



Original Research Paper

Typology of Muturu cattle farming system in southern Benin and implications for the conservation of the breed

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Abstract

Muturu cattle, a trypanotolerant indigenous breed native to the wetland ecosystems of southern Benin, represent a unique and threatened animal genetic resource. Despite their ecological resilience and socioeconomic importance, knowledge of production system diversity across their full distribution range remains limited, hindering effective conservation planning. This study established a typology of Muturu farming systems in Southern Benin. A cross-sectional survey was conducted among 58 herders across the Atlantique, Ouémé, and Zou departments. Data on herd structure, management, and constraints were analyzed using Multiple Correspondence Analysis (MCA) and Hierarchical Ascending Clustering (HAC). Three distinct clusters were identified. Cluster 1 (n=25), Ouémé comprised small-herd, sedentary and semi-sedentary systems practicing controlled mating and relying primarily on vaccination. Cluster 2 (n=32), Atlantique involved semi-sedentary wetland management with a heavy reliance on agricultural by-products and limited mating control. Cluster 3 (n=1), Zou represented a single institutional ranch managing 147 animals. Allele-specific PCR diagnostics confirmed the breed's genetic status, revealing successful *MSTN^{del16}* taurine amplification in 165 individuals, while 5 individuals exhibited simultaneous amplification with the *MSTN^{ins16}* zebu marker, confirming active genetic introgression. Structurally, Cluster 1 faces severe inbreeding risks due to small effective sizes, whereas Cluster 2 is highly vulnerable to genetic dilution from uncontrolled communal mating. Consequently, Muturu conservation requires targeted micro-regional policies, including community-based bull rotation networks for smallholders and utilizing the state ranch as an open nucleus herd for purebred genetic distribution.

Keywords: Muturu cattle; farming system typology; conservation; indigenous breeds; Benin

Introduction

West African indigenous livestock breeds constitute an irreplaceable reservoir of genetic diversity, forged by millennia of both natural and anthropogenic selection within demanding tropical environments. However, a significant number of these breeds are currently categorized as endangered or at risk due to rapid population declines driven by the dual pressures of indiscriminate crossbreeding

and expanding production system intensification (FAO, 2015). Within Benin, the livestock sector significantly bolsters the national economy, generating approximately 13% of the agricultural Gross Domestic Product (GDP), with the total value of the national herd estimated at 242 billion CFA francs (DSA, 2020). Cattle production is especially critical for national food security, supplying 39.8% of the country's total meat consumption (DSA, 2024). While cattle husbandry in northern Benin is dominated by Sahelian breeds managed under mobile, transhumant systems, the southern region relies on indigenous taurine and composite breeds reared within extensive, low-input operations (Sounon et al., 2019). Among these local resources, the indigenous Muturu cattle breed is highly distinguished by its exceptional bioclimatic adaptation to humid wetland and lacustrine ecosystems. Despite its modest growth performance, this breed holds profound socio-economic value for local communities, and its beef is highly prized by consumers (Kassa et al., 2016).

Nevertheless, the breed currently faces escalating threats, primarily driven by the progressive encroachment on traditional grazing areas and a high risk of cryptic genetic dilution through uncontrolled crossbreeding with exotic and other local populations (Adoligbe et al., 2020). These mounting environmental and structural pressures underscore the urgent need to design evidence-based conservation strategies grounded in a comprehensive understanding of existing production dynamics.

Safeguarding local animal genetic resources is paramount not only to preserve global biodiversity but also to secure sustainable, climate-resilient livestock production networks. These unique genetic lineages represent a non-renewable heritage that, once lost, cannot be recovered (Naves et al., 2011). Achieving effective conservation, however, requires insights that extend beyond mere biological characterization. It demands a thorough assessment of the farming systems in which these animals are embedded, including localized management choices, ecological constraints, and the socioeconomic motivations of the herders. In this regard, farm typology analysis serves as a powerful methodological framework, enabling the identification of homogeneous producer cohorts to effectively target with tailored technical and policy interventions (Vall et al., 2023).

