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Exploring Associations between Categories of Qualitative Morphological Traits in Indigenous Cattle through the Use of Multiple Correspondence Analysis

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Abstract

Characterization of cattle breeds based on morphological traits variation is essential for planning breed improvement programs and conservation strategies. This study aimed to use multiple correspondence analysis to evaluate qualitative morphological traits of and identify significant traits. The study found variations in qualitative morphological traits in the Hararghe cattle ecotype populations in the three districts. These findings provide valuable information for the characterization and conservation of cattle ecotypes in Ethiopia. The first two dimensions of the multiple correspondence analysis explained 29% of the total variance among the traits. The bi-dimensional graph showed that the sample cattle population in the Mayyuu district exhibited a clustering effect, in which the presence of curved horn shape, large hump size, absence of navel flap, and varying sizes of large perpetual sheath were predominant; while the cattle population in the Kurfa district clustered together with not pigmented skin, muzzle, eyelid and horn colours, polled horn shape, and medium hump size. Similarly, the values associated with the Jarso district were found to cluster together based on the absence of a horn, straight horn shape, small hump size, and varying sizes of navel flap.

Keywords: Hararghe cattle; Multivariate analysis; Qualitative morphological traits

Introduction

With an estimated 60 million cattle, 60 million sheep and goats, 52 million poultry, 4.5 million camels, 10 million bee colonies, and 7.2 million horses, Ethiopia is endowed with enormous livestock resources and has the highest livestock population in Africa [1]. It is essential that livestock products and byproducts (such as live animals, hides, skins, meat, milk, cheese, honey, and eggs) give the necessary animal protein to help raise people's nutritional status and also help to obtain foreign currency. However, draught animals are also necessary and provide draft power for ploughing and crop threshing in the country [2].

There are many indigenous breeds of cattle in Ethiopia that are adapted to a wide range of agro-ecological conditions. This diversity can serve as a genetic pool from which selection can be made for suitable strains and lines can be selected [3]. The genetic diversity within and among indigenous cattle breeds, as well as the genes and gene combinations they possess, are valuable for adapting to future changes in market conditions, social needs, advancements in human nutritional knowledge, threats to animal health, and overall climate changes [4]. Breed identification, estimation of their population size, documentation of their common uses, and description of the management systems in which they are maintained are the first pieces of information to be assessed before the improvement and conservation of animal genetic resources [5].

A large proportion of indigenous livestock populations in the developing world have not yet been fully characterized or evaluated at phenotypic and genetic levels [6]. The Harar cattle breed (also not adequately characterized) inhabits the Hararghe area of eastern Ethiopia where they are mainly used for meat, milk, and draught purposes. The breed is known to be one of the small East African zebus of Ethiopia with good potential for milk and meat production [7].

Even though phenotypic characterizations based on qualitative and quantitative morphological traits have been conducted [8–14] in different parts of Ethiopia the characterization work (especially for qualitative morphological traits) remains at a rudimentary level [15]. Especially, in the area of multivariate analysis, so far there are insufficient qualitative morphometric characterization studies conducted. The new direction for livestock classification and characterization is the application of multivariate statistical techniques [16-19]. These techniques are highly powerful in analyzing all morphological traits together and extracting the real variation within and among populations [20]. One of the critically important multivariate statistical tools for qualitative morphological traits is multiple correspondence analysis (MCA).

In many studies investigating breed characterization at the phenotypic level, for the analysis of qualitative morphological traits, contingency table analysis (Pearson's chi-square) is used. However, contingency tables have drawbacks including not precisely measuring the nature of the correlation between two traits and traits with many categories requiring large tables that are difficult to manage. Again, categories with few observations obfuscate the bivariate correlation and the Chi-square test cannot provide predicted values. Above all contingency tables can only be used to analyze the effect of a single categorical variable on the response.

The current study was thus intended to overcome the limitations of contingency tables by using MCA to evaluate qualitative morphological traits and identify significant traits compared to contingency table analysis. The study will thereby increase and promote the adoption of MCA by researchers in the field and help find the relative closeness of the key correlation factors so that necessary actions can be taken to the development of suitable policies for designing breeding programs and conservation.

