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REGULAR ARTICLES

Geographical assessment of body measurements and qualitative traits in West African cattle

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Abstract A total of 1015 adult cows belonging to nine West African cattle breeds were assessed for 16 body measurements and 18 qualitative traits to ascertain the existence of geographical patterns of variation. Sampling was carried out in 29 different provinces of Mali, Burkina Faso and Benin. For body measurements, taurine breeds took lower average values than the zebu breeds. Sanga cattle took intermediate values. Qualitative traits did not allow to differentiate among cattle groups (taurine, zebu or sanga) or breeds. Principal component analysis identified two factors explaining 56.4 and 9.2 % of the variance for body measurements, respectively. Two correspondence analysis dimensions computed on qualitative traits explained a small proportion of the variability (20.8 and 13.5 %, respectively). Contour plots were constructed using the eigenvalues computed for each individual and either factor or dimension identified; confidence regions calculated confirmed that body measurements clearly differentiated zebu and taurine cattle breeds while qualitative traits did not. Factor 1 was projected on a geographical map, using provinces as nodes, to assess breed-free variation for body measurements. A pattern of continuous variation from the Sahel area southwards was identified. Probably, breeding decisions promoting the crosses between zebu-like and taurine cattle are underlying this geographical pattern of variation. The implementation of selection strategies aiming at the increase of the productivity of native West African taurine cattle breeds while avoiding looses in trypanotolerant ability would be highly advisable.

Keywords Linear measurements · Qualitative traits · Cattle breeds · Geographical patterns of variation

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Introduction

There are approximately 33 million heads of cattle in West Africa. Of them, about 23 million heads correspond to humped zebu animals while the rest include a number of humpless taurine populations (Soudré 2011). In this continental region, most cattle production is carried out in the Sahel, the agricultural zone between the Sahara Desert and the coastal rain forests. This area represents a unique geo-climatic territory including very different ecological areas in a few hundred kilometres. In general terms, West Africa can be divided into three agroecological areas: (a) the arid Sahel area, roughly above 13° N latitude, with a maximum annual rainfall of 600 mm and characterised by sparse vegetation; (b) a tropical Sudano-Guinean area, southern 11° N latitude, with annual rainfall between 900 and 1500 mm on average; and (c) a transitional Sudan-Sahel with very variable rainfall (average of 750 mm per year).

Taurine cattle are only majority in the southern tsetse-infested Sudano-Guinean area due to their tolerance to trypanosomiasis (Soudré et al. 2013). The interest of the farmers to increase the size of their taurine cattle has led to an increasing use of Sahelian zebu for reproduction in both the transitional Sudan-Sahel and the southern Sudano-Guinean area. At present, zebu cattle overwhelm taurine cattle in the transitional area (MacHugh et al. 1997; Smetko et al. 2015). Numerous intermediate types are encountered in that Sudan-Sahel area (Soudré 2011).

Breeds are usually considered the operation units for the assessment of livestock diversity. However, definition of native African cattle breeds mainly follows geographic criteria (areas of origin or spreading) or considers the ethnic groups acting as stockbreeders. Moreover, information on African livestock breeds cannot always be easily found (see as an example the DAGRIS database at http://dagris.ilri.cgiar.org; Rege et al. 2007).

The increasing importance of zebu cattle in West Africa is mediated by the action of nomadic Sahelian ethnical groups (such as the Fulani or Peul) over the more temperate zones of southern West Africa in search of grazing lands and has been favoured by the increase of the duration of the dry seasons in West Africa since the 1970s. Evidence of introgression of Sahelian livestock genes southwards has been reported using molecular markers in sheep, goat and cattle (see Álvarez et al. 2009, 2014; Traoré et al. 2009, 2012; and references therein). However, such an issue has not been tested using phenotypic traits in cattle and only to a limited extent in other domestic ruminant species (Traoré et al. 2008a, 2008b).

The aim of the current research was to assess the variation on phenotypic traits among West African cattle and its relationship with geography. Although analyses were also carried out at both the breed and type of cattle levels for descriptive purposes, geographical variation of phenotypic traits was assessed avoiding bias resulting from arbitrary classification of individuals into populations. Assessment is carried out at both the quantitative and qualitative levels. Consequences for management and conservation of West African cattle are discussed.

Materials and methods

A total of 1545 adult female cattle (from 3 to 20 years old) were assessed for 16 body measurements (Table 2) and 18 qualitative traits (Table 3) considering the FAO (2011) guidelines on this issue. Age of the individuals was approached examining dentition. Body measurements were carried out using Lydthin stick, tape measure and Vernier calipre; animals were put on a flat floor and managed by the respective owners. The qualitative traits scored were defined using from 2 to 4 levels each except for horn shape (7 levels) and coat colour pattern (13 levels).

