a significant difference among locations were submitted to categorical principal component analysis (CATPCA) procedure of optimal coding. CATPCA is known to be the most appropriate approach to analyze the relationship between quantitative variables and different modalities of qualitative variables, and reduce the original set of variables into a smaller number of components (Semara et al. 2013 and Rouabhi et al. 2016). The principal reliable components were chosen using the methodology described by Stevens (1992) and adapted by Costantini et al. (2010) and Abdulkadir et al. (2012). From a total of ten (10) variables retained after the CATPCA analysis, nine (09) variables with loadings equal or higher than 0.5 on one of the two principal dimensions (**Table I**) were selected and submitted to a two-step cluster analysis. The optimal number of homogenous goat farming systems was retained after exploring several cluster solutions as described by Dossa et al. (2011).

Chi-square (χ^2) followed by Z-tests and Kruskal-Wallis followed by Mann Whitney U tests were used for pairwise comparisons of the identified goat farming systems. For all statistical analyses, values were considered significantly different at $p \leq 0.05$.

RESULTS

Goat farmer households' socio-economic characteristics

Most of the socio-economic characteristics of goat farmers were significantly related ($p \leq 0.001$) to their location (**Table II**). About 56% of surveyed farmers were men, although women dominated in Glazoué in the Sudano-Guinean zone (64%) and Kérou in the "Chaîne de l'Atacora" zone (57%). Irrespective of agro-ecological zone, two-third (76%) of the respondents were illiterate. The average age of surveyed goat breeders was 46±16 years and did not significantly vary across zones. In contrast, farmers' experience in goat farming differed significantly ($p \leq 0.001$) among zones, most experienced

Table I. CATPCA model summary and component loadings for goat farming systems in Benin (Résumé du modèle CATPCA et poids des composantes décrivant les systèmes d'élevage caprin au Bénin).

	Total	Dimension	
		1	2
Cronbach's alpha	0.859	0.648	0.527
Total eigenvalue	4.236	2.356	1.880
Total variance explained (%)	47.072	26.181	20.891
Variables		Component loadings	
Sex of farmer		-0.017	**0.770**
Practice of castration		**0.537**	0.484
Frequency of handfeeding during wet season		0.430	**0.505**
Housing mode at daytime during wet season		**-0.625**	-0.580
Presence of buck		**-0.504**	0.239
Number of reproductive does		**0.587**	-0.351
TLU* of other ruminants		**0.585**	-0.330
Household size		0.455	-0.263
Land size		**0.586**	-0.320
Locality		**0.705**	0.472

*TLU, Tropical Livestock Unit: standardized animal of 250 kg live weight; 1 cattle =0.8 TLU; 1 sheep/goat=0.1TLU.

Table II. Socio-economic characteristics of rural goat farmers in four districts of Benin (Caractéristiques socio-économiques des éleveurs de caprins en milieu rural dans quatre communes du Bénin).

Variable	Total	Kpomassè	Glazoué	Kérou	Tanguiéta	P value
	(N=478)	(n=120)	(n=118)	(n=120)	(n=120)	
			% of respondents			
Sex						0.001
Male	55.6	59.2^{a}	35.6^{b}	43.3^{b}	84.2^{c}	
Female	44.4	40.8^{a}	64.4^{b}	56.7^{b}	15.8^{c}	
Position in the household						0.001
Household head	51.3	52.5^{a}	29.7^{b}	38.3^{b}	84.2^{c}	
Wife	41.2	40.0^{a}	57.6^{b}	54.2^{b}	13.3^{c}	
Other	7.5	7.5^{ab}	12.7^{b}	7.5^{ab}	2.5^{a}	
Educational level						0.001
Formal education	24.3	32.5^{a}	39.8^{a}	12.5^{b}	12.5^{b}	
Informal education	5.2	10.8^{ab}	1.7^{b}	4.2^{b}	4.2^{b}	
None	70.5	56.7^{a}	58.5^{a}	83.3^{b}	83.3^{b}	
Main occupation						0.001
Crop farming	81.0	77.5^{ab}	66.9^{b}	83.3^{a}	95.8^{c}	
Livestock keeping	2.5	0.8^{a}	3.4^{a}	3.3^{a}	2.5^{a}	
Trade	8.2	10.8^{ab}	15.3^{b}	5.8^{a}	0.8^{c}	
Other	8.4	10.8^{a}	14.4^{a}	7.5^{a}	0.8^{b}	
Main source of income						0.001
Crop farming	79.1	70.0^{a}	70.3^{a}	82.5^{b}	93.3^{c}	
Livestock keeping	4.2	5.0^{a}	3.4^{a}	4.2^{a}	4.2^{a}	
Trade	10.5	14.2^{ab}	18.6^{b}	7.5^{a}	1.7^{c}	
Other	6.3	10.8^{a}	7.6^{a}	5.8^{a}	0.8^{b}	
			Mean ± Standard Error			
Age of respondents	45.6±15.53	43.7±15.13	46.6±15.16	46.1±17.54	46.1±14.10	0.377
Experience in goat farming	11.0±9.94	8.7^{a}±7.44	10.0^{a}±8.69	10.3^{a}±9.65	15.2^{b}±12.18	0.001
Cultivated land size	3.2±6.24	1.5^{a}±1.19	2.2^{b}±1.75	6.4^{c}±11.60	2.5^{bc}±1.58	0.001