Materials and Methods

Study area location

This study was conducted in three districts of the East Hararghe zone of the Oromia Regional State, Ethiopia. The geographic nature of the East Hararghe zone is characterized as 8% high land, 25% midland, and 67% low land with an altitude range from 500-3405 masl and a temperature range from 13^0C to 28^0C. The average annual rainfall of the zone is 400-1200 mm (East Hararghe Zone Agricultural Office) (Figure 1).

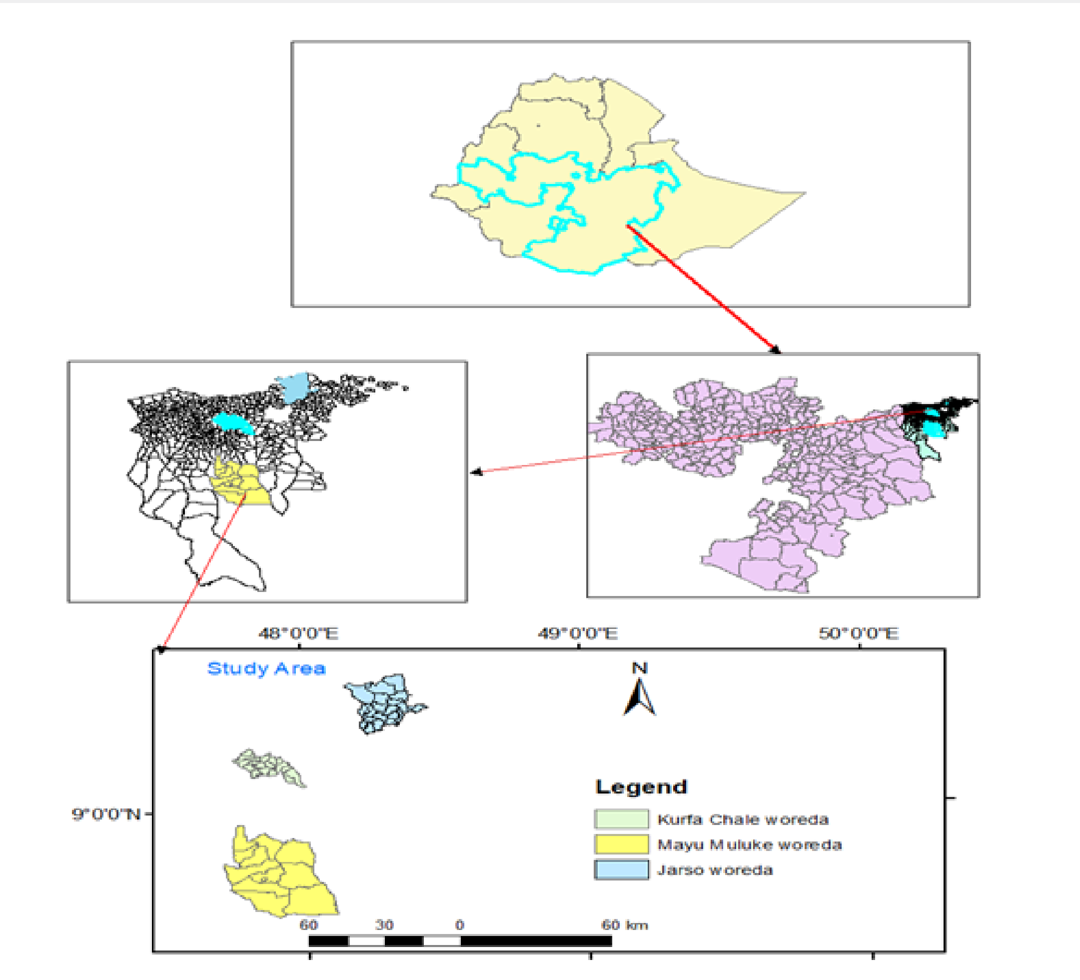

Figure 1: Map of the study area.

