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Livestock Research for Rural Development 28 (8) 2016

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Abstract

A study was carried out to assess the variation in morphological characteristics of four strains (namely, Pare, Gogo, Sukuma and Sonjo) of Small East African (SEA) goat breed in four regions of Tanzania as a first step towards their characterization. A total of 349 mature animals (85 to 92 animals per strain) were randomly sampled from 120 households located in the four regions. For each external qualitative traits (coat color and pattern, hair type and size, presence of wattles and beards, horn size, shape and orientation, ear size and orientation and facial and back profiles) and quantitative traits (body weight, heart girth, height at wither, body length, chest depth, rump height, ear length and horn length) were recorded. Discriminant, cluster and principal component analyses were used to classify the four SEA strains based on morphometric traits. Results for body measurements show that Pare goats had the largest body weight (29.8 ± 0.50 kg), heart girth (72.3 ± 0.51 cm), height at wither (61.4 ± 0.43 cm), body length (53.9 ± 0.51) and rump height (63.4 ± 0.60 cm) , followed by Gogo goats whereas Sukuma and Sonjo goats were the smallest and lightest. Sexual dimorphism was evident for all the body measurements with males being bigger and heavier than females in all populations. Correlations among morphometric variables were significant for most of the pairs of variables tested, the strongest being between body weight and heart girth (r = 0.70), rump height and wither height (r = 0.60) and body weight and chest depth (r = 0.51). Pare (39.6%) and Gogo (40.2%) were predominantly white coloured while Sonjo were red coloured (85.4%) and Sukuma had black and white colour (66.7%). Almost all goats were horned and did not have wattles and the majority of them had medium sized and horizontally oriented ears. Chest depth and body weight were the most powerful discriminating traits in separating the four goat strains. The squared mahalanobis distance based on morphological traits was largest between Pare and Sukuma goats (5.45) and smallest between Pare and Gogo goats (0.94). Cluster analysis revealed two separate groups; a group for Pare goats and another group comprised Gogo, Sonjo and Sukuma goats. A test for assignment of individual animals to their respective strain showed that most Sonjo (75.3%), Sukuma (70.5%) and Pare (67.9%) goats were assigned to their source populations while most of the Gogo goats (51.1%) were mis-assigned to other populations. It is concluded that the four strains of SEA goat breed are heterogeneous populations with large variability in morphological features and they could best be differentiated by chest depth, body weight and coat colour. ***Key words:*** *body measurements, qualitative traits*

Introduction

The population of goats in Tanzania is 15.6 million and about 97 per cent of them are indigenous belonging to the Small East African (SEA) breed (URT 2012). The SEA breed is comprised of a number of strains/ecotypes, which include Ujiji, Sukuma, Maasai, Gogo, Pare, Sonjo and Newala goats (Msanga et al 2001). Ujiji goats are found in the western zone near Lake Tanganyika while

Sukuma goats are found in the Lake zone, south of Lake Victoria. Maasai, Pare and Sonjo are found in the northern zone while Gogo and Newala goats are found in the central zone and southern zone, respectively. The distribution pattern of these strains reflects differences in their adaptability to local conditions and preferences of their traditional keepers. The most important purposes for keeping the SEA goats are provision of cash income and meat for home consumption, though they also serve as an investment to be drawn upon need. They are also used for payment of dowry, traditional/cultural ceremonies and provision of skins, milk and manure, in that order of importance to the households. The SEA goats are hardy animals and survive well under harsh environmental conditions and in marginal areas. Comparatively, the SEA goats outperform the upgraded or crossbred goats in many farmers' valued traits such as disease, drought and heat tolerance as well as survivability (Chenyambuga et al 2012).

Despite their wide distribution to almost all agro-ecological zones in the country and their socio-cultural importance, the different strains of SEA goats are not well characterised. All strains of indigenous goats are named after either geographic locations where they are predominantly kept or ethnic groups keeping them. Among the strains of SEA goats, only three strains (Dodoma, Kigoma and Mtwara) have been described phenotypically (Madubi et al 2000). However, the study by Madubi et al (2000) did not assess the relationships among the strains. Thus, the extent to which various strains of SEA goats are different from each other is not well known. Due to the purported low productivity of the SEA goats, efforts have been made to improve their productivity mainly through crossbreeding with exotic dairy and dual purpose breeds. This general trend poses a risk that to various strains of the SEA goats which are adapted to existing climatic and environmental stresses in Tanzania of being lost through replacement or upgrading. In addition, population admixture among the different strains of the SEA breed is diluting the uniqueness of formerly distinct populations. This situation, therefore, calls for establishment of conservation and sustainable improvement programmes. The establishment of conservation and improvement programmes requires grouping of the breeds/strains into distinct populations and an understanding of their genetic differences. This study was therefore undertaken to assess the variations of external phenotypic characteristics of four strains of SEA goats (Pare, Gogo, Sukuma and Sonjo) in Tanzania as a first step towards documenting specific information for each of the strains and specifying the homogeneity or distinctness of the strains.