To date, research on Muturu cattle in Benin has remained geographically fragmented, focusing almost exclusively on the lakeside municipalities of Aguégoués and Sô-Ava. These pioneering studies identified three primary categories of herders differentiated by their housing infrastructure, feeding regimes, animal health protocols, and ethnic backgrounds (Tobada et al., 2018; Dotché et al., 2025). While these investigations provided valuable localized insights, they failed to capture the full geographic distribution range of the breed in southern Benin, nor did they evaluate production system diversity across contrasting agro-ecological zones. Consequently, a comprehensive typology of Muturu cattle farming systems encompassing the breed's entire southern distribution remains unestablished. To address this critical knowledge gap, the present study aimed to establish a robust typology of Muturu production systems across its entire southern Beninese distribution and to analyze the specific implications of each identified system for the conservation and sustainable utilization of this endangered breed. The resulting insights are intended to inform targeted policy designs, guide community-based breeding programs, and prioritize management support for smallholders most vulnerable to genetic erosion.

Materials and Methods

Study Area

The study was conducted in southern Benin across three major departments: Ouémé, Atlantique, and Zou, which together constitute the core geographical distribution area of Muturu cattle in Benin (Figure 1). Data were collected in the municipalities of Akpro-Misséréké, Avrankou, and Adjarra within the Ouémé department; Abomey-Calavi and Sô-Ava within the Atlantique department; and Zangnanado, specifically at the Samiondji State Farm within the Zou department. The study area is characterized by a sub-equatorial climate with a bimodal rainfall pattern, consisting of two rainy seasons (April–July and September–October) and two dry seasons (November–March and a shorter dry spell in August) (DGEC, 2022). This climatic regime strongly influences pasture availability, water resources, and herd management practices, particularly in low-input extensive systems.

In the Ouémé department, temperatures range from 25°C to 30°C, with rainfall varying between 900 mm and 1500 mm. This zone is hydrographically influenced by the Ouémé River, Lake Nokoué, and the Porto-Novo lagoon. This environment yields diverse vegetation characteristic of the agro-ecological zones of low-lying floodplains and deltaic fisheries (DGCS-ODD, 2019).

In the Atlantique department, the average annual rainfall is approximately 1,200 mm, with temperatures fluctuating between a minimum of 22°C and a maximum of 33°C. The Atlantique department is largely deforested, and the original equatorial forest now exists only in small, fragmented relict patches of negligible extent (LECREDE, 2006).

The Zou department forms a plateau landscape with an altitude ranging from 200 to 300 meters. Here, the average annual rainfall varies between 900 mm and 1200 mm. The vegetation is dominated by natural oil palm groves (*Elaeis guineensis*) and grasses, interspersed with scattered patches of classified or sacred forests (DGCS-ODD, 2019).

The selection of these study sites was purposive and guided by both empirical evidence and institutional expertise. Specifically, these locations were chosen based on their documented importance in Muturu cattle production, as highlighted in previous studies (Koudandé et al., 2009; Adoligbe et al., 2020; Adoligbe et al., 2022), and through close consultation with Communal Extension Cells (CeC) of the Territorial Agricultural Development Agencies (ATDA). This combined approach ensured the inclusion of production zones that are highly representative of the contrasting ecological environments in which Muturu cattle are raised across southern Benin.

Survey Method

Ethics and authorizations

All study procedures were reviewed and approved by the Institutional Ethics Committee of the Polytechnic School of Abomey-Calavi, University of Abomey-Calavi (Approval No. 008-2025/EPAC/LARBA/URMAT/CE/R). Prior to data collection, institutional authorization was obtained from the Ministry of Agriculture, Livestock, and Fisheries (MAEP). Before each interview, the purpose of the study was explained to all participants in their preferred language (French or local vernacular), and verbal informed consent was obtained from each herder. Participation was entirely voluntary, and no incentive was provided.

