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Characterization of local sheep production system and morphology in Liberia

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ABSTRACT

In this study, we characterized the production system and morphology of local sheep in Liberia. We gathered husbandry information from 514 male and 190 female sheep farmers across all three agroecological zones of Liberia. We also described the basic morphological attributes of 709 female and 189 male sheep. The main motivation for raising sheep is income (81%) and meat production (14%), with cost and availability of feed (45%), housing (26%), diseases (18%), and cost of veterinary medicines (7%) being the main challenges. The predominant sheep breed in Liberia is the Djallonke (82%). Coat colour pattern of sampled sheep was plain/solid/uniform (61%) or patchy/pied (28%) with a few being spotted (11%). The sheep had mostly straight facial (79%) profile, were horned (74%) with straight horns (92%) which were either oblique (48%) or lateral (35%). The sheep had mainly erect ear orientation (60%) and cylindrical straight tails (83%). The high prevalence of crossbred sheep and the popularity of exotic breeds call for the need to conserve the Djallonke breed and/or to implement within breed selection. Community-based breeding programmes and formation of farmer associations should be encouraged by stakeholders to facilitate improvements of their animals. This should help reduce the challenges affecting sheep farmers and encourage especially the youth to go into sheep farming.

Key words: Conservation, disease, Djallonke sheep, feed, housing, Liberia

RÉSUMÉ

Dans cette étude, nous avons caractérisé le système de production et la morphologie des moutons locaux au Libéria. Nous avons recueilli des informations sur l'élevage de 514 moutons mâles et 190 femelles dans les trois zones agroécologiques du Libéria. Nous avons également décrit les attributs morphologiques de base de 709 moutons femelles et de 189 moutons mâles. La principale motivation pour élever des moutons est le revenu (81 %) et la production de viande (14 %), le coût et la disponibilité des aliments pour animaux (45 %), le logement (26 %), les maladies (18 %) et le coût des médicaments vétérinaires (7 %) étant les principaux problèmes. La race ovine prédominante au Libéria est le Djallonke (82%). La couleur de la robe des moutons échantillonnés était unie/solide/uniforme (61 %) ou inégale/pied (28 %), quelques-uns ayant été repérés (11 %). Les moutons avaient surtout un profil facial droit (79 %), étaient cornus (74 %) avec des cornes droites (92 %) qui étaient obliques (48 %) ou latérales (35 %). Les moutons avaient principalement l'orientation de l'oreille dressée (60%) et les queues droites cylindriques (83%). La forte

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prévalence des moutons croisés et la popularité des races exotiques appellent à la nécessité de conserver la race Djallonke et / ou à mettre en œuvre dans la sélection de la race. Les programmes communautaires et la formation d'associations d'agriculteurs devraient être encouragés par les parties prenantes afin de faciliter l'amélioration de leurs animaux. Cela devrait contribuer à réduire les défis qui touchent les éleveurs de moutons et encourager en particulier les jeunes à se lancer dans l'élevage de moutons.

Mots clés : Conservation, maladie, mouton de Djallonke, fourrage, logement, Libéria

INTRODUCTION

The need to increase livestock production to feed an ever-increasing human population is now more urgent than ever (FAO, 2018). Expected negative effects of climate change on livestock production justify the need to conserve and sustainably use available local animal genetic resources (AnGR) which are relatively more adaptive (AUIBAR, 2018) and resilient to the effects of environmental challenges. Conservation and sustainable utilization of local AnGR however requires information on their morphology and production system (FAO, 2012; Osei-Amponsah *et al.,* 2017). Morphological characteristics relating to production and reproduction provide useful baseline information on the normal morphological aspects important in the production of the breed (https://doi.org/10.1007/s11250-001-985-x).The characterisation of small ruminant populations in developing countries will play a major role in their maintenance for future improvement in livestock production (Birteeb *et al.,* 2013).