^{abc} Within a row, values with different superscript letters are significantly different at P ≤ 0.001 level

farmers were observed in the "Chaîne de l'Atacora" zone. The main stated objective for farming goat was commercial purpose/sale (74%), followed by use for festivities/celebrations (16%), household consumption (6%), gifts (3%) and sacrifices (1%). In 79% of surveyed households, goats were kept together with other livestock species which included local chicken (55%), sheep (13%), pig (12%), cattle (8%), guinea-fowl (7%), duck (4%) and others (rabbits, pigeon and snail).

Irrespective of agro-ecological zone, crop production was the main activity of 81% of the respondents. Their majority (77.1%) cultivated on their own land except 88% of those surveyed in the Guinean-congolian zone who were exploiting leased lands. Furthermore, the average cultivated land size was significantly lower in the Guinean-congolian zone than in the other zones, the biggest cultivated land sizes were observed in Kérou in the Borgou-Nord agro-ecological zone.

Goat herd characteristics and management practices

Herds size and structure

Goat herd size and structure were significantly (p <0.001) related to agro-ecological zone (**Table III**). The number of goats owned by a single household ranged between 1 to 72 goats with an average herd size of 9 heads. The biggest herd sizes were recorded in Glazoué and Kérou and the smallest in Kpomassè and Tanguiéta. Irrespective of agro-ecological zone, the herds were dominated by adult reproductive female (39.4%) whereas the proportion of reproductive male in the herds was generally low (2.9%).

Housing and manure management

Depending on season, time of day and agro-ecological zone, goats were either left freely roaming in the village, tethered in the yard or penned. However, there were significant variations across agro-ecological zones (**Figure 2**). In the Sudano-Guinean (Glazoué) and Borgou Nord (Kérou) zones, herds were mainly kept free-roaming through the village at daytime and left free in the household's yard at night. In contrast, the animals were tethered the whole day during the rainy season in 94% and 73% of herds in "Chaîne de l'Atacora" (Tan-

Table III. Average goat herd sizes and structure in four different districts of Benin (Taille moyenne et structure des cheptels caprins dans quatre communes au Bénin).

Variable	Total (N=478)	Kpomassè (n=120)	Glazoué (n=118)	Kérou (n=120)	Tanguiéta (n=120)	P value
			Mean ± Standard Error			
Herd size (n)	9.1±0.43	6.8^{a}±0.50	9.7^{a}±0.89	14.1^{b}±1.23	6.0^{a}±0.36	0.001
Herd structure*(%)						
Potential breeding female	46.8±1.00	46.5^{a}±2.27	40.1^{a}±1.90	47.0^{ab}±1.73	53.6^{b}±1.93	0.001
Potential breeding male	2.9±0.35	2.9±0.83	3.4±0.76	3.3±0.67	2.0±0.53	0.083
Rearing female	12.4±0.92	11.5^{ab}±1.96	22.0^{c}±2.28	9.9^{a}±1.12	6.5^{b}±1.48	0.001
Rearing male	6.1±0.56	8.0±1.29	6.7±1.07	4.6±0.92	5.3±1.12	0.176
Suckling female	16.6±0.79	16.2±1.76	15.4±1.42	18.0±1.47	16.8±1.63	0.519
Suckling male	15.0±0.77	14.5^{ac}±1.76	12.4^{ab}±1.42	17.3^{c}±1.38	15.8^{ac}±1.56	0.022

*Potential breeding female/male (>12 months); rearing female/male (6-12 months); suckling female/male (<6 months).
^{abc} Within a row, values with different superscript letters are significantly different at P ≤ 0.001 level

guiéta) and Guineo-Congolese (Kpomassè) zones respectively (**Figure 2**).