Survey design and specie specificity verification

A cross-sectional survey was conducted between July and November 2024, covering the departments of Ouémé, Atlantique, and Zou. Data were collected through structured face-to-face interviews with cattle herders, complemented by direct on-farm observation of herds and production units. Interviews were conducted in French or translated into local languages (Fon, Goun) by trained bilingual enumerators where necessary.

Because no exhaustive national or local registry of Muturu cattle herders existed at the time of the study, a random sampling strategy was methodologically unfeasible. The Muturu is a critically threatened, rare indigenous breed with small, highly fragmented populations scattered across remote wetland zones. To overcome these challenges, a purposive snowball sampling approach was adopted. Initial seed respondents were strategically established through Communal Extension Cells (CeC). While the absolute sample size is 58 herders, this cohort captures nearly the entire remaining population of single-breed Muturu keepers within the target departments, offering high qualitative representativeness of the active traditional production matrix in southern Benin.

To minimize the risk of genetic introgression in the sampled population, a rigorous multi-stage phenotypic validation protocol combined with molecular tools was applied. First, zootechnicians cross-referenced animals against canonical FAO and Rege morphological standards for West African Shorthorn taurines (Muturu): a compact body frame, exceptionally short horns with a brachyceros profile, a deep dewlap, and a solid black or deep dark-red coat. Second, strict exclusion criteria were applied: any herd containing animals displaying zebu phenotypic markers such as a thoracic hump, drooping ears, or elongated horns was excluded from the study. Third, species discrimination and genetic purity assessment were performed using species-specific short InDel regions. The *MSTNdel16* locus for *Bos taurus* and the *MSTNins16* *Bos indicus* locus were amplified and analyzed using

Deoxyribonucleic acid (DNA) from 170 individuals by Allele-Specific Polymerase Chain Reaction (AS-PCR), as described by Cosenza et al. (2025).

Data collection

A structured questionnaire was developed based on FAO guidelines for livestock diversity surveys (FAO, 2012) and validated through a pilot test conducted with five herders not included in the main survey. The questionnaire was digitized using the KoboCollect platform, enabling real-time data entry, automatic range checks, and GPS recording of farm locations.

The questionnaire was organized into six thematic modules: (i) Sociodemographic characteristics : household size and composition, ethnic group, gender, age, and education level of the herd owner; (ii) Production objectives: reasons for livestock keeping, kinship relationships to animals, and market orientation; (iii) Herd structure and management: herd size and composition, production system type, housing practices, and animal mobility; (iv) Feeding and watering: feed types and supplements used, water sources, and seasonal variation in watering practices; (v) Reproduction and genetics: mating practices, origin and selection criteria of breeding males, calving periods, and within-herd parentage relationships; (vi) Health and constraints: frequency and type of veterinary care, most common disease symptoms, and main constraints limiting production.

Statistical Analysis

All data collected via KoboCollect were exported in CSV format and processed in R version 4.3.2 (R Core Team, 2023). The analysis comprised three sequential steps: descriptive statistics, multivariate dimensionality reduction, and hierarchical clustering.

Descriptive statistics

Qualitative variables were summarized as absolute frequencies and relative proportions. To assess statistically significant differences in the distribution of categorical variables across departments, pairwise comparisons of proportions were performed using the `pairwise.prop.test` function. A significance threshold of $\alpha = 0.05$ was applied throughout.

Multivariate dimensionality reduction.

The optimal number of clusters was determined using the Hierarchical Ascending Classification (HAC) algorithm applied to the principal coordinates of the MCA. The final selection of three clusters was guided by the knee criterion (inflection point) calculated from the inter-cluster inertia gain curve. The three-cluster solution marks the exact mathematical threshold where adding an additional cluster yields a negligible reduction in total within-cluster variance, maximizing both statistical parsimony and ecological interpretability

Cluster characterization.