The state of animal genetic resources in Liberia within the context of agricultural production and their importance to socio-economic development was described by Karnuah *et al.* (2018a). Although mutton is a popular livestock product in Liberia, sheep production has been on the decline in recent decades. In the 1990s goat and sheep production were at par with each other in Liberia, but by 2011, the country had lost close to 50% of its sheep population (MOA, 2015). The drastic decline was due to the effect of 14 years of civil war where most animals were killed and eaten by fighters. Moreover, restocking efforts have not targeted sheep as has been done for goats by various stakeholders (FED, 2012; Land O' Lakes, 2013). Therefore the population of sheep is yet to be at par with that of goats as during the pre-war. Unfortunately baseline characterization data on sheep production is not available. Yet this information is needed for the establishment of sustainable livestock research and development plans and to guide restocking and animal health programmes (FAO, 2012; Karnuah *et al.,* 2018a). The objective of this study therefore was to describe the morphological characteristics of local sheep in Liberia and the prevailing sheep production and management system so as to enable stakeholders make appropriate decisions to enhance the future utilization and conservation of this AnGR.

MATERIALS AND METHODS

Source and collection of data. The study was part of the Government of Liberia's Technical Cooperation Project with the Food and Agricultural Organization (FAO) of the United Nations and a previous paper (Karnuah *et al.,* 2018a) has described the study area and data collection process. Briefly, we sampled local sheep in their production systems in 15 counties of Liberia, much of which is dominated by flat to rolling coastal plains with mangroves and swamps (MOA, 2008). Data collected included general information on demographic characteristics of sheep farmers, sheep production and management practices as well as the morphometric attributes of

sheep. Phenotypic characterization descriptors provided by FAO (2012) were used in the design of a questionnaire; the responses were recorded on an electronic data capture system (Aanensen *et al.,* 2009). Linear and morphological measurements including heart girth, whither height, body length and body weight were also carried out using a measuring tape and weighing scale according to FAO Guidelines (FAO, 2012).

Data analysis. Data were analysed using Statistical Analysis Systems (SAS) software (SAS, 2012) and the Survey Package in R (R Core Team, 2016) to take advantage of their very flexible options for summarizing categorical and quantitative variables and clear figures. Analyses carried out included categorical analysis of qualitative data using chi square, descriptive analyses of quantitative data, regression analysis to determine the effects of linear body measurements on body weight and correlation between the parameters. Relative frequencies of various characterization parameters and the results are summarized in tables and figures that follow.

RESULTS AND DISCUSSION

Background of respondents. Demographic attributes of 704 sheep farmers made up of 190 females and 514 males interviewed are shown in Table 1. Significantly higher proportion of male farmers have basic (48%) or secondary (29%) education compared to the females with just 3% of sheep farmers having tertiary education. Majority of the sheep farmers (82%) did not belong to any livestock associations. The absence of well-organized farmer/breeder associations to support governmental initiatives has hindered efforts to develop an appropriate and integrated livestock recording system for Liberia's AnGR (MOA, 2008). Popular sheep farming counties such as Gedeh, Nimba, River Cess, Gbarpolu and Bassa are potential areas to help farmers come together with such

Table 1. Demographic characteristics of sheep farmers by gender in Liberia

	Gender of farmers			Chi Square value	Prob	df
	Female (%)	Male (%)	Total			
Educational status						
None	52	19	198(28%)	79.97**	<0.0001	3
Basic	37	48	317(45%)			
Secondary	8	29	166(24%)			
Tertiary	3	4	23 (3%)			
All farmers	27	73	704(100%)			
Membership of Livestock Association						
No	80	82	579(82%)	0.33ns	0.57	1
Yes	20	18	128(18%)			
Total	27	73	707(100%)			
Average age, household size and number of animals of sheep farmers						
		Female			Male	
	Mean ± SE	*n*	CV(%)	Mean ± SE	*n*	CV(%)
Age of farmer	47.5 ± 0.98	190	28	47.2 ± 0.57	514	27
Household size	7.6 ± 0.24^{b}	189	43	8.9 ± 0.18^{a}	508	47
Number of animals	1.3 ± 0.07^{b}	190	72	1.5 ± 0.05^{a}	514	72
Gender Head Ratio		127(20%)			509(80%)	

NB: ns – not significant (P>0.05); ** - highly significant (P<0.01); within rows means followed by different superscripts are significantly (P<0.05) different

associations to safeguard breed conservation and utilization of sheep genetic resources.