Materials and methods

Sampling sites and animals used

A total of 120 flocks and 349 animals (Gogo, n = 92, Sukuma, n = 87, Pare, n = 85 and Sojo, n = 85) were included in this research. Animals included in this study were the Gogo goats (n = 92) from Bahi and Chamwino districts (Dodoma region), Pare goats (n = 85) from Same district (Kilimanjaro region), Sonjo goats (n = 85) from Ngorongoro district (Arusha region) and Sukuma goats (n = 87) from Misungwi and Kwimba districts (Mwanza regions). These regions are geographically separated and have different agro-climatic conditions. Bahi and Chamwino districts have a semi-arid conditions with dry savannah climate characterized by long dry season, uni-modal and erratic rainfall. Ngorongoro district has different climate and physical features that range from hot arid lowlands around Lake Natron and the slightly undulating plains of the Serengeti to well-watered open highlands. Same district comprises of highlands which are part of the Pare mountain ranges and lowlands which have semi-arid to dry climate. Misungwi and Kwimba districts experience a bimodal rainfall pattern, the short rains and the long rains with a dry spell in between. Table 1 below shows the summarized weather conditions of the study areas.

Table 1. Summary of the weather conditions of the study areas

Districts	Temperature (°C)	Annual rainfall (mm)	Altitude (m.a.s.l)
Bahi and Chamwino	18 - 31	400 - 600	995
Ngorongoro	15 - 21	600 - 2000	400 - 1500
Kwimba and Misungwi	11 - 28	800 - 950	1000 - 1500
Same	10 - 28	500 - 1000	655 - 1950

Study design and sampling procedure

Information on breed characteristics was collected through a cross-sectional survey in six districts of four administrative regions of Tanzania. Animals included in this study were the Gogo goats (n = 92) from Bahi and Chamwino districts (Dodoma region), Pare goats (n = 85) from Same district (Kilimanjaro region), Sonjo goats (n = 85) from Ngorongoro district (Arusha region) and Sukuma goats (n = 87) from Misungwi and Kwimba districts (Mwanza regions). The goat populations in different districts were considered as strains of the SEA breed rather than breeds as all indigenous goats in Tanzania belong to SEA breed. Care was taken to avoid villages and wards in which there have been interventions involving crossbreeding with exotic breeds. The districts were purposely selected based on the criterion of having large number of goats belonging to the population of interest. In each district, two villages were randomly selected. In total 12 villages from the six districts, located at least 10 km away from each other were randomly selected. A total of 10 households per village were randomly selected. In each household, at least 1 male and 1 female mature goat (over 1 year of age) which were unrelated were randomly selected for measurement of quantitative traits and description of qualitative traits. Due to lack of birth records of the animals, the age of each selected goat was estimated from dentition.

Data Collection

For each goat, eight quantitative traits were measured i.e. body weight (BW), heart girth (HG), height at wither (WH), body length (BL), chest depth (CD), rump height (RH), ear length (EL) and horn length (HL). Body weight in kg was measured using Salter hanging spring type scale (Salter House wares, Tonbridge, UK). The linear measurements were taken using a measuring tape (Shanghai Kearing Stationary, Shanghai, China) after making the animal stand squarely on an even ground and recorded in centimeter. Qualitative traits (coat color and pattern, hair type, hair size, presence of wattles, beard and horns, horn shape, horn size and orientation, ear size and orientation, facial profile and back profile) were observed and recorded. In addition, information was sought from the owners of the animals regarding the history of the various goat types, special distinguishing features of the goat populations, production systems and husbandry practices.

Statistical Analysis

Least square means and standard error (s.e.) for the quantitative traits were computed using GLM procedures of SAS (2004) and the MANOVA options was used to calculate partial correlations among body measurements. The effects of strain, age and sex on body measurements were assessed by fitting a linear model which included the strain with four levels (Gogo, Pare, Sonjo, Sukuma); age with 3 levels (below 2 years, 2 to 3 years and above 3 years), sex with 2 levels (male and female) as fixed effects and the interaction of the three factors. Frequencies and percentages of occurrence of qualitative traits were generated using the FREQ procedure of SAS (2004) and the chi-square (χ^2) test was carried out to test the significance of the association between the qualitative traits and the strains. Stepwise discriminant analysis was performed using the stepwise selection in PROC STEPDISC procedure of SAS (2004) to find a subset of morphometric variables that would best separate the four strains. The level of significance ($p \leq 0.05$) and partial coefficient of determination value ($R^2 \geq 0.01$) were used to retain the variable in the final model. The CANDISC procedure was used to perform univariate and multivariate one-way analyses of variance and to derive canonical functions, linear combinations of the quantitative variables that summarize variation between strains and compute the squared mahalanobis distances between pairs of strains. The ability of these canonical functions to identify each individual goat to respective strain was calculated as the percent correct assignment of each vegetation zone using the DISCRIM procedure of SAS. Cluster analysis was done using CLUSTER procedure and was used to construct a dendrogram showing the relationship of the strains. Principal component analysis was also performed to assess further the relationship among the strains.