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Sampling techniques for data collection

Discussions were held with the district experts of the rural and agricultural development offices and the farmers' representatives regarding the distribution of local cattle in the study area dominated by the Hararghe highland cattle population. Purposive selection was employed first, wherein three districts were selected based on the distribution of the Hararghe highland cattle population and their mobility. In the second stage, two kebeles from each district were selected based on their suitability for cattle production, accessibility, and the willingness of farmers to participate in the study. Finally, sample cattle owners were randomly selected using a systematic sampling procedure.

In collecting data on qualitative morphological traits, the format adopted from the standard description list developed by [6] was utilized. Thus, qualitative morphological traits collected in this study were hair coat colour pattern, hair coat colour, skin colour, muzzle colour, eyelid colour, hoof colour, presence of horn, horn orientation, hair length, ear shape, ear orientation, hump size, navel flap, perpetual sheath, head profile and tail length.

Statistical data analysis

SAS-program version 9.4 [21] was used for all statistical analyses in this study.

Exploratory data analysis

To obtain descriptive statistics and chi-square tests, the qualitative morphological traits underwent exploratory data analysis using the PROC FREQ procedures of SAS [21]. The contingency tables (Pearson's Chi-square) were employed in analysing the data.

Multiple Correspondence Analysis (MCA)

To ascertain potential correlations among more than two categorical traits, MCA was utilized. MCA is a multivariate technique that is specifically designed to explore both inter- and intra-relations of two or more categorical variables by evaluating the proximity and distance among them [22-24]. The objective of MCA is to demonstrate the alterations of groupings in both rows and columns of categorical data that are arranged in a contingency table format, in a graphical representation that is situated in a lower-dimensional space [25]. This technique offers numerous advantages over alternative methodologies such as Chi-square analysis, G-test, Z-test, Fisher Exact test or Log-linear models, as it provides a more comprehensive and detailed understanding of the data and can present results in a visual format [23,26,27]. Using MCA, each level of the categorical traits is represented by a dot in a multi-dimensional space. The proximity of these dots to one another indicates their degree of similarity, based on the respective quadrants in which they are located. Conversely, dots that are situated far apart from each other are unrelated [28].

Results and Discussion

Exploratory data analysis

The table provides information on the coat colour pattern, coat colour type, skin colour, muzzle colour, and eyelid colour of the animals. The traits investigated demonstrated variability in terms of frequencies and percentages, particularly across varying districts (Table 1).

Table 1: Total frequency (and percentage in brackets) for each level of the qualitative morphological traits across study districts.

Variables and attributes N (%)		District				
		Jarso	Kurfa	Meyu Muluke		
		N (%)	N (%)	X^2	Prob>ChiSq	
CCP	Patchy	21 (14.0)	25 (16.7)	32 (21.3)	0.323	0.9883
	Plain	84 (56.0)	78 (52.0)	94 (62.7)		
	Spotted	45(30.0)	47 (31.3)	24 (16.0)		
CCT	Black	22 (14.7)	29 (19.3)	16 (10.7)	15.572	0.1125
	Red	31 (20.7)	24 (16.0)	23 (15.3)		
	Roan	32 (21.3)	31 (20.7)	25 (16.7)		
	White	20 (13.3)	32 (21.3)	35 (23.3)		
	White and gray	19 (12.7)	14 (9.3)	16 (10.7)		
	White and red	26 (17.3)	20 (13.3)	35 (23.3)		
SC	Not Pigment	131 (87.3)	130 (86.7)	120 (80.0)	3.8	0.1496
	Pigment	19 (12.7)	20 (13.3)	30 (20.0)		