Sheep production. The main reasons for sheep production in Liberia are for meat and adding saving to income with crop-livestock and free-range systems being popular (74%) across agroecological zones (Figure 1). Some farmers raise sheep for important religious festivals to be slaughtered for meat. Among the sheep farmers, their motivation for sheep production was mainly for meat or income (89%), followed by socio-cultural reasons (8%) with breeding and manure production being very minor (3%) reasons. This finding agrees with those of Dosa *et al.* (2015) who reported that irrespective of city, sheep were primarily kept for their financial functions whereby sheep were perceived as having higher economic value than goats. In terms of housing, close to 60% of sheep farmers provide no housing/shed for their animals with permanent structures being more popular in the coastal zone whilst temporary sheds are popular in the forest zone (Figure 1). Sheep production is also mainly based on crop-livestock systems with 63% of all sheep farmers also being crop farmers. In fact, less than 20% of sheep farmers keep livestock alone and in the forest and savannah zones, that is 75% and 70% of all sheep farmers are also crop farmers, respectively. Irrespective of agroecological zone, the most popular sheep tending management system encountered was free grazing which was practiced by 75% of sheep farmers (Figure 1). Tindano *et al.* (2017) reported that 70% of Mossi Djallonke sheep farmers in Burkina Faso grazed their flocks freely in natural pasture during the dry season.

The average age of a sheep farmer was 47 years, and this suggests a need to encourage and provide incentives to more youth to go into agriculture and sheep farming. Male farmers had relatively larger herd sizes and household sizes than female heads of households. Sheep farming was mainly undertaken with family labour (98%) as shown in Table 2. Hired labour was only reported by a few farmers in the forest and savannah agro-ecological zones with farmers in the coastal zone depending solely on family labour. Male sheep farmers were also