At nighttime, goats were housed either in enclosure or in the farmer's room/ kitchen in respectively 87% and 94% of herds in Kpomassè and Tanguiéta, whereas the majority (respectively 72% and 80%) of herds in Glazoué and Kérou were left free-roaming.

Manure was collected in more than 50 % of surveyed herds and was either dumped or used for soil fertilization. A significant (p<0.05) proportion of goat herders in Tanguiéta (95.5% against 18%; 23% and 33% in Kpomassè, Glazoué and Kérou respectively) valorized the collected manure.

Feeding and watering

Goat feeding was generally based upon extensive grazing on fallow areas or non-exploited communal lands. Supplementary feeding was mainly provided in Kpomassè (33% of herds in dry season and 80% in rainy season) and Tanguiéta (53% of herds during the rainy season). More than the two third of farmers in Glazoué and Kérou (87% and 71%, respectively) reported that they sometimes offered supplementary feeds to their animals. The type of the supplementary feeds was significantly (χ^2=368.6, p≤0.001) related to the location (**Figure 3**). Fresh herbs collected along roadsides were mainly reported in Kpomassè and Tanguiéta whereas crop residues (straws or spate of corn, groundnut fans, rice straw, straw of millet or sorghum, sheets of cassava or sheets of cowpea) and wastes obtained from processing agricultural products (bran of corn, bran of rice, peelings of cassava or yam, oil cake soya bean) were more common in Glazoué and Kérou. Almost all farmers (98%) reported that they sometimes provide drinking water, fetched mainly from wells, to their goats.

Feeding and watering Breedin and reproductive performances

Mating was generally uncontrolled in all investigated herds. The presence of buck was reported in only 24% of the surveyed herds. Furthermore, only 4% of surveyed farmers reported that they ensured the mating of their female goats by borrowing a buck from other village herds. In contrast to Kérou (15%) and Glazoué (59%), castration was commonly practiced in Kpomassè (87%) and Tanguiéta (87%), mainly to improve animal growth (92%), increase animal docility (4%), eliminate generic swell of male (3%) or to control the mating (1%).

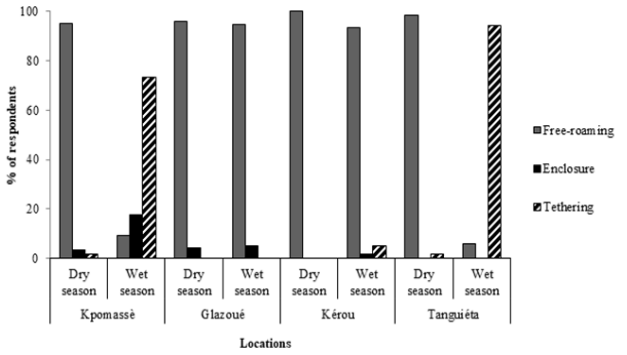

Figure 2. Goat housing during the daytime by season and location in Benin (Mode de logement des caprins en journée selon les saisons et les localités du Bénin).

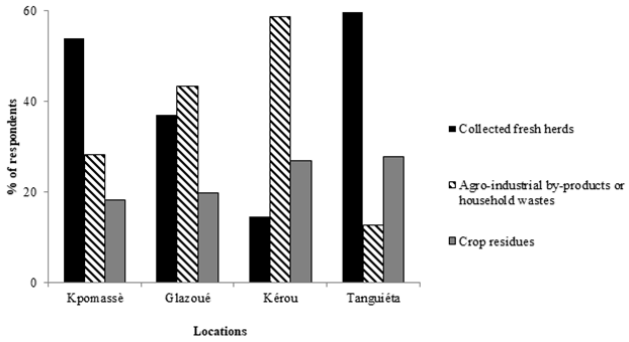

Figure 3. Feed supplements in goat herds across location in Benin (Complémentation alimentaire dans les troupeaux caprins au Bénin selon les localités).