Dataset was edited to ensure that (a) individuals had records for all the traits assessed and (b) assignment of records to breed, sampling location or age of the individuals was not ambiguous. After editing, 1015 adult cows belonging to the Zebu Azawak (29), Borgou (80), Gourounsi (137), Lagunaire (95), Lobi (74), Zebu Mbororo (64), N'Dama (18), Somba (124) and Zebu Peul (394) cattle breeds, sampled in 29 different provinces and 79 different villages of Mali, Burkina Faso and Benin, were available. Sampling was scheduled on a geographic basis, and therefore, individuals belonging to different breeds were sampled regardless of the sampling site or the ethnical group of the owner. A full description of sampling is given in Table 1. From two to five different herds were sampled for each village. Each sampling location was georeferenced using GPS Garmin-50 devices (Garmin Ltd., Olathe, KA). For statistical purposes, cattle were grouped into the following age classes: 3 years old (53 individuals), 4 years old (101), from 5 to 10 years old (637) and older than 10 years (224). Latitude and longitude varied from 6° 3′ N (Benin) to

Table 1 Description of sampling

Breed	Type	Agroecological area	Country	*N*	Provinces	Villages
1. Zebu Azawak	West African zebu	Sahel	Burkina Faso	29	2	5
2. Borgou	Sanga	Sudan-Sahel and Sudano-Guinean	Benin	80	9	11
3. Gourounsi	Sanga	Sudan-Sahel and Sudano-Guinean	Burkina Faso	137	2	6
4. Lagunaire	Humpless shorthorn	Sudano-Guinean	Benin	95	9	10
5. Lobi	Humpless shorthorn	Sudano-Guinean	Burkina Faso	74	1	9
6. Zebu Mbororo	West African zebu	Sahel	Burkina Faso	64	1	5
7. N'Dama	Humpless longhorn	Sudan-Sahel and Sudano-Guinean	Mali	18	2	6
8. Somba	Humpless shorthorn	Sudano-Guinean	Benin	124	1	10
9. Zebu Peul	West African zebu	Sahel	Benin	128	18	20
			Burkina Faso	266	3	15
Totals				1015	29[a]	79[a]

The following information is given per breed: type of cattle into which the breed is classified; countries and the ecological areas in which sampling was carried out; and number of cattle (*N*), provinces and villages involved

[a] Individuals belonging to different breeds could have been sampled in the same province or village

13° 34′ N (Burkina Faso) and from 9° 48′ W (Mali) to 3° 23′ E (Benin), respectively. Roughly a third of the individuals (343) were sampled in the Sahel area, 10 % (99) in the Sudan-Sahel area and the rest in the Sudan-Sahel area.

In any case, the cattle breeds assessed are widely representative of the whole type variation in West African cattle (Table 1). Sample includes *Bos taurus* (longhorn and shorthorn), *Bos indicus* (zebu) and sanga (taurine×zebu crosses) cattle and the main agroecological areas of West Africa. Most breeds sampled are widely distributed throughout West Africa: N'Dama cattle is spread from Guinea to Congo; the main spreading area of zebu Azawak is Eastern Mali and Northern Nigeria; distribution of Borgou cattle includes Benin, Togo and Western Nigeria while that of Lagunaire and Lobi include Togo and Ivory Coast; Mbororo cattle (also known as Red Fulani) is present from eastern Mali, through Niger and northern Nigeria to western Chad and northern Cameroon.

Statistical analyses

Most statistical analyses were carried out using the SAS/STAT package (SAS Institute Inc., Cary, NC). Using PROC GLM of SAS/STAT, least squares means and their corresponding standard errors were computed at the breed level for each body trait via fitting a linear model with the following fixed effects: environmental area (with 3 levels: Sahel, Sudan-Sahel and Sudano-Guinean), age of the individual (4 levels; see above) and breed (9 levels). Relationships among body measurements were summarised via principal component analysis (PCA), using the PROC FACTOR of SAS/STAT, to determine

Table 2 Least squares means (in cm) and their standard errors (in brackets) for the 16 body measurements assessed in West African cattle