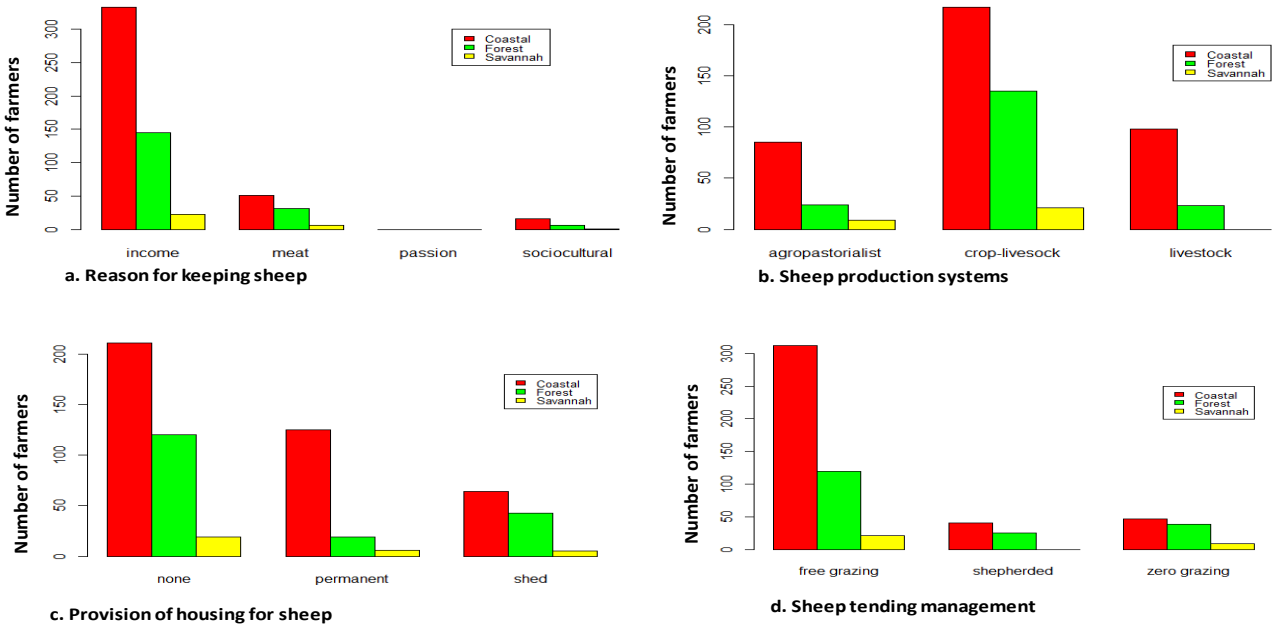

Figure 1. Variation of sheep production practices accross agro-ecological zones

predominantly household heads which gave them control over family labour. Table 2 also shows that commercial sheep farmers were found mainly in the coastal (71%) and the forest zones (59%) whilst almost all sheep farmers in the savannah zone were substance farmers (94%). Sheep multiplication farms were not popular in Liberia and represented just 5% of all sheep farms surveyed. River/lake (74%) and deep wells (24%) are the major sources of water for sheep across ecozones with no farmer in the savannah zone mentioning either pipe-borne or rain harvesting.

Sheep farmers reported diseases, drought and heat tolerance as the major adaptive traits of their animals. Indeed, the farmers indicated disease tolerance (55%), followed by drought tolerance (28%) and heat tolerance (17%). These are very important adaptive traits for breeding climate resilient sheep and a justification for genomic characterisation of local breeds to identify genes associated with such adaptive traits (Birteeb *et al.,* 2013) for introgression of favourable alleles into crossbred sheep in future breeding programmes. This is in line with the need to consider traits of adaptive and economic importance to farmers in the design of breeding policies (FAO, 2015; Konig *et al.,* 2016). The most common mating system observed among

Table 2. Sheep production attributes by agroecological zone in Liberia

	Agroecological zone				Chi Square value	Prob	df
	Coastal (%)	Forest (%)	Savannah (%)	Total			
Holding type							
Commercial farmer	71	59	6	439 (62%)	89.6**	<0.0001	4
Peasant farmer	28	31	94	233 (33%)			
Breeding centre	1	10	0	32 (5%)			
All types	62	33	5	704 (100%)			
Source of water					17.7**	0.0070	6
River/lake	78	65	72	515 (74%)			
Deep well	20	31	28	170 (24%)			
Pipe borne	1	4	0	14(2%)			
Rain	1	0	0	1(0%)			
All water sources	62	33	5	700 (100%)			
Source of Labour					21.5**	<0.0001	2
Family	100	96	91	686 (98)			
Hired	0	4	9	13 (2%)			
All labour sources	62	33	5	699 (100%)			
Challenges of sheep farming							
Disease	19	12	39	119 (18%)	16.6**	<0.0001	14
Feed	50	40	16	300 (45%)			
Housing	19	40	38	165 (26%)			
Veterinary medicine	8	5	6	44 (7%)			
Theft	4	3	0	25(4%)			
Land	1	0.5	0	5 (1%)			
All Challenges	62	33	5	668 (100%)			

NB: ns – not significant (P>0.05); ** - highly significant (P<0.01)

the sheep farmers was uncontrolled, non-seasonal, natural mating involving the use of multiple sires (91%). This is not surprising given the predominantly free-range husbandry system which gives the farmer very little control over breeding rams. The determination of price among sheep farmers in Liberia depend on several factors such as financial need (65%) among farmers with none or basic education or market readiness (68%) among farmers with tertiary education who appeared to have better deals in selling their stock. In the Tolon District of Ghana, Birteeb and Donkor (2016) indicated that sex and fur texture were the key determinants of price in the livestock market.