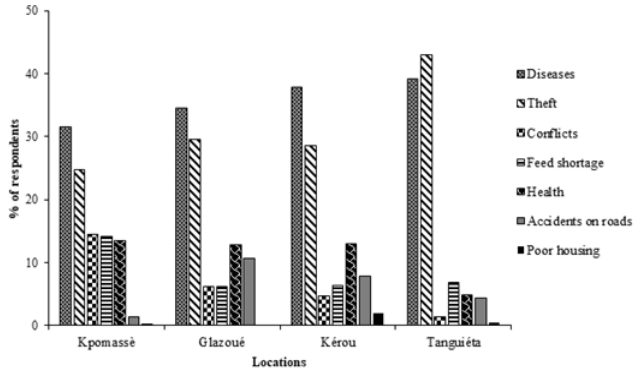

Figure 4. Main constraints in goats farming across location in Benin (Principales contraintes liées à l'élevage caprin au Bénin selon les localités).

It was usually done using the Burdizzo method (88%), by the removal of testicles using a knife (3%) or by other traditional methods (9%).

The average litter size per doe was reported to increase from 1.3 at the first parity to 2.5 at the fourth parity. Litter sizes were significantly lower in "Chaîne de l'Atacora" agro-ecological zone (Tanguiéta) than in the three other zones. The reported average kidding interval was 7.4 months; the lowest value was recorded in the Guineo-Congolian zone (Kpomasse).

Irrespective of agro-ecological zone, the average fertility, fecundity, parturition, and abortion rates were estimated at 118.93%, 69.75%, 72.12% and 2.26% respectively.

Health

The main symptoms of diseases mentioned by interviewed herders referred to gastro-intestinal parasitic diseases (49.6 % of responses), pest of small ruminants (35. 9 % of responses), cutaneous parasitic infections (9.5 % of responses), udder inflammation (1.3 % of responses) and digestive troubles (0.4 % of responses). Only 8.4% surveyed goat farmers have reported that they prevent their goat flocks from the pest of small ruminants through vaccination. Likewise, only 10% reported frequent deworming of their animals.

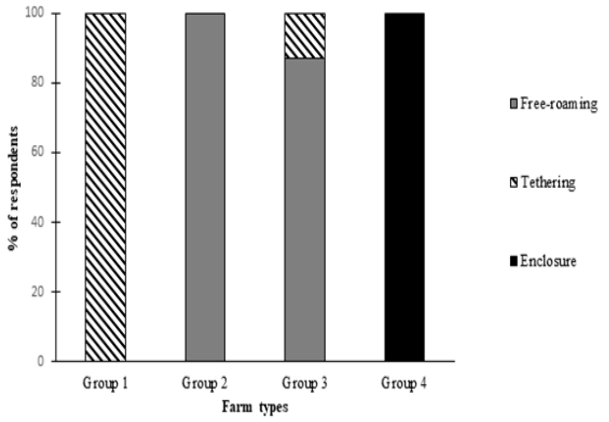

Figure 5. Different modes of daytime housing of goat during the wet season per farm type (Différents modes de logement des caprins en journée pendant la saison des pluies selon les types d'élevage).

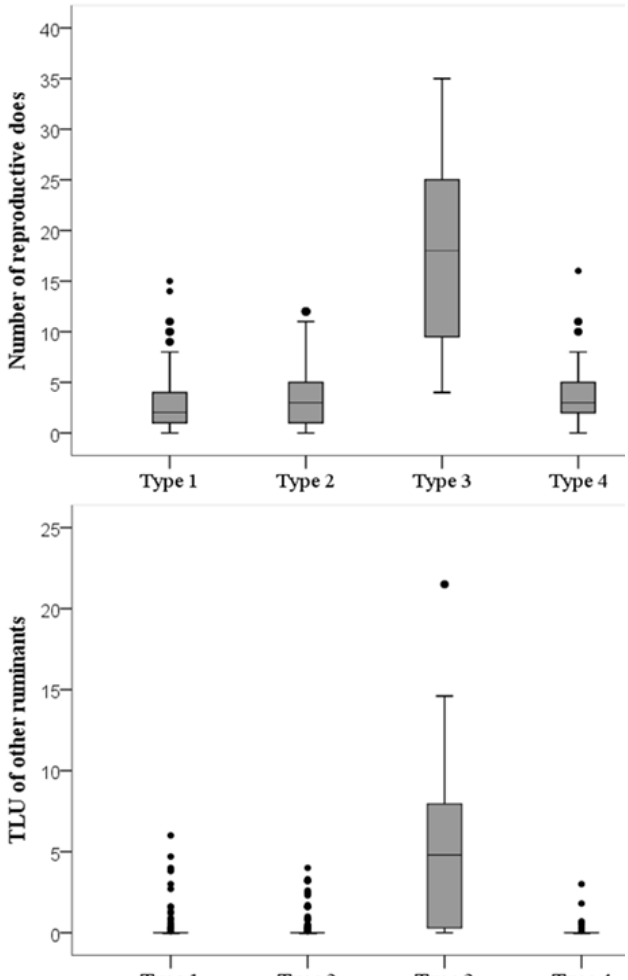

Figure 6. Average number of reproductive does and Tropical Livestock Unit (TLU) of other ruminants per farm type (Effectif moyen de femelles reproductrices et Unité de Bétail Tropical (UBT) des autres ruminants élevés selon le type d'élevage).