Results

Variation in quantitative traits among the four strains of SEA goats

Least square means for body measurements of the different strains are presented in Table 2. Overall, Pare goats had the highest values for all body measurements, except for EL. Sonjo and Sukuma had the lowest values for all body measurements except for EL. Sonjo goats did not differ ($P > 0.05$) from Sukuma for HG, CD and HL. Generally, the Pare goats outperformed the rest of the strains with respect to BW, HG, WH, BL, RH, CD and HL and they were heavier than Gogo, Sonjo and Sukuma goats by 4.7, 7.0 and 7.5 kg, respectively.

Table 2. Least Squares Means (± s.e) for body weight and linear body measurements of the four strains of SEA goats

Variable	Strain				Overall means
	Gogo	Pare	Sonjo	Sukuma	
BW (Kg)	25.1 ± 0.60^{b}	29.8 ± 0.50^{a}	22.8 ± 0.48^{c}	22.3 ± 0.50^{c}	28.97
HG (cm)	67.9 ± 0.63^{b}	72.3 ± 0.51^{a}	65.8 ± 0.50^{c}	65.6 ± 0.52^{c}	68.70
WH (cm)	58.7 ± 0.52^{b}	61.4 ± 0.43^{a}	57.1 ± 0.42^{c}	55.8 ± 0.43^{d}	58.71
BL (cm)	51.3 ± 0.63^{b}	53.9 ± 0.51^{a}	50.7 ± 0.50^{b}	48.4 ± 0.52^{c}	51.60

RH (cm)	61.0 ±0.72^{b}	63.4 ± 0.60^{a}	59.2 ± 0.58^{b}	56.4 ± 0.60^{c}	60.31
CD (cm)	31.5 ±0.34^{b}	33.7 ± 0.28^{a}	29.6 ± 0.27^{c}	29.0 ± 0.28^{c}	31.44
EL (cm)	12.0 ±0.20^{a}	11.3 ± 0.16^{b}	10.4 ± 0.16^{c}	12.1 ± 0.17^{a}	11.40
HL (cm)	9.3 ±0.47^{ab}	9.6 ± 0.39^{a}	8.6 ± 0.37^{b}	8.6 ± 0.39^{b}	9.21

Means with different superscripts across columns differ significantly at P<0.05.
Note: BW- Body weight, HG- Heart girth, WH- Withers height, BL- Body length, RH- Rump height, CD- Chest depth, EL- Ear length and HL- Horn length.

Variation in quantitative traits by sex and age

All of the targeted quantitative traits (BW, HG, WH, BL, RH, CD, EL and HL) were evaluated in relation to sex and age of animals (Table 3). The results show that male animals had higher values ($P \leq 0.05$) than females for all quantitative traits studied with the exception of the EL. Concerning the age of the goats, it is clearly shown that old animals (above 3 years) had greater values ($P \leq 0.05$) for all traits compared to the young animals (below 2 and between 2 and 3 years) except for the EL trait. The EL values were not statistically different ($P > 0.05$) among the three age categories analyzed in the present study. The effects of interaction between sex and breed, age and breed and between sex and age on body measurements were not statically significant ($P > 0.05$) and were therefore removed from the final model during data analyses.

Table 3. Comparison of quantitative traits (LSM ± s.e.) by sex and age

Variable	Sex		Age categories (yrs)		
	Male	Female	Below 2	2-3	Above 3
BW (kg)	26.1 ± 0.35^{a}	23.9 ± 0.35^{b}	21.1 ±0.61^{a}	24.7 ± 0.33^{b}	29.0 ± 0.40^{c}
HG (cm)	68.9 ± 0.37^{a}	66.9 ± 0.37^{b}	64.4 ±0.64^{a}	67.2 ± 0.34^{b}	72.0 ± 0.42^{c}
WH(cm)	59.1 ± 0.31^{a}	57.5 ± 0.31^{b}	56.4 ±0.53^{a}	58.2 ± 0.28^{b}	60.2 ± 0.35^{c}
BL (cm)	51.9 ± 0.37^{a}	50.3 ± 0.37^{b}	48.4 ±0.64^{a}	50.5 ± 0.34^{b}	54.3 ± 0.42^{c}
RH (cm)	60.6 ± 0.43^{a}	59.4 ± 0.43^{b}	58.3 ±0.74^{a}	59.6 ± 0.39^{b}	62.1 ± 0.48^{c}
CD (cm)	31.3 ±0.20^{a}	30.6 ± 0.20^{b}	29.4 ±0.35^{a}	31.2 ± 0.18^{b}	32.2 ± 0.18^{c}
EL (cm)	11.4 ±0.12	11.5 ± 0.12	11.5 ± 0.20	11.3 ± 0.11	11.5 ± 0.13
HL (cm)	9.92 ±0.27^{a}	8.11 ± 0.28^{b}	7.85 ± 0.48^{a}	9.09 ± 0.25^{b}	10.1 ± 0.32^{c}

Means with different superscripts across columns differ significantly at P<0.05; BW: Body weight, HG: Heart girth, WH: Withers height, BL: Body length, RH: Rump height, CD: Chest depth, EL: Ear length and HL: Horn length.