Challenges of sheep farming. Sheep farmers reported cost and availability of feed (45%), housing (26%), diseases (18%) and cost of veterinary medicines (7%) as their main challenges (Table 2). However, major variations were recorded across the agroecological zones as indicated by the significant Chi Square value. The major challenges were feed in the coastal zone, feed and lack of animal shed in the forest zone and disease and lack of animal sheds in the savannah zone. These challenges affect all livestock species (Karnuah *et al.,* 2018a and b) and need to be addressed not only to increase productivity but to motivate and encourage more farmers to go into livestock production in Liberia. The cost and accessibility to veterinary services and medicines is a huge challenge to livestock farming in Liberia. As indicated by the MOA (2015), animal diseases are the major constraint to livestock development in Liberia and there is little information available on major diseases, and little or no research on animal production and health. Sheep production in Liberia is also negatively affected by poor or no housing/shed and fencing facilities, resulting in theft of animals on one hand and damages of farm crops on the other hand. Few sheep farmers (4%) reported loses of their animals due to theft. Provision of animal sheds and fencing infrastructure for sheep, the accessibility and

Figure 2. Images of sampled sheep by breed type in Liberia

availability of feeds and veterinary medicine should help improve sheep production in Liberia. Previous studies have reported such constraints as major causes of sheep mortality (Lakew *et al.,* 2017) and therefore needs to be addressed for a successful sheep industry in Liberia.

Morphological characterization. The survey revealed that Djallonke sheep is the predominant sheep breed in Liberia, accounting for 82% of all sheep surveyed, followed by various crossbreds between local and exotic breeds such as the Black Headed Persian (17%), and the Sahelian (2%) (Figure 2). Local names for the Djallonke include *Yonkpoe, Woley, Bor, Baar, Mbah, Bolee, Blabeh, Blie, short sheep, Mabawah amusum, Guinea sheep* and *Saar,* whilst the Sahelian breed is known locally as *Wlie* and *tall sheep.*

Morphometric characterisation of sampled sheep indicated that on the average females were older (3 years) than the male sheep (2 years). On the other hand, male sheep were significantly (P<0.05) superior to females in all morphometric parameters measured. For instance, average body weights for female and male sheep were 24 and 28kg; body length 57 and 62cm; height at withers 52 and 55cm and chest girth 68 and 70cm respectively. Irrespective of sex, the relatively high coefficient of variation in body weight of sheep can be attributed to the wide variation in estimated age of animal (Table 3). In addition, the large variations in body weight of sampled sheep suggest opportunities for genetic improvement of local sheep of Liberia by selection (Boubekeur *et al.,* 2015). As indicated by Lakew *et al.* (2017), local sheep have potential for multipurpose roles and also generate income for smallholders and any

Table 3. Summary statistics of key quantitative variables of sheep by sex

Variable	Females			Males		
	Mean ± SE*	n*	CV* (%)	Mean ± SE	n	CV (%)
Body weight (kg)	24.5 ± 0.24[b]	709	27	28.7 ± 0.73[a]	189	35
Body length (cm)	57.6 ± 0.23 [b]	709	11	61.9± 0.71 [a]	189	16
Height at withers (cm)	52.2 ± 0.23 [b]	709	12	55.7 ± 0.66 [a]	189	16
Chest girth (cm)	67.1 ± 0.31 [b]	709	13	70.4 ± 0.80 [a]	189	16
Horn length (cm)	13.9 ± 0.18 [b]	369	25	16.5 ± 0.42 [a]	158	32
Ear length (cm)	9.7 ± 0.05 [b]	709	13	11.2 ± 0.19 [a]	189	23
Tail length (cm)	23.0 ± 0.13 [b]	709	16	28.9 ± 0.89 [a]	189	42
Estimated age (years)	3.1 ± 0.10a	704	54	1.9 ± 0.08 [b]	188	58