Following hierarchical clustering, a test value (v-test) was applied to assess the association between variable modalities and the identified clusters. This test enable the identification of statistically significant modalities ($p < 0.05$) that characterize and define the clusters or typologies. Graphical outputs were generated using the R package "factoextra" (Kassambara & Mundt, 2020). The codes for the various modalities used to classify the farms are described in the table1.

Results

Sociodemographic characteristics of respondents

A total of 58 Muturu cattle herders were surveyed across the three study departments: Ouémé (n=25; 43.1%), Atlantique (n=32; 55.2%), and Zou (n=1; 1.7%). Cattle ownership was almost exclusively male (98.27%), with only one female herder recorded (Table 2). Most surveyed farms (75.86%) belonged to households comprising between 5 and 10 members.

Reasons and objectives for livestock keeping

Herders reported multiple, overlapping reasons for keeping Muturu cattle (Table 3). Regarding breed preference, hardiness was cited by all respondents (100%). In terms of production objectives, income generation was the dominant motivation (94.83%), confirming the primarily commercial orientation of Muturu cattle keeping in southern Benin. Secondary objectives included use as draught labor (13.79%), soil fertilization through manure (10.34%), and participation in traditional ceremonies (10.34%).

Herd characteristics

A total of 422 animals were counted across the 58 visited farms, giving a mean herd size of 7.3 animals per farm. The vast majority of herders (91.37%) maintained small herds of 1 to 10 animals, with only three farms exceeding 20 head (Table 4). Female animals dominated the herds (82.94%; n=350 out of 422), a sex ratio consistent with a breeding-oriented production system in which cows are retained for reproduction and calves while males are more rapidly sold or slaughtered. There were no herds in the range of 20 to 30 animals.

Muturu cattle farming system

Three production systems were identified among the surveyed herders (Table 5, Figure 2). The sedentary system was the most prevalent (62.06%; n=36), characterised by animals kept permanently near the homestead with no seasonal movement. The semi-sedentary system was practised by 36.20% of herders (n=21), involving daily guided movement to pasture under a herdsman's supervision. The ranching system was represented by a single farm (1.72%), operating on enclosed improved pastures with organized feeding and health infrastructure.

Feeding, watering, and habitat management

Boreholes constituted the primary source of water for Muturu cattle (79.31%), followed equally by rivers and lakes (44.82% each), tap water (31.03%), and collected rainwater or dams (Table 6). During the rainy season, watering methods were evenly split between directing animals to the water source and supplying water directly to them, though no statistically significant difference between watering methods was found ($p=0.353$). Regarding feeding practices, herders relied mainly on natural grazing (100%), supplemented with agricultural byproducts (79.31%), hay (74.14%), and crop residues (68.96%). Cultivated pastures and concentrate feeds were used only marginally. Furthermore, the absence of dedicated housing was the norm (87.93%), with animals typically spending nights tethered or corralled in open courtyards near the homestead.

Reproduction management

Mating was controlled by 63.79% of herders, while 36.21% allowed uncontrolled mating (Table 7). Calving occurred throughout the year in the majority of herds (96.55%). Formal selection of breeding males was practised by few herders (29.31%). In descending order, the selection criteria cited were: body conformation (27.87%), mating performance (26.23%), coat color (24.59%), body size (18.03%), and temperament (3.28%), none of which differ significantly from one another ($p=0.004$). Among herders practising male selection, the breeding bull was most commonly borrowed (52.94%).

Pedigree and lineage identification

Table 8 presents the kinship relationships identified within the visited herds. On many of the farms visited, close inbreeding relationships were documented. Father-daughter and brother-sister pairings were each identified in 44.82% of herds, mother-son relationships in 39.65%, and half-sibling pairings in 36.20%. The distribution of relationship types did not differ significantly from one another ($p=0.284$), indicating that no single inbreeding type was markedly more prevalent than others. Herders typically distinguished animals primarily through morphological markers: coat color and body conformation (86.20% each), body markings (77.58%), and maternal lineage (74.13%).