The average global mortality rate (irrespective of age and sex groups) was estimated at about 35.5 %, significantly higher (p<0.0001) in Kpomassè (52.7%) and Glazoué (34.0%) than in Kérou and Tanguiéta. Pre-weaning mortality rate averaged 38.6% with no significant different (p>0.05) among agro-ecological zones.

Constraints

Irrespective of agro-ecological zone, diseases resulting in high mortalities, and theft, followed by feed scarcity were the main production reported constraints (**Figure 4**).

Typology of goat herds

Two axes were defined in the Categorical Principal Components Analysis (CATPCA), with 47% of total variance. The Alpha-Cronbach coefficient was very satisfactory for the overall model (0.859), as well as for dimensions 1 and 2 (**Table I**). A four-cluster solution with three variables (mode of housing at daytime during the wet season, number of does, and total units of other

ruminant species in TLU) was retained in the two-step cluster analysis, because it had a satisfactory average silhouette measure (0.8) and provided a clear differentiation of the farms as well as a better interpretability.

Multinomial logistic regression analyses, using presence of buck in the herd, gender of goat owners, practice of castration, type of feed supplementation in rainy season, mode of housing at nighttime, education level of goat owner and cultivated land size as explanatory variables, indicated 83 % of correct classification of the goat farms in their a-priori groups (**Table IV**). The Cox and Snell pseudo R-square of the model was 0.655. The model Chi-Square was statistically significant at $p<0.001$ and the goodness-of-fit equal to 1, indicating a good fit. **Figure 5**, **Figure 6**, **Table V** and **Table VI** present the profiles of the different types of goat herds, their main characteristics and performances.

Group 1: Tethered herds

This group included about 43% of surveyed herds in which a few number of does (2.9±2.24 heads) was kept and mixed with a very few number of other ruminant species, mainly sheep. The goats were tethered in the household's compound at daytime and penned at nighttime during the rainy season. The farmers frequently fed the animals with fresh herbs collected along roadsides and from fallows. Almost two-third of farmers practicing this goat tethering system cultivated less than 2 ha of land and more than their half (57%) valorized the goat manure as fertilizer in their crop fields. The majority (84%) of herds in this group had no buck, most of their owners (86%) usually castrated the male goats before their reach maturity. Most of the herds were owned by men (71.9%), illiterate (75%) and mainly located in Tanguiéta (54.7%) and Kpomassè (42.9%).

Group 2: Small Scavenging herds

This group included 47% of the surveyed goat herds. Like herds from Group 1, they were composed of a small number of does (3.6±2.90 heads in average). However, in sharp contrast with the previous group of farms, the animals were left free-roaming in the village all year round. They grazed on natural vegetation and were offered no feed supplement. Castration was less commonly practiced in these herds. But only 30% of them had a buck. About two-third of them were owned by women. These herds were mainly located in Glazoué (49.1%) and Kérou (42.8%).

Group 3: Large scavenging herds

This herd type was the least commonly observed (less than 5% of surveyed herds). Compared with herds from Group 1 and 2, they were mostly composed of significantly ($p<0.001$) larger number of reproductive does (17.7±9.48) and of other ruminants. The owners, mainly men (70%), also owned larger sizes of cultivated lands, 52% of them owning more than 4 ha. This goat herd type was mostly (78%) encountered in Kérou. But they shared many similarities with herds from Group 2 in terms of goat housing (free-roaming all year round) and feeding (animals were mainly fed on natural grazing without supplementation). In contrast to herds in the two previous groups (Groups 1 & 2), more than two-thirds (70%) of herds in this group had at least one buck dedicated to reproduction.

Group 4: Semi-scavenging herds

This group, which gathered 6% of the total number of surveyed herds, is very close to group 1 in terms of the owner's gender, the number of does and the size of owner's cultivated land. The majority of herds in this group was characterized by the total absence of buck dedicated to reproduction. This group is also similar to Group 1 in terms of management practices, for instance seasonal confinement, provision of feed and frequent supplementation to animals, practice of castration and manure valorization as fertilizer. But instead of the daytime tethering practice observed in Group 1, goats were permanently penned at daytime and nighttime during the rainy season. More than two-thirds (72%) of herds in this group were located in Kpomassè.