Correlations among the quantitative traits

Correlation among the quantitative traits was assessed and the correlation coefficients are shown in Table 3. Overall, there were positive phenotypic partial correlations among all the traits evaluated in this study. The correlation coefficients were significant for most of the traits, except between EL and WH, EL and BL, EL and RH as well as EL and HL (Table 4).The highest correlations were observed between BW and HG (r=0.70), WH and RH (0.60) and BW and CD (r=0.51).

Table 4. Partial correlation coefficient and significance levels among various morphometric traits

Traits	BW	HG	WH	BL	RH	CD	EL	HL
BW	1.00							
HG	0.70**	1.00						
WH	0.49**	0.39**	1.00					
BL	0.45**	0.32**	0.37**	1.00				
RH	0.49**	0.41**	0.60**	0.31**	1.00			
CD	0.51**	0.43	0.38**	0.36**	0.24**	1.00		
EL	0.12*	0.13*	0.13	0.09	0.09	0.14*	1.00	
HL	0.37**	0.21**	0.28**	0.36**	0.25**	0.30**	0.07	1.00

BW: Body weight, HG: Heart girth, WH: Withers height, BL: Body length, RH: Rump height, CD: Chest depth, EL: Ear length and HL: Horn length
**P<0.05, **P<0.0001*

Variation in qualitative traits among the four strains of SEA goats

Occurrence of colour and colour patterns in the four strains of SEA goats are shown in Table 5. Overall, the predominant colour patterns were plain white, plain red, pied black and white and pied white and red. The majority of Gogo and Pare goats were mainly plain white coloured. Other colour patterns which occurred at higher frequencies in Gogo goats were pied black and white while in Pare goats were pied white and red. Most Sonjo goats had plain red colour and a few were spotted white and red. The majority of Sukuma goats were predominantly pied black and white. In addition, a significant proportion of Sukuma goats were pied white and red.

Table 5. Occurrence (%) of colours and colour patterns in four strains of Small East African goats

Colour pattern	Gogo	Pare	Sonjo	Sukuma
Plain Red	1.09	6.25	85.1	1.67
Plain White	40.2	39.6	0	5.00
Spotted (Black and Brown)	0	2.08	0	0
Spotted (Black and White)	5.43	0	0	0
Spotted (White and Brown)	1.09	0	0	0
Spotted (White and Grey)	3.26	2.08	0	0
Spotted (White and Red)	0	0	12.8	1.67
Pied (Black and White)	34.8	14.6	0	66.7
Pied (Brown and Red	0	2.08	0	0
Pied (White and Brown)	5.43	0	0	0
Pied (White and Red)	0	33.3	0	21.7
Plain Black	6.52	0	2.13	3.33

Plain Brown	1.08	0	0	0
Plain Grey	1.08	0	0	0

Chi-square value = 319.5; P value = 0.0001

Table 6 shows the frequencies of external phenotypic qualitative traits of the four strains of SEA goats. The results show that the majority of Gogo and Sukuma goats had smooth hair compared to Pare and Sonjo goats which had course hairs. Apart from the differences in hair type, the strains also differed in terms of hair length. Pare and Sukuma goats had short hairs whereas Gogo and Sonjo had medium sized hair. Generally, the majority of goats in all strains were horned, but had no wattles. Beards were observed at relatively higher frequency in Pare and Gogo goats compared to Sonjo and the Sukuma groups.

Table 6. Percentage of occurrence of different qualitative traits in four strains of Small East African goats

Variable	Category	SEA Strain				*p*
		Gogo (n=92)	Pare (n=85)	Sonjo (n=85)	Sukuma (n=87)	
Hair type	Smooth	84.8	27.1	29.8	78.3	0.0001
	Coarse	15.2	72.9	70.2	21.7	
Hair size	Long	23.9	4.17	2.13	6.67	0.0001
	Medium	52.2	35.4	68.1	30.0	
	Short	23.9	60.4	29.8	63.3	
Wattle	Present	5.43	0	10.6	6.67	0.159
	Absent	94.6	100	89.4	93.3	
Beard	Present	45.7	54.2	29.8	33.3	0.0433
	Absent	54.3	45.8	70.2	66.7	
Ear size	Large	20.7	2.08	21.3	10.0	0.0001
	Medium	55.4	83.3	29.8	83.3	
	Small	23.9	14.6	48.9	6.67	
Ear orientation	Horizontal	78.3	68.8	63.8	88.3	0.0001
	Pendulous	15.2	31.3	12.8	0	
	Erect	6.52	0.00	23.4	11.7	
Horn	Present	96.7	97.9	97.9	100	0.582
	Absent	3.26	2.08	2.13	0	
Horn shape	Spiral	0	0	2.13	0	0.0003
	Straight	67.4	47.9	42.6	83.3	
	Curved	32.6	52.1	53.2	16.7	
Horn orientation	Upward	23.9	47.9	66.0	16.7	0.0001
	Backward	73.9	52.1	31.9	80.0	
	Lateral	2.17	0	2.13	3.33	
Facial profile	Straight	50.0	91.7	44.7	78.3	0.0001
	Concave	50.0	8.33	55.3	21.7	
Back profile	Curved	1.09	0	0	15.0	0.0001
	Straight	98.9	100	100	85.0	