NB: SE = Standard error of mean; n – sample size; CV – coefficient of variation; within rows means followed by different superscripts are significantly (P<0.05) different

Table 4. Spearman correlation coefficients of key quantitative variables of sheep in Liberia

	Body length	Body weight	Height at withers	Chest girth	Horn length	Ear length	Tail length
Body weight	1.00	0.99**	0.99**	0.99**	0.97**	0.80**	0.88**
Body length	<.0001	1.00	0.98**	0.99**	0.96**	0.78**	0.87**
Height at withers	<.0001	<.0001	1.00	0.98**	0.96**	0.80**	0.88**
Chest girth	<.0001	<.0001	<.0001	1.00	0.97**	0.79**	0.88**
Horn length	<.0001	<.0001	<.0001	<.0001	1.00	0.70**	0.82**
Ear length	<.0001	<.0001	<.0001	<.0001	<.0001	1.00	0.90**
Tail length	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	1.00

NB: ** Significant at 0.01; * Significant at 0.05 level of significance. ns – not significant.

Upper diagonal – correlation coefficients; Lower diagonal – P values.

genetic improvement programme should aim at farmers' need to consider simultaneously their traits of preference and existing traditional herding and breeding practices.

The summary statistics of the key quantitative variables of sheep by sex (Table 3) shows that males were significantly (P<0.05) superior in all linear body measurements than females. In the study by Birteeb and Donkor (2016) on Djallonke sheep in Ghana they reported that the females had higher values in all body measurements than males, but higher variability of all body measurements were associated with males. The highly significant correlations between body weight and the linear body measurements of sheep (Table 4) indicates that body weight can be predicted from these linear measurements by using appropriate regression models. For instance, we fitted simple linear regression models between body weight and all the other morphological parameters shown in Figure 3. The best fit for predicting body weight was obtained when body length was fitted with an R^2 value of 97% (Fig. 3). This indicates that one can predict body weight of sheep from body length with a high degree of accuracy. The live weight of Djallonke sheep in Ghana was significantly corrected with all linear body measurements (Birteeb and Donkon, 2016).

Morphologically, in terms of coat colour pattern sampled sheep were mainly plain/solid/uniform (61%) and patchy/pied (28%) with a few being spotted (11%) confirming the variation in coat colour pattern of the predominant Djallonke sheep breed (Table 5; Figure 4). This finding agreed with researchers in both Burkina Faso and Ghana where they observed patchy/pied colour pattern among the Djallonke sheep (Traore *et al.,* 2008; Birteed and Donkor, 2016). Patchy/pied colour is multiple colours combinations (black, brown, white, red). In addition, in terms of temperament, most sheep were either docile (48%) or moderate (47%), with just 5% being described as wild. Liberian sheep were also characterised to have mostly straight facial (79%) profile, horned (74%) with straight horns (92%) which were either oblique (48%) or lateral (35%). Table 5 also shows that a significantly higher proportion of males (97%) were horned with more females (52%) showing oblique horns. The high incidence of horns in the sampled population indicates that this is a