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MC	Not Pigment	140 (93.3)	133 (88.7)	131 (87.3)	3.245	0.1974
	Pigment	10 (6.7)	17 (11.3)	19 (12.7)		
EC	Not Pigment	128 (85.3)	125 (83.3)	120 (80.0)	1.535	0.1974
	Pigment	22 (14.7)	25 (16.7)	30 (20.0)		
HC	Not Pigment	127 (84.7)	139 (92.7)	131 (87.3)	4.791	0.0911
	Pigment	23 (15.3)	11 (7.3)	19 (12.7)		
Horn	Absent	26 (17.3)	34 (22.7)	22 (14.7)	3.34	0.1882
	Present	124 (82.7)	116 (77.3)	128 (85.3)		
HC	Not Pigment	139 (92.7)	135 (90.0)	125 (83.3)	1.103	0.5761
	Pigment	11 (7.3)	15 (10.0)	25 (16.7)		
HShape	Curved	47 (31.3)	55 (36.7)	47 (31.3)	10.999	0.2017
	Loose	6 (4.0)	6 (4.0)	6 (4.0)		
	Polled	27 (18.0)	25 (16.7)	22 (14.7)		
	Straight	63 (42.0)	56 (37.3)	55 (36.7)		
	Stump	7 (4.7)	8 (5.3)	20 (13.3)		
HO	Downward	25 (16.7)	27 (18)	27 (18)	0.273	0.9915
	Tip point later	59 (39.3)	57(38)	60 (40)		
	Upward	66 (44)	66 (44)	63 (42)		
ES	Rounded	0 (0)	0 (0)	0 (0)	0	0
	Straight edge	0 (0)	150 (100)	150 (100)		
EO	Dropping	5 (3.3)	4 (2.7)	3 (2.0)	0.158	1
	Lateral	145 (96.7)	146 (97.3)	147 (98.0)		
HSize	Large	21 (14.0)	26 (17.3)	25 (16.7)	3.251	0.5167
	Medium	46 (30.7)	39 (26.0)	33 (22.0)		
	Small	83 (55.3)	85 (56.7)	92 (61.3)		
NF	Absent	26 (17.3)	42 (28)	47 (31.3)	19.486	0.0034
	Large	27 (18)	15 (10)	8 (5.3)		
	Medium	62 (41.3)	58 (38.7)	68 (45.3)		
	Small	35 (23.3)	35 (23.3)	27 (18)		
PS	Absent	124 (82.7)	108 (72)	103 (68.7)	15.78	0.015
	Large	6 (4)	6 (4)	15 (10)		
	Medium	6 (4)	18 (12)	11 (7.3)		
	Small	14 (9.3)	18 (12)	21 (14)		
HP	Concave	28 (18.7)	37 (24.7)	34 (22.7)	1.632	0.4423
	Straight	122 (81.3)	113 (75.3)	116 (77.3)		

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Values before brackets are frequencies while those in brackets are percentages; X2 = chi-square; *Significant at p<0.05; ns (not significant); CCP = coat colour pattern, CCT = coat colour type, SC = skin colour, MC = muzzle colour, EC = eyelid colour, HC = horn colour, HShape = Horn shape, HO = horn orientation, ES = ear size, EO = ear orientation, HSize = hump size, NF = navel flap, PS = perpetual sheath, and HP = head profile.

In all three districts, most observations for CCP were plain, followed by spotted and patchy. These results suggest that plain coat colour pattern is the most common attribute for CCP in all three districts. Similar reports were also found by [29] for local cattle in the Babile district, [30] for local cattle in the west Gojjam zone, and [31] for Begait cattle in Tahtay Adiabo district. Coat colour is used in cattle choice, ownership recognition, and calling [32]. The heterogeneity in the coat colour revealed the presence of several ecotypes within the breed, which need advanced research at a molecular level.

In all districts, white and red were the most common attributes for CCT, followed by roan, black, white and gray. The results suggest that white and red are the most common coat colour types. The high coat colour variability observed in the population implies the existence of heterogeneity within the breed. These multiple coat colour and colour pattern variations come from the preferential selection of the farmers toward animals with different coat colour patterns [33] and uncontrolled mating. In all three districts, the majority of observations for skin colour were not pigmented, suggesting that unpigmented SC is the most common attribute.

Muzzle colour: In all three districts, the majority of observations for muzzle colour were not pigmented.