Body trait	Zebu Azawak	Borgou	Gourounsi	Lagunaire	Lobi	N'Dama	Zebu Mbororo	Somba	Zebu Peul	Factor 1[a]	Factor 2[b]
N	29	80	137	95	74	18	64	124	394		
Facial length (from orbital fossa to upper lip)	49.3 (0.49)	46.6 (0.38)	43.4 (0.30)	37.9 (0.37)	40.8 (0.41)	40.2 (0.64)	51.6 (0.38)	40.7 (0.37)	48.5 (0.19)	*0.864*	0.344
Facial width (maximum width between facial tuberosities)	26.2 (0.65)	19.6 (0.51)	17.2 (0.4.0)	20.5 (0.49)	17.3 (0.54)	12.9 (0.85)	20.3 (0.50)	15.1 (0.49)	23.1 (0.26)	*0.765*	−0.221
Cranial width (minimum width of the frontal bone)	29.8 (1.18)	24.6 (0.91)	11.2 (0.72)	23.1 (0.87)	12.3 (0.98)	10.0 (1.53)	37.4 (0.89)	18.4 (0.88)	30.5 (0.46)	0.373	*0.652*
Muzzle circumference	39.9 (0.6)	37.4 (0.46)	35.2 (0.37)	33.1 (0.44)	34.9 (0.50)	38.8 (0.77)	38.4 (0.45)	34.6 (0.45)	38.1 (0.23)	0.137	*0.547*
Horn length (greater curvature)	21.7 (1.82)	30.7 (1.41)	18.7 (1.12)	5.2 (1.35)	18.1 (1.51)	33.0 (2.36)	55.5 (1.38)	17.9 (1.36)	37.9 (0.71)	*0.688*	0.469
Ear length	19.5 (0.39)	17.9 (0.31)	14.2 (0.24)	13.1 (0.29)	15.0 (0.33)	12.2 (0.51)	22.1 (0.30)	10.5 (0.29)	19.9 (0.15)	*0.766*	0.297
Height at withers	118.4 (1.21)	112.1 (0.94)	99.0 (0.75)	80.8 (0.90)	91.5 (1.01)	103.7 (1.57)	122.1 (0.92)	95.9 (0.91)	116.6 (0.48)	*0.797*	*0.482*
Heart girth	151.9 (2.05)	142.0 (1.59)	130.4 (1.26)	111.2 (1.52)	128.2 (1.71)	131 (2.66)	154.1 (1.55)	126.8 (1.53)	148.3 (0.80)	*0.635*	0.475
Height at hips (*tuber coxae*)	124.6 (1.29)	117.3 (1.01)	103.8 (0.8)	82.2 (0.96)	96.3 (1.08)	109 (1.68)	129.2 (0.98)	102.2 (0.97)	123.3 (0.51)	*0.827*	0.446
Body length (from lateral tuberosity of the humerus to *tuber ischii*)	127.3 (1.92)	127.0 (1.49)	104.6 (1.18)	101 (1.43)	115.4 (1.6)	116.4 (2.49)	132.9 (1.46)	114.6 (1.44)	127.7 (0.75)	*0.671*	0.345
Thorax depth	57.9 (0.83)	55.0 (0.64)	48.9 (0.51)	43.1 (0.61)	49.2 (0.69)	55.7 (1.07)	59.8 (0.63)	50.3 (0.62)	56.0 (0.32)	*0.518*	*0.526*
Tail length	80.6 (2.03)	88.6 (1.57)	95.6 (1.25)	60.8 (1.51)	79.6 (1.69)	63.0 (2.63)	81.8 (1.54)	61.8 (1.52)	79.1 (0.79)	0.176	−0.020
Shoulder width (between lateral tuberosities of the humerus)	21.3 (0.83)	19.5 (0.64)	15.9 (0.51)	15.9 (0.62)	29.4 (0.69)	22.5 (1.07)	22.3 (0.63)	20.5 (0.62)	20.8 (0.32)	0.113	*0.487*
Pelvic width (between *tuber ischii*)	35.3 (0.74)	33.3 (0.57)	28.1 (0.46)	24.9 (0.55)	31.4 (0.62)	29.6 (0.96)	35.9 (0.56)	29.8 (0.55)	33.5 (0.29)	0.181	*0.765*
Ischium width (between *tuber ischii*)	16.5 (0.45)	13.9 (0.35)	13.1 (0.27)	10.4 (0.33)	12.6 (0.37)	13.2 (0.58)	17.4 (0.34)	13.2 (0.33)	16.4 (0.17)	*0.610*	0.461
Rump length (from *tuber coxae* to *tuber ischii*)	41.4 (0.62)	37.5 (0.48)	37.4 (0.38)	30.3 (0.46)	36.7 (0.52)	36.8 (0.80)	43.2 (0.47)	38.8 (0.46)	40.6 (0.24)	*0.864*	0.344