Discriminant analyses for the quantitative variables

The stepwise discriminant analysis was conducted to evaluate the variations or similarities among the goat populations in order to determine the membership of individuals to their respective populations using the traits under study. The results show that, all the quantitative traits were found to be significant ($p < 0.001$) except HL. Among the traits, CD had the most discriminant power, followed by BW, HG and WH as indicated by their higher R^2 and F-value as shown in Table 7.

Table 7. Discriminating power of various body measurements of Small East African goats

Step	Trait	Partial R^2	F-Value	Wilks' lambda (λ)	P< Lambda	Average Squared Canonical Correlation	P>ASCC
1	CD	0.38	70.0	0.62	<.0001	0.13	<.0001
2	BW	0.30	49.8	0.50	<.0001	0.19	<.0001
3	HG	0.27	41.9	0.46	<.0001	0.21	<.0001
4	WH	0.27	41.8	0.45	<.0001	0.21	<.0001
5	RH	0.23	35.1	0.44	<.0001	0.22	<.0001
6	BL	0.21	29.8	0.42	<.0001	0.23	<.0001
7	EL	0.20	29.5	0.41	<.0001	0.24	<.0001
8	HL	0.03	3.49	0.40	<.0001	0.24	<.0161

BW: Body weight, HG: Heart girth, WH: Withers height, BL: Body length, RH: Rump height, CD: Chest depth, EL: Ear length and HL: Horn length

Moreover, the results indicate that all quantitative traits studied significantly contributed to the differentiations of individuals from the different strains ($P < 0.001$). Three canonical variables (CAN 1, CAN 2 and CAN 3) were generated following the canonical discriminant analyses in this study. The canonical discriminant analysis performed was used in weighting the contribution of each trait to each of the three canonical variables. Both CAN 1 and CAN 2 accounted for 96.7% of the total variation and significantly ($P<0.001$) contributed to variation among the strains (Table 8). The first canonical variable CAN 1, which accounted for 69.3% of the variation loaded highly for CD and BW while the CAN 2 accounting for an additional 27.4% loaded highly for EL.

Table 8. Standardized coefficients for the canonical discriminant function, the canonical correlation, the eigenvalue and the percentage total variance accounted for

Trait	Discriminant Variate		
	CAN 1	CAN 2	CAN 3
BW	0.82	0.19	-0.21
HG	0.76	0.24	-0.18
WH	0.78	0.03	-0.16
BL	0.68	-0.05	0.40
RH	0.72	-0.13	0.18

CD	0.92	0.18	0.04
EL	0.04	0.92	0.28
HL	0.25	0.09	0.16
Adjusted canonical correlation	0.65	0.47	0.15
Approximate standard error	0.03	0.04	0.05
Eigenvalue	0.77	0.30	0.04
Variance accounted for (%)	69.3	27.4	3.29
Cumulative Variance (%)	69.3	96.7	100

CAN 1- Canonical variable 1, CAN 2-Canonical variable 2 and CAN 3-Canonical variable 3.

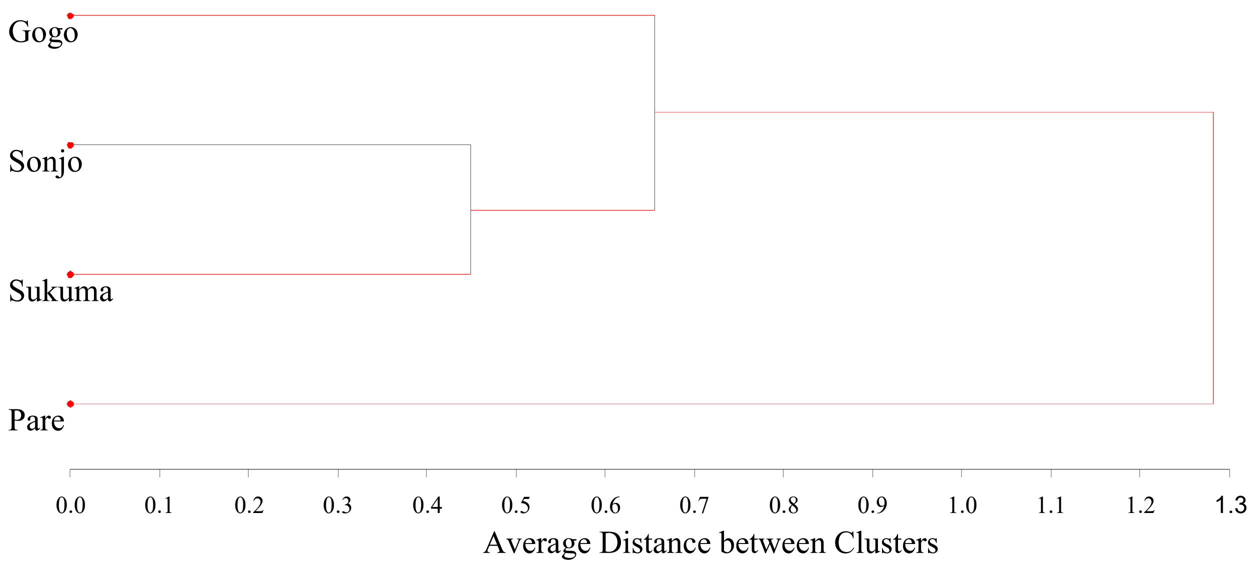
The squared mahalanobis distances between the pairs of the SEA strains are shown in Table 9. The largest inter-population distance was observed between Pare and Sukuma (5.45) and the smallest inter-population distance was between Pare and Gogo goats (0.94).