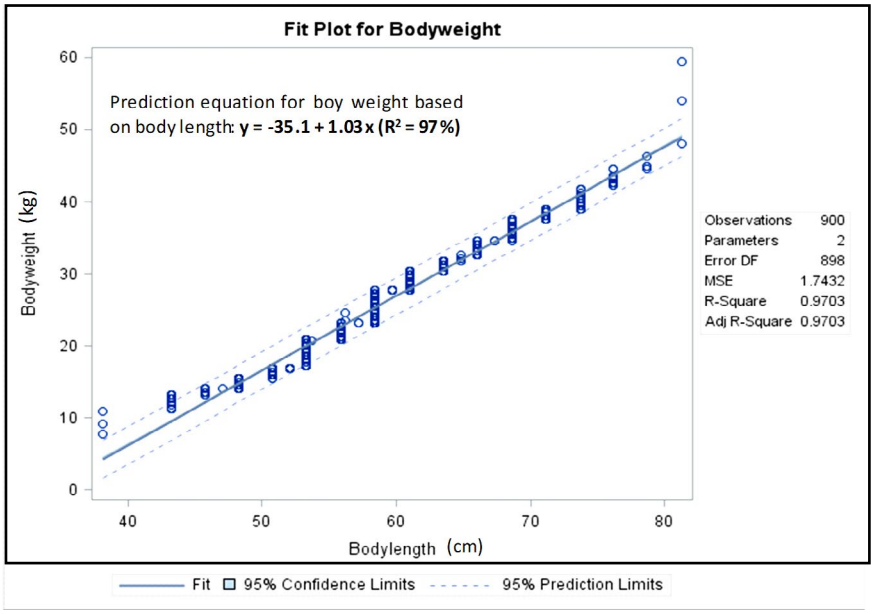

Figure 3. Prediction plot for body weight using body length of sheep

characteristic of Djallonke sheep.

Liberia Djallonke sheep had predominantly erect ear orientation (60%) and cylindrical straight tails (83%) (Figure 4). However, in terms of rump profile, the Djallonke sheep were predominantly flat whilst the crossbred sheep were more sloppy than flat. Thus, the predominant Djallonke sheep breed could be described as having mainly plain coat colour patter, erect ears, straight cylindrical tails and a flat rump profile. Tail type of Djallonke sheep could thus be said to be different from local sheep of Ethiopia, which had short fat, short thin, or rump fat tails (Tesfay *et al.,* 2017). Gebreyowhens and Tesfay (2016) reported lateral ear orientation (93.5%), uniform coat pattern (49 %) with beige colour, medium hair length with course hair (61%), curved (50%) horn shape with lateral orientation (58%), as major morphological attributes of highland sheep in Northern Ethiopia. These variations in morphological attributes indicates a strong genotypic effect as well as adaptation of various sheep breeds to their environments.

Table 5. Frequency of some morphological parameters of sheep by sex for Liberian sheep

	Sex of animal		Total	X^2	P
	Female (%)	Male (%)			
Coat colour pattern					
Patchy/pied	26	35	248 (28%)	9.8**	0.0074
Plain	62	58	548 (61%)		
Spotted	12	7	101 (11%)		
All coat colour patterns	79	21	897 (100%)		
Temperament					
Docile	48	45	425 (48%)	17.7**	0.0001
Moderate	48	44	422 (47%)		
Wild	4	11	46 (5%)		
All Temperaments	79	21	893 (100%)		
Facial profile					
Straight	82	67	708 (79%)	22.6**	<0.0001
Concave	17	31	176 (20%)		
Convex	1	2	12 (1%)		
All Profiles	79	21	896 (100%)		
Horn presence					
Present	68	97	652 (74%)	63.8**	< 0.0001
Absent	32	3	227 (26%)		
All	79	21	880 (100%)		
Horn shape					
Straight	91	96	570 (92%)	5.9*	0.0527
Spiral	4	3	23 (4%)		
Scurs	5	1	23 (4%)		
All shapes	75	25	616 (100%)		
Horn orientation					
Backward	13	29	112 (17%)	23.9**	<0.0001
Lateral	36	32	225 (35%)		
Oblique	52	39	313 (48%)		
All orientations	72	28	650 (100%)		

NB: * – significant (P<0.05); ** - highly significant (P<0.01)