Results and sample size (*N*) are given per breed. Eigenvectors computed for the two factors indentified using principal component analysis are also given. Eigenvectors higher than |0.480| are in italics

[a] Eigenvalue=8.462; proportion of the total variance explained=56.4 %

[b] Eigenvalue=1.377; proportion of the total variance explained=9.2 %

Table 3 Frequencies (in percentage) of each level of the qualitative traits assessed in West African cattle per type (sanga, taurine and zebu) of cattle

Qualitative trait	Code	Definition	Cattle type			Correspondence analysis	
			Sanga (217)	Taurine (487)	Zebu (311)	Dimension 1	Dimension 2
Cephalic profile[ns]	1	Concave	2.8	2.3	1.8	0.423	0.514
	2	Convex			5.4	*1.917*	−0.117
	3	Straight	97.2	97.7	92.5	−0.063	−0.008
Ear shape[ns]	1	Horizontal	100.0	99.7	99.8	0.000	0.001
	2	Drop		0.3	0.2	0.209	−0.600
Muzzle pigmentation	1	Pigmented	95.4	93.7	71.9	−0.346	0.096
	2	Not pigmented	4.6	6.3	28.1	*1.736*	−0.480
Eyelid pigmentation	1	Pigmented	94.9	95.4	71.3	−0.346	0.085
	2	Not pigmented	5.1	4.6	28.7	*1.751*	−0.428
Hoof pigmentation	1	Pigmented	96.8	97.7	86.8	−0.171	0.036
	2	Not pigmented	3.2	2.3	13.3	*2.008*	−0.420
Horn colour[ns]	1	Black	15.2	33.8	14.1	−0.503	−0.201
	2	Grey	2.8	2.7	5.0	0.536	0.119
	3	Brown	54.4	40.1	52.4	0.143	−0.499
	4	Two coloured	27.7	23.5	28.5	0.039	1.048
Dewlap size	1	Well developed	17.1	1.0	12.1	0.315	*1.602*
	2	Poorly developed	12.4	21.5	50.0	0.479	0.025
	3	Small	70.5	77.5	38.0	−0.338	−0.293
Hump position	0	Absence	65.9	100.0	1.6	−0.643	−0.397
	1	Cervicothoracic	1.4		62.7	0.719	−0.423
	2	Thoracic	32.7		35.7	0.261	1.259
Backline	1	Straight	100.0	100.0	96.6	−0.037	0.003
	2	Concave			1.2	*1.904*	−0.461
	3	Convex			2.2	*2.361*	−0.014
Horn shape	0	Polled	0.5			−0.616	*−1.809*
	1	Cup	40.6	43.7	14.7	−0.516	−0.390
	2	Crescent	21.7	32.8	39.2	0.112	−0.022
	3	Lyre	19.8	1.0	31.3	0.823	1.055
	4	Wheel	13.4	7.3	1.4	−0.592	−0.393
	5	Crown	4.6	15.6	13.1	−0.140	−0.434
	6	Spirale	0.9			*−1.318*	*−1.361*
	7	Backwards	0.5		0.4	*1.780*	*−1.948*
Spotting pattern	1	Absence	44.7	29.5	52.6	0.438	−0.139
	2	Pied	17.1	19.5	15.7	−0.244	0.105
	3	Spotted	38.3	51.0	31.7	−0.390	0.111
Coat colour pattern	1	Black	15.2	15.9	4.4	−0.498	−0.627
	2	Black-pied	21.2	38.1	21.3	−0.626	0.341
	3	White	20.7	3.6	11.5	0.587	1.275
	4	Red	1.8	1.3	1.4	−0.427	0.321
	5	Red-pied	5.5	6.0	9.2	0.223	−0.213
	6	Roan	5.5	1.7	1.4	−0.447	−0.303
	7	Fawn	6.9	9.9	0.8	−0.176	−1.024
	8	Diluted fawn	7.4	4.6	11.2	0.413	0.331
	9	Grey	11.1		9.6	−0.089	−0.520
	10	Blond	2.8		0.4	0.623	−0.757
	11	Fawn-blond		6.6	14.3	0.831	−0.687

Table 3 (continued)