Table 9. Squared mahalanobis distances between pairs of populations of the Small East African goats

Subpopulation	**Gogo**	**Pare**	**Sonjo**	**Sukuma**
Gogo	0			
Pare White	0.94	0		
Sonjo	2.41	4.12	0	
Sukuma	2.42	5.45	2.44	0

The relationship and variation among the populations were further assessed using cluster analysis based on quantitative traits. In the dendrogram shown in Figure 1 two main clusters are revealed. One cluster was composed of the Pare goats only while the other was composed of the three remaining strains of SEA (Gogo, Sonjo and Sukuma). The dendrogram further show that Sonjo and Sukuma goats were closely related and Gogo goats were more related to Sonjo and Sukuma group than to the Pare goats.

Figure 1. A dendrogram showing relationships among the four populations of the Small East African goats of Tanzania



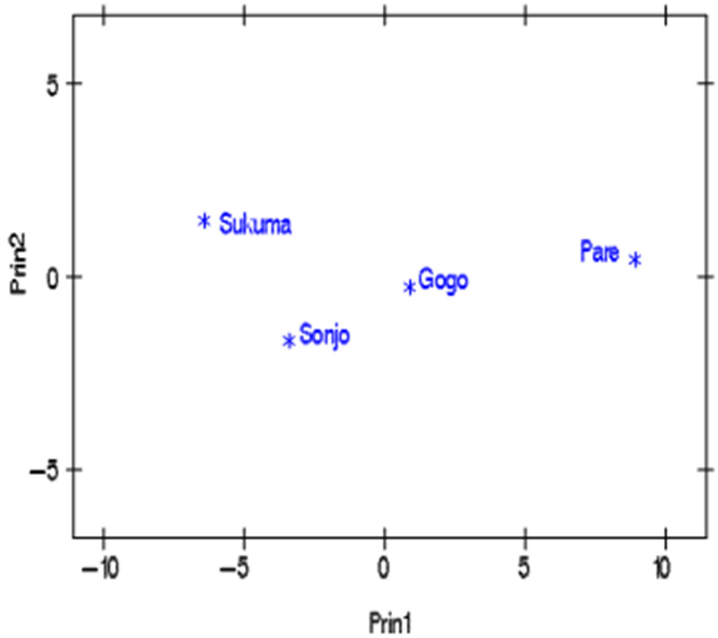
To further assess the differentiation of the four strains or populations, an assignment test was performed to assign the individual animals to their source population (Table 10). In total 65.7% of the individuals were correctly assigned to their populations of origin. The greatest percentage of individuals assigned to their source populations belonged to the Sonjo goats, followed by Sukuma and Pare goats. This indicates that these populations are sufficiently differentiated from each other. On the other hand, the Gogo goats had the greatest percentage of individuals mis-assigned to other populations, the majority of them (23.9%) being wrongly assigned to the Pare goats. Therefore, the Gogo goats were poorly differentiated from the other populations.

Table 10. Percent of individual goats assigned to their respective populations

Source population	**Correctly assigned (%)**	**Miss-assigned to other subpopulations (%)**			
		Gogo	**Pare**	**Sonjo**	**Sukuma**
Gogo	48.9	-	23.9	13.0	14.1
Pare	67.9	16.7	-	11.9	3.57
Sonjo	75.3	11.8	2.35	-	10.6
Sukuma	70.5	13.6	1.14	14.8	-
Overall	65.6	10.5	4.6	6.6	4.7

The relationships among the SEA goat strains were further assessed using principal component analysis (PCA). Figure 2 is the scatter plot showing the relationships among the strains based on the first four components. The first three principal components accounted for 86 % of the total variation. The first PC explained 69.3% of the variation and clearly separated Pare and Gogo goats from other strains. Pare and Gogo goats which had higher quantitative trait values are at the right side while Sonjo and Sukuma which had smaller values are on the left side of the scatter plot.