DISCUSSION

This study covers a wide range of goat farmers with various socioeconomic in various agro-ecological conditions. The CATPCA approach and the criteria used for the current typology allow to effectively get a multidimensional profile of the goat herds and the relationships between rural goat management and different factors such as farmers characteristics and constraints associated to their location (Emtage et al. 2006 and Dossa et al. 2011). The housing mode has been used by Manjeli et al. (1994) and Tsegaye (2009)

Table IV. Results of the likelihood-ratio tests of multinomial logistic regression performed with variables not used in the two-step cluster analysis on goat farms in Benin (Résultats des tests de rapport de vraisemblance de régression logistique multinomiale réalisés avec des variables non exploitées dans l'analyse de classification "two step")

Variable	−2 Log-likelihood	χ^2	df	P value
Intercept	240.93	0.00	0	
Housing mode at night time	280.15	39.22	8	0.001
Type of feeding in the wet season	371.82	130.89	12	0.001
Presence of buck	270.87	29.94	4	0.001
Sex of farmer	273.14	32.21	4	0.001
Practice of castration	253.45	12.52	4	0.006
Formal education level of farmer	277.12	36.19	8	0.001

Table V. Major characteristics of rural goat farmers across the four farm types in Benin (Principales caractéristiques des éleveurs de caprins en milieu rural dans les quatre types d'élevage au Bénin).

Variable	Type 1 (n=203)	Type2 (n=222)	Type 3 (n=23)	Type 4 (n=29)	P value
Farmers' socio-economics characteristics					
	Mean ± Standard Error				
Experience (years)	12.4^{a}±073	9.1^{b}±0.57	19.4^{c}±2.71	10.1^{ab}±1.84	0.001
Household size (n)	6.9^{a}±0.25	7.9^{a}±0.47	11.1^{b}±1.37	6.7^{a}±0.58	0.004
	% of respondents				
Location					
Kpomassè	42.9^{a}	5.0^{b}	0.0^{b}	72.4^{c}	0.001
Glazoué	0.0^{a}	49.1^{b}	13.0^{c}	20.7^{c}	
Kérou	2.5^{a}	42.8^{b}	78.3^{c}	6.9^{a}	
Tanguiéta	54.7^{a}	3.2^{b}	8.7^{b}	0.0^{b}	
Farmer gender					
Male	71.9^{a}	36^{b}	69.6^{a}	82.8^{a}	0.001
Female	28.1^{a}	64^{b}	30.4^{a}	17.2^{a}	
Education level					
Formal education	17.7^{a}	27.9^{b}	13^{ab}	51.7^{c}	0.001
Informal education	6.4^{a}	3.6^{a}	4.3^{a}	10.3^{a}	
None	75.9^{a}	68.5^{a}	82.6^{c}	37.9^{b}	
Cultivated land (ha)					
<2 ha	65.0^{a}	59.9^{a}	34.8^{b}	58.6^{ab}	0.001
2 to 4 ha	25.1^{a}	21.2^{a}	13.0^{a}	27.6^{a}	
>4 ha	9.9^{a}	18.9^{b}	52.2^{c}	13.8^{ab}	
Cattle keeping	5.4^{a}	8.6^{a}	60.9^{b}	3.4^{a}	0.001

^{abc} Within a row, values with different superscript letters are significantly different at P ≤ 0.001 level

to categorize goats farming systems respectively in Cameroun and Ethiopia whereas farmers' resources endowment (TLU of other ruminants; cultivated land size) as well as the number of reproductive females in the herds have been used in many others studies on farming system typology (Tefera et al. 2004; Gunia et al. 2010; Dossa et al. 2011 and Sakané et al. 2013).