Qualitative trait	Code	Definition	Cattle type			Correspondence analysis	
			Sanga (217)	Taurine (487)	Zebu (311)	Dimension 1	Dimension 2
	12	Dun-red	1.4	8.6	7.8	0.218	−0.093
	13	Fawn-red	0.5	3.6	6.6	0.807	−0.399
Sooty pattern^{ns}	0	Absence	58.1	44.7	47.6	0.270	0.208
	1	Light	23.0	21.2	39.2	0.085	−0.148
	2	Apparent	7.8	9.9	9.4	−0.526	−0.225
	3	Strong	11.1	24.2	3.8	−0.958	−0.316
Brindle	0	Absence	71.4	67.9	84.9	0.144	−0.141
	1	Light	12.9	14.6	9.2	−0.330	0.182
	2	Apparent	6.9	11.6	4.0	−0.632	0.544
	3	Strong	8.8	6.0	1.8	−0.644	1.115
Dorsal stripe	0	Absence	92.6	88.1	98.2	0.060	0.018
	1	Black	5.5	5.3	1.0	−0.951	−0.683
	2	Presence	1.8	6.6	0.8	−0.933	0.198
Black hair in legs	1	Presence	63.6	76.8	55.6	−0.354	−0.223
	2	Absence	36.4	23.2	44.4	0.619	0.390
Coloured belly	1	Presence	45.2	52.0	18.5	−0.524	0.461
	2	Absence	54.8	48.0	81.5	0.271	−0.239
White blaze^{ns}	1	Presence	15.7	19.9	13.3	−0.588	0.343
	2	Absence	84.3	80.1	86.8	0.110	−0.064

Sample size is given in brackets. Eigenvectors computed for the two dimensions identified via correspondence analysis for each level of either the assessed traits are also given. Eigenvalues higher than |1.30| are in italics. Dimension 1 explains 20.8 % of the total variability. Dimension 2 explains 13.5 % of the total variability. Chi-square Mantel-Haenszel test showed that incidence of all the analysed traits varied significantly among cattle types for $p<0.001$ except for those traits labelled with ns as superscript

the number of independent traits that account for most of the phenotypic variation in body measurements. This analysis was computed from the correlation matrix among measurements to ensure that all traits were treated as equally important, giving the same weight to the variables regardless of their own variance. A VARIMAX rotation was applied to the retained components in order to obtain factor pattern coefficients considerably less correlated than the original body measurements. Only factors accounting for more variation than any individual type trait (eigenvalue >1) were retained.

Frequencies of each level of the qualitative traits analysed were computed using the PROC FREQ of SAS/STAT. A chi-square Mantel-Haenszel test was applied on the computed frequencies. The association between the qualitative traits was assessed via correspondence analysis using the PROC CORRESP of SAS/STAT. Two dimensions (and their correspondent eigenvectors) were computed to account for the greatest proportion of the chi-square for association between the categories of the qualitative traits scored.

Information provided by the principal component and correspondence analyses were summarised constructing contour plots with 75 % confidence region of the among individuals using the eigenvectors computed for each individual and the library ggplot2 of R (http://CRAN.R-project.org/).

Geographic-based analyses

Latitude and longitude coordinates corresponding to each individual assessed were averaged by province to estimate geographic *midpoints* or nodes for sampling. Furthermore, eigenvalues corresponding to each sampled individual for the factors and correspondence analysis dimensions retained explaining most of the variability were averaged by province as well. Such average values were used to construct interpolation maps drawn using the Spatial Analyst Extension of ArcView, available at www.esri.com/software/arcview/. The inverse distance weighted (IDW) option with a power of 2 was selected for the interpolation of the surface. IDW assumes that each input point has a local influence that diminishes with distance. The area of sampling of each breed was used as geographic coordinates, and the six nearest neighbours were used for the calculation. Interpolation surfaces were divided into five equal classes.