Figure 2. Scatter plot showing the relationships among the SEA strains based on quantitative traits



Discussion

From the results, it is clear that Pare goats were the heaviest and largest strain, followed by Gogo while Sonjo was the smallest strain. The study has revealed that the strains of the SEA goats have different body measurement values. Differences in genetic makeup as well as climatic factors and husbandry practices may be the causes of the observed variation in morphometric traits of the SEA goat strains. The different SEA strains are adapted to different agro-climatic conditions existing in their native areas and, hence, have different morphological characteristics. The present study revealed that the Gogo goats have larger size than Sukuma and Sonjo goats. The larger weight values of the Gogo goats compared to other types of SEA goats have been reported previously (Madubi et al 2000). However, it has been noted that the mean mature weight of Gogo goats in the present study is lower than that reported by Madubi et al (2000) (31.8 kg) and Chenyambuga et al (2012) (28.1 kg) for the same strain, indicating a decreasing trend in live body weight as years goes on. This could possibly be a result of increasing inbreeding within the population and/or deteriorating environmental conditions and decreasing grazing land.

Based on the findings of this study, it can be said that the four populations of SEA goats have bigger body size and heavier weight than the other types of SEA goats found in Uganda (i.e. Mubende, Teso and Lugware goats) (Jimmy et al, 2010), Malawi (Karua and Banda 1993) as well as the Dwarf goats of West Africa .Yakubu et al (2010a). Body weight (BW) is a trait of economic importance in livestock production. In the present study, high correlations were observed between BW and HG and CD. This is in agreement with the findings of other studies on SEA goats in Uganda (Jimmy et al 2010) and Rwanda (Manzi et al 2011). The significant correlation implies that BW can be accurately predicted from HG and CD. This is advantageous because in the absence of weighing scales, measuring of either HG or CD, which can be easily measured using a tailor's tape, the values of BW can be determined without additional cost and time. Furthermore, the positive and significant correlations observed between body weight and HG and CD suggest that selection for any of these linear body parameters will cause direct improvement in body weight.

The present study has shown that the majority of Pare and Gogo goats are white while Sonjo goats are red and Sukuma goats have black and white coat colour. The coat colours of SEA goats observed in this study concurs with the findings by Madubi et al (2000) who found white coloured goats to be the most predominant in Gogo goats. However, Msanga et al (2001) reported Gogo goats as multi-coloured, the common colours being white, brown, black, black and white spotted or pied. According to Mason and Maule (1960), the common colours in SEA goats are black, brown, white and grey and they occur in various combinations of bi-colour or multi-colour. In contrary the present study has shown that there is more or less unique colour for each strain of the SEA. The difference in coat colour is a reflection of genetic differences among the strains. Over dominance of certain colour in a particular strain of SEA goats could be a result of selective breeding done by farmers to maintain the colour of their choice. This is due to cultural values attached to goats of certain colours. It has been reported that culture and tradition have an influence on the traits preferred by farmers (Ouma et al 2005). Depending on the ethnic group and its culture, goats of certain colours are preferred to those of other colours during traditional rituals or offering of spiritual sacrifices, this then makes coat colour a criterion for selection of breeding animals. In a study on cattle, preference for coat colour was higher than fertility traits indicating wide recognition of the ecological significance of coat colour by the cattle keepers in the area (Garoma et al, 2013). A study by Adedeji et al (2012) indicated that some coat colours are not preferred by farmers in Nigeria. According to the study, despite the good performance of black West African Dwarf goats, some farmers were greatly against rearing them due to the belief that anything black is evil (Adedeji et al, 2012). Finch and Western (1977) attributed variation in coat colour among pastoralists' cattle herds to natural selection, individual choices, ceremonial and ritual uses of various coloured animals. In their study the authors found natural selection to be in favour of white or light coloured animals over dark animals as an adaptation to heat and nutritional stress. In another study on Pare goats, farmers said they pay more attention to coat colour because of the adaptive role it plays in semi-arid and hot conditions of their area (Msemwa, 2013). This is consistent with the observations in the present study as white colour was dominant in Gogo and Pare goats which are found in semi-arid areas where there is high heat and scarcity of feeds.

Security of animals during grazing was another reason for preference for certain coat colours over others. For example, some farmers in Dodoma region where the Gogo goats are raised said that they prefer white coloured goats because it is easier for them to trace and see a white animal when lost during grazing. However, with cultural changes as a result of modernization in rural communities and availability of goat markets, traits of economic importance like body weight and growth rate are becoming more relevant than qualitative traits like coat colour. This was observed in some parts of Ngorongoro district where white coloured Gala goats from Kenya, which are larger were preferred to plain red coloured Sonjo goats which are small in size. It was noted that farmers in Ngorongoro district are replacing the Sonjo with Galla goats due to economic reasons. However, in a long run, this practice will make the Sonjo to be at risk of being lost. According to FAO (2005), the risk of losing indigenous animals in developing countries is increasing as the poor farmers who keep the animals become integrated with global market chains and move out of traditional livestock production system. Farmers in Ngorongoro district have foregone the relatively smaller sized Sonjo goats which are better adapted to feed and water shortages because of their small size and thus low maintenance requirement. Thus, it is important that conservation strategies for this strain be established in order to ameliorate the loss of this important genetic resource.