Factors affecting the management of rural goat herds

Our findings confirm the low input management systems in which goats still involve in African rural areas. The free roaming (groups 2 and 3) and seasonal confinement (group 1 and 4) systems identified in the current study are similar to those described by Amole et al. (2014) and Agossou et al. (2017) as West African traditional goats farming systems. Moreover, the dominance of the extensive (low-input-output) system is in line with previous observations in Benin (Van den Broek & Gbégo 1994 and Dossa et al. 2007) and other tropical countries (Adesehinwa & Okunlola 2000; Ajala et al. 2008; McDermott et al. 2010 and Alexandre et al. 2012). In accordance with the main reasons of goat keeping reported by Dossa et al. (2008) and Ajala et al. (2008), the majority of farmers surveyed in the present study were keeping goat as a complementary activity to crop cultivation and not as their main activity. This probably explains why many goat owners allocate only few of their time and resources in this activity. Lebbie (2004) noticed that goats are often marginalized in African households and many farmers often rely in their survivability and their ability to find the minimal feed required to perform. Similarly, Boyazoglu et al. (2005) stressed that goats are suffering from poor attention by both farmers and national institutions in developing countries. This is particularly true of the extensively managed goat herds of group 2 mainly kept by women farmers who own small herds and small land size. These findings highlight the limits of women to appropriately manage goats despite the important role they play in goat farming within African households and the usefulness of this species for their financial autonomy within the households

Table VI. Herd management practices and performances of goat herds across the four farm types in Benin
(Pratiques de gestion et performances des troupeaux caprins dans les quatre types d'élevage caprin au Bénin).

Variable	Type 1	Type2	Type 3	Type 4	P value
	(n=203)	(n=222)	(n=23)	(n=29)	
Goat herds management					
	% of respondents				
Practice of castration (%)	85.7[a]	39.6[b]	43.5[b]	75.9[a]	0.001
Presence of buck in the herd (%)	15.8[a]	30.2[b]	73.9[c]	27.6[ab]	0.001
Use of manure for soil fertilization (%)	57.1[a]	16.7[b]	34.8[c]	37.9[ac]	0.001
Housing mode overnight (%)					
Free roaming	6.9[a]	71.6[b]	65.2[b]	3.4[a]	0.001
Tethered	4.4[a]	1.8[a]	4.3[a]	3.4[a]	
Enclosure	88.7[a]	26.6[b]	30.4[b]	93.1[a]	
Frequency of handfeeding at wet season (%)					
Frequently	65.5[a]	21.6[b]	21.7[b]	79.3[a]	0.001
Not frequently	34.5[a]	78.4[b]	78.3[b]	20.7[a]	
Feeding mode (%)					
Natural grazing	5.4[a]	0.5[b]	0.0[ab]	0.0[ab]	0.001
Natural grazing + supplement	17.2[a]	94.6[b]	95.7[b]	10.3[a]	
Collected fresh herb	32.5[a]	1.4[b]	0.0[b]	27.6[a]	
Collected fresh herb + supplement	44.8[a]	3.6[b]	4.3[b]	62.1[a]	
Herd performances					
	Mean ± Standard Error				
Fertility rate	71.8±2.98	72.8±2.73	56.5±5.93	76.8±9.21	0.254
Abortion rate	2.7[a]±0.74	1.6[a]±0.49	3.7[b]±1.42	3.6[ab]±1.60	0.005
Fecondity rate	112.9±5.39	127.1±5.15	87.2±10.26	117.3±13.55	0.051
Global mortality rate	40.7±3.41	29.2±2.27	22.0±4.79	42.0±7.49	0.149
Pre-weaning mortality rate	38.5±4.43	38.1±4.07	37.7±10.47	42.3±10.09	0.776

[abc] Within a row, values with different superscript letters are significantly different at P ≤ 0.001 level

(Verbeek et al. 2007; Odeyinka &Torimiro 2006 and Dossa et al. 2008). According to Yisehak (2008), women lack of access to land, credit, technology and training is an important factor contributing to the underdevelopment of goats farming in African rural areas. The influence of resources owned by farmers in the adoption of adequate agricultural management practices have been reported in several studies (Tefera et al. 2004; Sakané et al. 2013 and Chikowo et al. 2014). This relationship between farmers' resources endowment and their farming practices is reinforced by the possession of large herd size as observed in Group 3. Likewise, Ducrotoy et al. (2017) have found a correlation between household size and goat herd size in Nigeria. In addition to farmers' resources, the impact of their education level in management practices is shown in this study by the adoption by most educated goat farmers of the enclosure system (group 4). Similar results have been reported by Hassan et al. (2015) and Laouadi et al. (2018). The considerable proportion of educated people practicing enclosure system in Kpomassè and Glazoué is consistent with the higher rate of schooling in Southern Benin people compared with Northern Benin (INSAE 2016), revealing a relationship between farmer location and goat management practices. Another evidence of the influence of location on goat husbandry systems is the practice of goat tethering in Kpomassè and Tanguiéta (Group 1). In these regions, cultivated crop fields are very close to homesteads where goats are freely roaming. Consequently, many cases of conflicts between goat and crop farmers due to damages caused by wandering goats to crops were reported. Amole et al. (2014) viewed goat confinement as a strategy for keeping goats in densely human-populated areas. The high density of human population in Kpomassè (INSAE 2016) corroborates