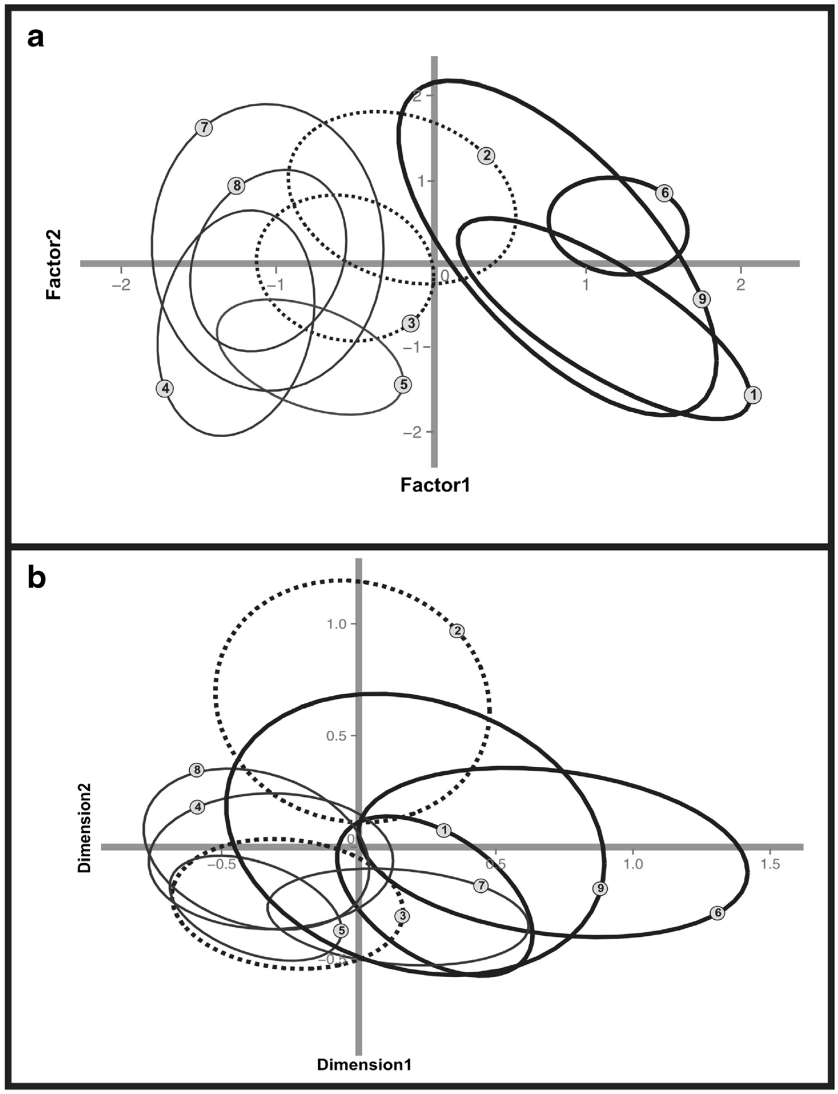

Fig. 1 Contour plots showing the 75 % confidence region of the relationships among the analysed individuals per breed. Plot **a** shows the information provided by the principal component analysis carried out on body measurements: Factor 1, on the *X*-axis, explained 56.4 % of the total variance while factor 2, on the *Y*-axis, explained 9.2 % of the total variance. Plot **b** shows the information provided by the correspondence analysis carried out on qualitative traits: Dimension 1, on the *X*-axis, explained 20.8 % of the total variance while dimension 2, on the *Y*-axis, explained 13.5 % of the total variance. *Thin line contours* correspond to taurine breeds; *dotted line contours* correspond to sanga breeds; and *thick line contours* correspond to zebu breeds. Numbers on contours mean the following: *1* Zebu Azawak; *2* Borgou; *3* Gourounsi; *4* Lagunaire; *5* Lobi; *6* Zebu Mbororo; *7* N'Dama; *8* Somba; and *9* Zebu Peul

Results

Table 2 gives least squares mean estimates for the 16 body measurements analysed per cattle breed. Note that the estimates given are corrected for the influence of the other fixed effects included in the model fitted. In general, estimates for taurine breeds were smaller than those computed for the zebu breeds, with the sanga cattle taking intermediate values between these two main strains of West African cattle. As an example, height at withers (in cm) varied from 80.8±0.90 (Lagunaire) to 103.7±1.57 (N'Dama) in taurine cattle; from 116.6±0.48 (Zebu Peul) to 122.1±0.92 (Zebu Mbororo) in zebu cattle; and from 99.0±0.75 (Gourounsi) to 112.1±0.94 (Borgou) in sanga cattle. This trend was the same for the main body measurements such as hip height, body length, thorax depth or pelvic width. Estimates obtained for the 16 body measurements analysed per class of age of the individual are given in Table S1.

Table 3 summarises the frequency of apparition of the qualitative traits scored per type of cattle (taurine, zebu and sanga). The same information is given at the breed level as Supplementary material (Table S2). Most features scored were present in the three cattle types (and breeds) suggesting no population selection for qualitative traits in West African cattle. Only the most characteristic traits distinguishing between zebu and taurine cattle such as convex cephalic profile or presence/absence of hump had clearly different frequencies between cattle types.