The distribution and frequencies of all other qualitative traits in this study were influenced by the strain of the goat with the exception of presence or absence of horns and wattles. It is hypothesised that unconscious indirect selection of linked traits could be going on in some of the study areas, thus affecting the frequency and distribution of the qualitative traits. The wattle and horn genes across all the populations seem to be at the brink of extinction. Similar results have been obtained by Yakubu et al (2010b) who observed lower frequencies of wattle gene in West African Dwarf and Sokoto goats and attributed it to lack of crossbreeding programmes through artificial breeding. Significant association between some qualitative traits with reproduction and other economically important traits has been reported for goats elsewhere (Adedeji et al, 2012; Sanusi et al, 2012).

The relatively higher and significant inter-population distances between Pare and Sukuma and Pare and Sonjo indicate that these pairs of strains are divergent, probably because of isolation caused by large geographical distance between them, and this has limited the possibility of interbreeding. Thus, these strains have sufficiently differentiated as a result of reproductive isolation and different selection pressure. These have resulted into the strains having different phenotypic traits and, hence, may be considered as different populations. This is supported by the fact that relatively high proportions of individual goats from the different strains were correctly assigned to their respective source population, implying that these populations are sufficiently differentiated from each other. It is worthy to note that within the SEA breed phenotypic variations exist and can be exploited for implementing selection among the local populations for the traits of interest. For example, the Pare and Gogo goats are better in terms of body weight and size traits compared to the Sukuma and Sonjo goats. In a previous study of local goats of Tanzania, Madubi et al (2000) reported that Ujiji goats, a strain of the SEA goats, are slightly larger than the Sukuma goats and have high twinning rate.

Assessment of the relationship among the four SEA strains using cluster analysis method revealed that the Pare goats are clearly differentiated from the Gogo, Sonjo and Sukuma goats while the Sonjo and Sukuma goats are closely related. The Gogo goats are somehow distantly related to the Sonjo and Sukuma goats. The variations in morphometric traits among the strains could be due to inherent genetic differences as a result of reproductive isolation. Yadav et al (2013) working with four sheep breeds clustered the sheep population into two distinct groups which reflected the geographical distance of their respective habitat. In the present study, however, clustering together of the Sonjo and Sukuma as one group and Gogo goats as a sub group does not correspond to the geographical distance of their habitats as the strains are geographically distantly located and chances of intermingling is negligible. In addition to geographical distance, Yadav et al (2013) mentioned management practices, agro-climatic conditions and biophysical resources to be the factors associated with phenotypic divergence between breeds. The phylogenetic relationship exhibited by the four goat populations in the present study may be the results of adaptation of the goats to different climatic conditions and husbandry practices. The large geographic distances between the locations in which the strains are found eliminate any possibility of interbreeding among the populations and, therefore, there is low level of gene flow among the populations.

Differences in sex and age of the goats in terms of quantitative and qualitative traits were also evaluated. This may be useful in regard to breeding and selection within a population. For breeding purpose, it is important to know which buck to use for which does and what age is appropriate for mating in both sexes. Previous studies have demonstrated the importance of sex in breeding and variation of morphological traits (Yadav et al 2013). With regard to age, the majority of body measurements have been found to proportionately increase with age in African goats (Manzi et al 2011) except EL as was in the present study.

Conclusions and Recommendations

- The present study has shown that the strains of SEA goats are heterogeneous populations with large variability in body measurements and coat colour. The difference based on morphometric traits is highest between Pare and Sukuma goats and Pare and Sonjo goats.
- The Gogo goats are somehow distantly related to the Sonjo and Sukuma goats while the Sonjo and Sukuma goats are closely related.
- The strains of the SEA goats are best differentiated by measuring CD and BW.
- It is recommended that molecular characterization be carried out to compliment these results.
- Also performance evaluation programs incorporating more traits like survivability and reproductive traits be carried out to be able to prioritize the strains for genetic improvement and conservation.

Acknowledgements

This study was jointly funded by a grant from the Tanzania Commission of Science and Technology (COSTECH) and the National Research Foundation (NRF) of South Africa under the Bilateral Research Partnership Programme between the two countries. We thank COSTECH for a separate funding for Mr. Athumani Nguluma in the form of PhD support. We thank the livestock farmers for allowing us to use their animals. We thank Mary Jackson, Hashim Matimbwa and Isack Kerario for their assistance in data collection. We are grateful to the Livestock Officers and Village Extension Officers for the cooperation they provided during data collection.

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Received 6 November 2015; Accepted 1 July 2016; Published 1 August 2016