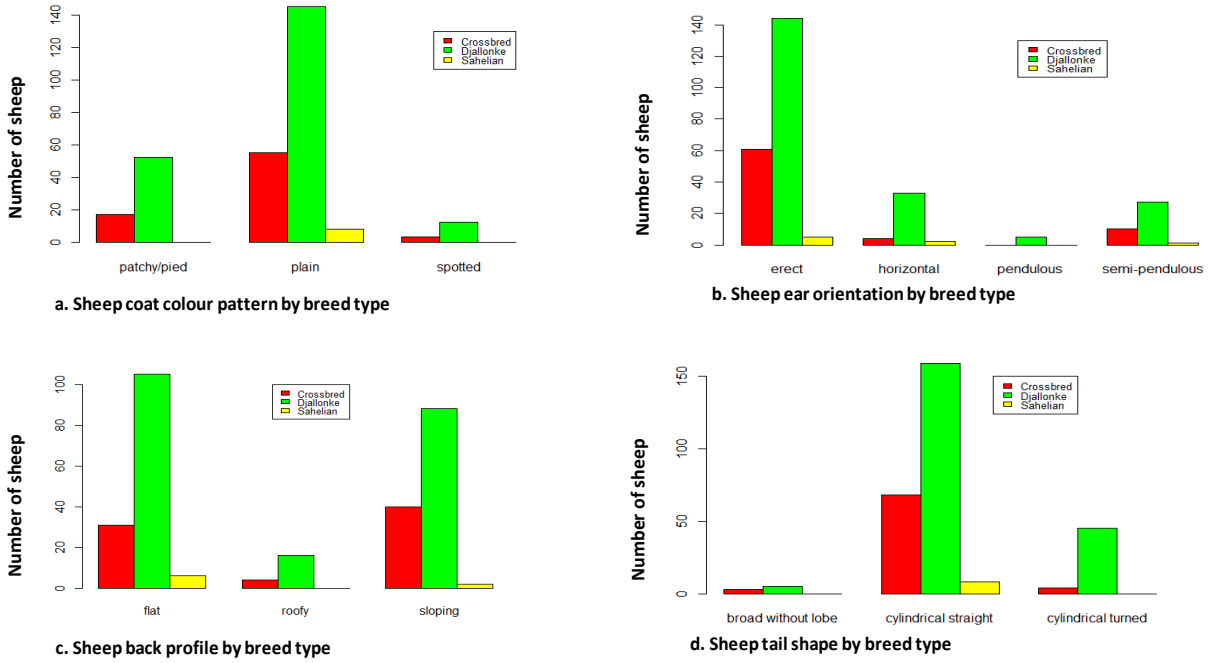

Figure 4. Morphological attributes by breed sheep

CONCLUSION

The sheep genetic resources of Liberia are made up predominantly of the local Djallonke breed, which is transboundary in West Africa. Both female and male farmers keep the animals in subsistence free-range husbandry systems for additional income and meat production for socio-cultural and religious festivals as the main motivational factors. About 60% of farmers provide housing/shed for their animals. In the forest and savannah zones, 75% and 70% of all sheep farmers were also crop farmers, respectively. Sheep multiplication farms were few, with only 5% of all farms surveyed using this practice. Drought, disease and heat tolerance are the major adaptive traits of Djallonke sheep in Liberia. The most common mating system among the sheep famers is uncontrolled, non-seasonal, natural mating. Morphologically, Djallonke sheep have plain coat colour pattern, black or white coat colour, erect ears with straight backline and facial profile. Male sheep were significantly superior to female in all morphometric traits measured. The average body weight for male sheep was 28 kg compared to 24 kg for females, body length was 62 cm for male and 57cm for female, while wither height was 55 cm for male and 52 for female, respectively. The key challenges hampering sheep production in Liberia are feed costs and unavailability, poor housing, diseases and the high cost of veterinary services. These have negative consequences on sustainable use, productivity and conservation of sheep genetic resources in Liberia. Community-based breeding programme for sheep farming as recommended for goats (Karnuah *et al.,* 2018b) should be pursued.

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STATEMENT OF NO-CONFLICT OF INTEREST
The authors declare that there is no conflict of interest in this paper.

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