PCA allowed to identify two factors with an eigenvalue >1 (Table 2). Factor 1 explained 56.4 % of the variance for body measurements in West African cattle while factor 2 gathered a small proportion (9.2 %) of the variability. Factor 1 clearly summarised the information provided by those traits characterising the size of the individuals. Less representative, factor 2 tended to summarise the width of the thorax and the abdomen of the individuals. Traits such as cranial width,

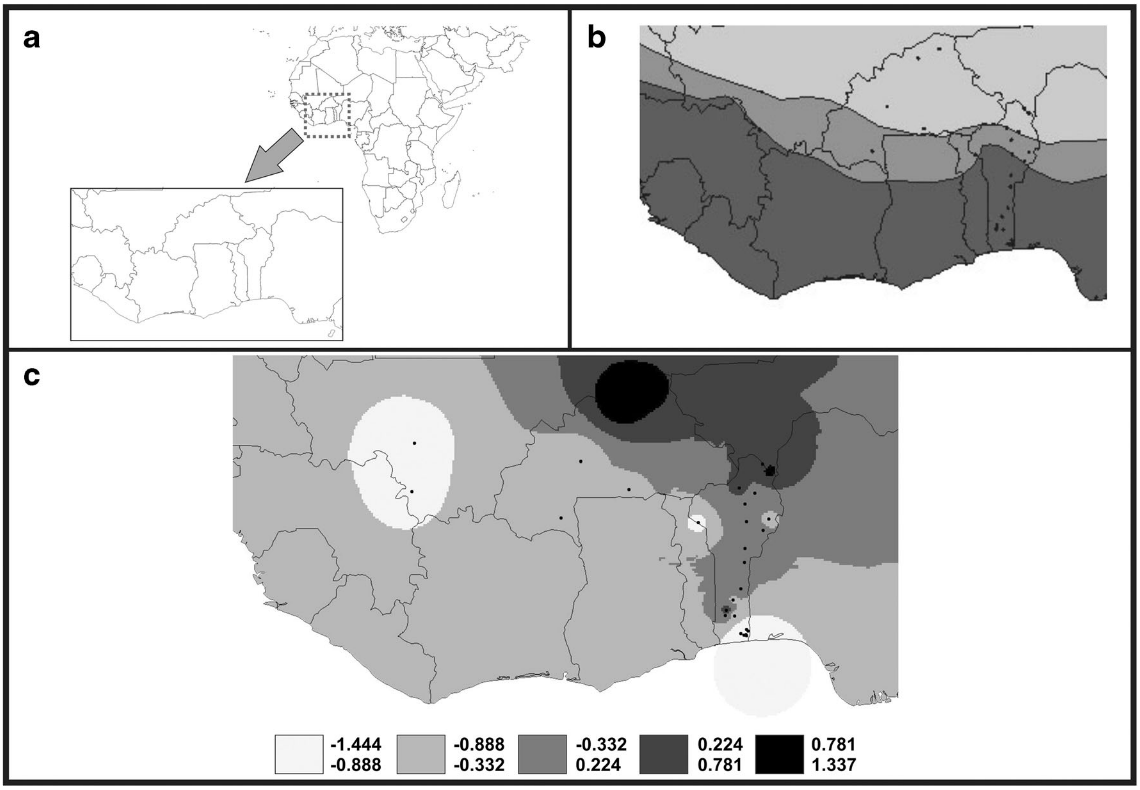

Fig. 2 Sampling area (**a**), locations of the provinces in which cattle were sampled together with the limits of the three main environmental areas of West Africa (Sahel, in the North, Sudano-Guinean in the South and central Sudan-Sahel area; **b**) and synthetic map illustrating geographical variation of the first principal component (**c**) identified using principal component analyses (PCA)

shoulder width and pelvic width were the most important for the computation of that factor (Table 2).

As a consequence of the high variability found, the two dimensions identified using correspondence analysis gathered a small proportion of the variability of the dataset for qualitative traits. Dimensions 1 and 2 explained 20.8 and 13.5 % of the total variability, respectively. A dispersion plot (not shown) constructed using the two correspondence dimensions retained informed that no differentiation existed among levels of the qualitative traits assessed.

The solutions provided by both the PCA and the correspondence analysis at the individual level were plotted in a two-dimensional space and summarised per cattle breed (Fig. 1). Figure 1a shows a clear differentiation, on the *X*-axis, between zebu and taurine cattle, while the sanga cattle breeds tended to have intermediate positions. On the contrary, no clear differentiation could be assessed between cattle breeds using qualitative trait information (Fig. 1b). The 75 % confidence regions computed for each breed were intermingled even if cattle type is considered.

Factor 1 was projected on a geographical map to give breed-free information on the variation in body measurements in West African cattle (Fig. 2). While the higher scores for factor 1 were found in the Sahel area (darker spots in Fig. 2c) and the lower scores (white spots) were located at the provinces in which taurine cattle is more frequent, there was a clear pattern of variation related with body size from the Sahel area southwards. This pattern was independent on the environmental area in which sampling was done. Consistently with the lack of differentiation assessed for qualitative traits (Table 3; Fig. 1b), no geographical pattern of variation could be identified for correspondence analysis dimension 1 (see Supplementary Figure S1).