Eyelid colour: In all three districts, the majority of observations for eyelid colour were not pigmented. The current research output agreed with that of [34] who found that most female cattle's muzzle colour was pigmented, followed by non-pigmented, which was noted in both sexes in cattle from Gamo Gofa Zone South West Ethiopia. Presence of horn and horn colour: In all three districts, presence of horn was the most common attribute, followed by absent; while the majority of observations for horn colour were not pigmented. The current result was comparable to Arado cattle breed as indicated by [35], who found in the North- western zone of Tigray region and [36] for the Lidia cattle breed. This may be linked to a breed's character, as well as having an aesthetic appeal for the breed's owners. Horned cattle are visually attractive and may protect themselves and other groups of animals from attackers [37].

Horn shape and orientation: In all three districts, upward was the most common attribute for HO, followed by tip point later and downward; while upward horn orientation was the most common attribute, followed by tip point later and downward.

Ear size and orientation: In all three districts, all observations for ear size were straight edge; while the majority of observations for ear orientation were lateral, followed by dropping. The current research output agreed with those of [38] for Arsi-Bale cattle, [39] for Malle cattle, and [40] for local animal in the Hadiya zone.

Hump size: In all three districts, small hump size was the most common attribute, followed by medium and large. The current observation for hump size was similar to those of [41,42] for Begait cattle. Bulls with humps are well-structured and often moderate in size, while most cows have smaller humps [30,39].

Multivariate Analysis

The measure of eigenvalues indicates the level of categorical information accounted for by each dimension. A higher eigenvalue signifies a larger amount of total variance among the traits on that particular dimension. Typically, the first two or three dimensions possess higher eigenvalues than the remaining dimensions. Table 2 provides the eigenvalues and percentages of variance of the dimensions. Furthermore, a steady decrease in eigenvalues is evident. The first principal axis accounted for 15% of the principal inertia, while the second principal axis accounted for 13%. Collectively, the first two principal axes accounted for 29% of the principal inertia. A similar study conducted by [29] revealed that the first two dimensions explained 18% of the total variations (Table 2).

The MCA map was constructed step wisely. For each of the traits, the MCA was applied, and traits were selected using the squared cosine test. All traits with cos2 > 0.2 in at least one of the three first MCA dimensions were maintained. Figure 2 shows a bi-dimensional graph representing the associations among the categories of the analyzed traits. To examine the association between the districts and qualitative traits, the district was included in the analysis as a supplementary variable.

MCA may be elucidated as a visual depiction that generates a resolution wherein most associated categories are situated nearby while uncorrelated ones are positioned at a distance. Categories that are situated in proximity to the mean value are located closer to the origin of the MCA plot, whereas those that are situated further away are positioned at a greater distance. Thus, the dimensions are construed by the placement of the categories on the map, utilizing their loading over the dimensions as critical indicators.

On the dimensions identified Figure 2, it was observed that the cattle population in the Mayyuu district exhibited a clustering effect, in which the presence of curved horn shape, large hump size, absence of navel flap, and varying sizes of large perpetual sheath were predominant. Conversely, the cattle population in the Kurfa district clustered together having non pigmented skin, muzzle, eyelid and horn colours, polled horn shape, and medium hump size. Similarly, the values associated with the Jarso district were found to cluster together based on the absence of horn, straight horn shape, small hump size, and varying sizes of navel flap. Similar results were found when they reported that Neuquen Criollo breed could be characterized in different ecotypes.