this assertion whereas the high pressure on land or land shortage in the same location probably explain the land lease and the cultivation of small farms (less than 2ha in average) by the majority of farmers surveyed in this area. In contrast to Kpomassè, crop cultivation around homesteads in Tanguiéta is less due to high human population density (INSAE 2016). Actually, farmers in this region build their houses very far from each other and then valorize the space in cultivating some crop fields. This could explain why the majority of farmers in Tanguiéta collect and valorize manure. Manure collection by farmers in Tanguiéta and Kpomassè is facilitated by goat housing, which points out the opportunity of crop-livestock integration in goat confinement systems (Amole et al. 2014). Unlike manure valorization, the use of crop residues is observed in all farm types, however feed supplementation is more frequent in tethering and confinement systems. In Kpomassè, dry season feed supplementation is provided to goats in many farms. These findings suggest that feed shortage is an important driver of the adoption by goat farmers of improved herd management practices. Feed shortage is mainly due to the shrinkage of communal grazing, a direct consequence of high human population density. Hence, in agreement with Castel et al. (2003), we can argue that the intensification of goat production in rural areas is an inevitable process driven by the increasing pressure on land in all African areas (Hiernaux et al. 2009; Gaiser et al. 2011 and Valbuena et al. 2012).

Goat farming systems and herd performances

Except the abortion rate, no significant relationship has been observed between the reproductive performances and goat farming systems or farmers' location. Irrespective of farm type, the values of fecundity rate recorded in this study were lower than those (91-140 %) obtained by Ejlertsen et al. (2012) and Abdul-Rahman (2017) for West African Dwarf goats under guinea Savannah conditions. These low rates of fecundity may be explained by the absence of reproductive male in the majority of herds. Breeding buck were mostly absent in confined systems which certainly increases the delays in serving females compared to extensive systems (Reynolds & Adediran 1994). This lack of breeding buck in herds is favored by the high rate of castration in majority of herds mainly in Kpomassè and Tanguiéta. These farmers have therefore to improve their breeding practices in maintaining at least one breeding male to ensure frequent mating in herds. The values of abortion rates obtained in the current study were considerably lower than those reported by Dossa et al. (2007), but these values are not reliable since many abortions could occur and not noticed by the farmer as very little attention is given to the animals. Similar to the reproductive performances, no significant differences in goat mortality rates were observed across management systems. However, the general mortality calculated in the present study is similar to those (36.34 %) reported by Tuah et al. (1992) in Ghana and higher than the values (20 à 25 %) calculated by Dossa et al. (2007) in Southern-Benin. Such rates of mortalities are consistent with the occurrence of diseases referred by farmers in all localities and provide the evidence of the lack of adoption of proper disease control and prophylactic measures by goat farmers. The frequency of gastro-intestinal parasitic diseases in Glazoué and Kérou are in accordance with the practices of free-roaming system in these areas (Sebei et al. 2004). Conversely, external parasitic diseases, which were more reported in Kpomassè are certainly due to the association of high humidity and a lack of hygiene in habitats where goats are confined. We therefore argued that, farmers in adopting goats housing should ensure that they provide the animals with the necessary hygiene, feeding and healthcare. Housing reduces mortalities and losses due to road accidents and conflicts with other farmers (Dossa et al. 2007; Ajala et al. 2008) but in the smallholder system, goats are more likely to gain weight when they are kept under free-roaming system than when confined (Mohammed 2014). Indeed, confined systems required more efforts, labour and technical skills from farmers than extensive system (Monteiro et al. 2017). Hence, to ensure good animal performances, farmers need to upgrade their knowledge in goat management and match improvement in housing with adequate feeding, health and breeding practices.

CONCLUSION

Goats are poorly managed in most of the rural households in Benin. Animals kept in the permanent free-roaming system receive very little attention and care from the farmer compared with those that are seasonally tethered or penned. Nevertheless, herd performances do not vary with management system and are generally poor. Indeed, in all farm types, animal housing, feeding and health remain the major challenges. Improved family goat farming and goat herd productivity can be achieved by enhancing the technical skills of goat farmers through tailored trainings and professional farm management advice.

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