Discussion

Even though assessment of morphological traits are relatively common in small ruminants (see as an example Legaz et al. 2011 and references therein), such kind of research is less frequent in cattle and mainly aiming at the ascertainment of the relationships between body measurements and performance (Mwacharo et al. 2006; Lesosky et al. 2013). The main goal of the current research is different: both body measurements and qualitative traits are analysed to assess if they follow any geographical pattern in the breeding scenario of West Africa in which no selection programmes exist and unsupervised matings are the rule.

The cattle populations analysed are breeds sensu FAO (2000): a homogenous, subspecific group of domestic livestock with definable and identifiable external characteristics that enable it to be separated by visual appraisal from other similarly defined groups within the same species. However, the current analysis clearly informs on the fact that visual differentiation of breeds rely upon body measurements rather than on qualitative traits (Fig. 1). Definition of cattle breeds in developed countries pay much attention to qualitative traits, namely coat colour and horn shape. However, variation for such traits in Africa depends on geographical and climatic features and is reinforced by local preferences of the stock keepers (Desta et al. 2011). This is clearly reflected in a lack of differentiation between cattle groups or breeds at the qualitative trait level even when cattle types (zebu and taurine), which are differentiated by the existence of hump or not, are considered (Table 3 and Table S1; Fig. 1b). Furthermore, geographical (breed-free) analyses illustrated that variation of qualitative traits in West African cattle mainly depends on local events (Figure S1).

Regarding body measurements, the assessed breeds showed clear differences for most analysed traits (Table 2). In any case, the current analysis highlights that body measurements reflect to a greater extent the differences between cattle groups (Fig. 1a). The main cattle types analysed in the current study (taurine and zebu) are expected to derive from independent domestication events (Chen et al. 2010; Pérez-Pardal et al. 2010a, 2010b) and show large morphological differences: native humpless West African cattle are small sized and even dwarf while West Africa zebu is always humped and larger. Since these two cattle types are expected to be bred in separated agroecological areas (the northerner Sahel for zebu and the southerner Sudano-Guinean area for taurine cattle), the current dataset is likely to be useful to assess geographical differences among cattle populations in West Africa.

Interestingly enough, the current analysis has identified a clear geographical pattern of variation for body size in West African cattle (Fig. 2). Even though the academic separation of cattle types into different West African ecological areas would lead to expect a geographical discontinuity, the pattern identified clearly points out to a continuous variation. To our knowledge, this is the first time in which such pattern of variation is reported. Studies aiming at the assessment of geographical differentiation of West African livestock populations carried out using neutral molecular markers reported that the identification of patterns of genetic variation is difficult due to the lack of selection and high levels of gene flow due to transhumance and extensive commercial trade (Traoré et al. 2012; Álvarez et al. 2014). Furthermore, the gene flow among livestock populations in West Africa does not follow a simple pattern according to latitude, but it is affected by local environmental conditions (namely those favouring the presence of tsetse flies) and human action (Traoré et al. 2012; Álvarez et al. 2014).

The current results suggest that human action is underlying the continuous variation of body size identified in West African cattle. Although native West African taurine cattle can tolerate trypanosome challenge, their small size limits their productivity and ability for draft purposes. The increase of the duration of the dry seasons in West Africa since the 1970s together with the deforestation and uncontrolled use of chemical trypanocidal prophylaxis have allowed an increasing use of zebu and zebu-like individuals for reproduction on taurine cattle to substantially improve productivity in the whole agricultural West African system. Nevertheless, cross between trypanosusceptible and trypanotolerant cattle have been experimentally shown to affect the ability to tolerate trypanosome challenge (Orenge et al. 2012). Trypanotolerance is a heritable trait resulting from a unique process of natural adaptation to challenging environmental conditions. The current study points to a possible dilution of trypanotolerant ability in West African cattle through unsupervised crossbreeding (Álvarez et al. 2015). The implementation of conservation and selection strategies aiming at the increase of the productivity of native West African taurine cattle breeds while avoiding loses in trypanotolerant ability would be highly advisable.

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Statement of animal rights No ethics statement was required for data collection. Body measurements and trait scores were obtained from different technicians visiting farms with the permission of the owners. Animals were managed by the owners.

Conflict of interest The authors declare that they have no competing interests.

Informed consent Informed consent was obtained from all the owners of the animals scored.

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