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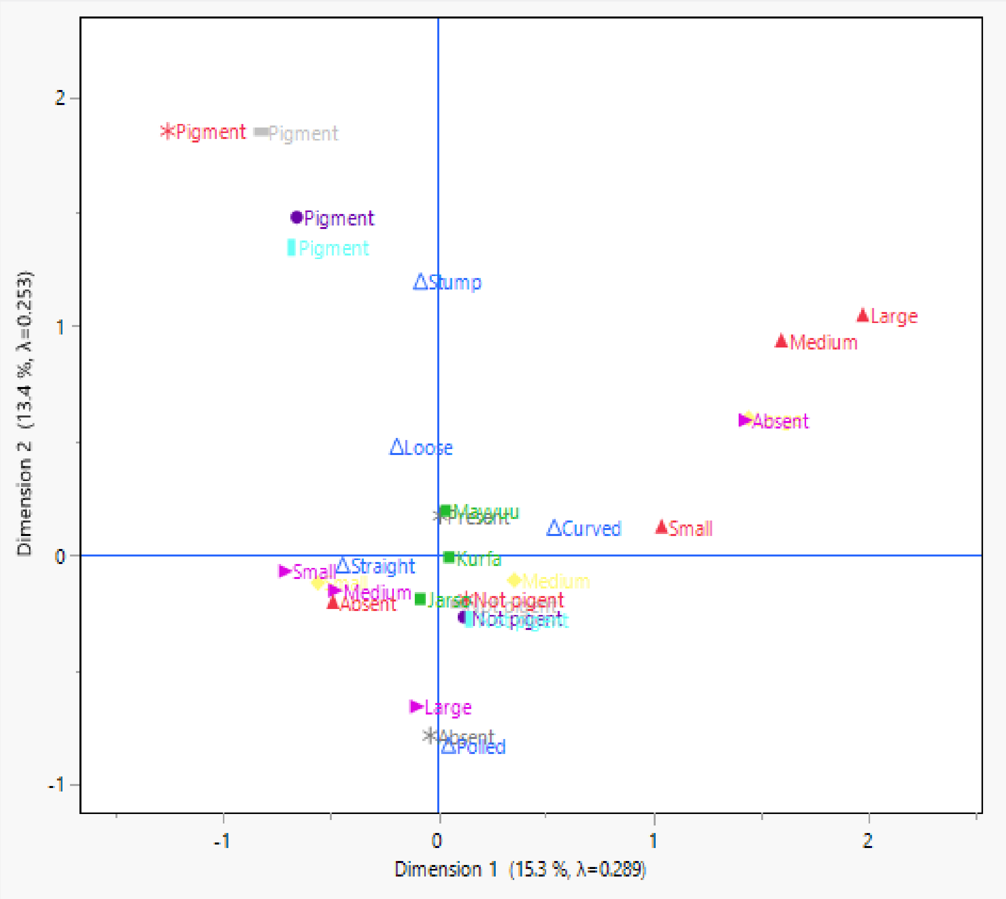

Figure 2: Two-dimensional biplot illustrating the association among qualitative morphological traits. Skin colour, muzzle colour, eyelid colour, horn presence and colour, horn shape, hump size, navel flap presence, perpetual sheath presence and size.

Table 2: Principal inertias (eigenvalues), the percentages and cumulative percentages for all dimensions of the data matrix.

Eigenvalues	Inertia	ChiSquare	%	Cumulative %
0.54	0.29	1732.95	15.29	15.29
0.5	0.25	1515.87	13.37	28.66
0.45	0.2	1217.14	10.74	39.4
0.41	0.17	1009.63	8.91	48.3
0.38	0.14	854.72	7.54	55.84
0.36	0.13	764.04	6.74	62.58
0.34	0.11	679.11	5.99	68.57
0.32	0.1	627.25	5.53	74.11
0.3	0.09	551.03	4.86	78.97
0.3	0.09	522.7	4.61	83.58
0.27	0.07	431.23	3.8	87.38
0.25	0.06	381.37	3.36	90.75

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0.25	0.06	365.83	3.23	93.98
0.24	0.06	352.75	3.11	97.09
0.2	0.04	232.32	2.05	99.14
0.13	0.02	97.88	0.86	100

Conclusion

Overall, these results of this study provided valuable insights into the distribution of qualitative morphological traits in cattle across the three districts. The use of the MCA method resulted in the identification of systematic relationships among traits and trait categories. In addition, it provided a unique and simplified interpretation of large complex data. Specifically, the aptitude of MCA to handle multidimensional data renders it as a valuable tool for investigating the factors that influence qualitative morphological traits. The outcomes of this investigation illuminate the pattern recognition of these traits and indicate the possibility for further research to consider additional traits and extensive datasets.

Conflict of Interest

Authors declare that there is no conflict of interest.

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