Biosecurity measures and common symptoms observed in cases of disease

Veterinary health practices and commonly observed disease symptoms are presented in Table 9. Most farms implemented both preventive and curative health measures, including vaccination (70.68%) as well as internal and external deworming (56.89% and 50%, respectively). The differences in frequency among these three health measure type were not statistically significant ($p=0.069$), indicating a broadly comparable level of adoption.

Despite these measures, disease events were still reported on several farms across the study area. The most frequently observed symptoms were diarrhea (46.55%), general weakness (44.82%), and weight loss (37.93%).

Livestock products used

Muturu cattle were raised almost exclusively for meat (96.55%) and hides (96.55%), with both products

produced at equivalent rates across the sample Table 10. Milk production was reported by only two farms (3.45%), confirming the predominantly non-dairy orientation of Muturu cattle production in southern Benin.

Challenges faced by cattle herders

The main constraints encountered by Muturu cattle herders are presented in Table 11. Two constraints were significantly more prevalent than all others: farmer-herders conflicts (41.38%) and financial constraints (36.21%). Other reported constraints included reptile bites, a lack of veterinary services, labor shortages, calf mortality, feeding difficulties, and insufficient time for herd management

Species specificity verification

Genetic purity was assessed using species-specific short insertion/deletion (InDel) regions. A total of 165 DNA samples yielded successful amplification with the allele-specific PCR assay employing the reverse primer MSTNdel16. In contrast, five DNA samples showed simultaneous amplification with both the MSTNdel16 and MSTNins16 primers, suggesting the presence of introgressed individuals and highlighting the potential risk of genetic dilution within the breed.

Characterization of the farms

The Multiple Correspondence Analysis (MCA) revealed that the first three dimensions explained 38.29% of the total inertia. Axis 1 (16.79%) represents a Geographical and Mating Management Gradient, separating the managed, sedentary smallholder systems of the Ouémé department from the unmanaged, extensive wetland setups. Axis 2 (12.02%) describes a Scale and Institutional Demarcation Gradient, separating smallholder production from large-scale public ranching operations characterized by high female counts. Axis 3 (9.48%) isolates Feed and Prophylaxis Intensity, highlighting variations in veterinary reliance and feeding constraints.

Hierarchical Cluster Analysis (HCA)

Hierarchical Ascending Classification applied to the MCA factors scores identified three optimal clusters, as indicated by the largest inertia gain in the dendrogram (Figure 4). The inertia jumps in the dendrogram were plotted according to the number of clusters selected (i.e., 3 clusters). Cluster 1 comprised 25 farms (43.1%), Cluster 2 comprised 32 farms (55.2%), and Cluster 3 comprised a single farm (1.7%).

Typology of visited farm based on farming systems, farming practices, farming objectives, herd size, location, and challenges encountered

The distribution of clusters in the MCA space is shown in Figure 5. Clusters 1 and 3 opposed each other along the first dimension, while Cluster 3 was distinct along the second dimension. The distribution of the three clusters in MCA space is shown in Figure 5. Clusters 1 and 2 were opposed along the first MCA dimension, while Cluster 3 was clearly separated along the second dimension, consistent with its distinct large-scale ranching profile.

V-test analysis ($|v| > 1.96$; $p < 0.05$) identified the modalities significantly characterising each cluster, the most discriminating were used to describe each group.

Cluster 1: Sedentary family-based system ($n=25$; Ouémé department). Herders in this cluster resided primarily in the Ouémé department ($v=5.70$; $p=1.144830e-08$) and raised their animals under sedentary or semi-sedentary systems. Mating was controlled in the majority of cases ($v=3.80$; $p=1.412734e-04$).

Vaccination was the predominant preventive health measure ($v=4.52$; $p=5.906408e-06$), complemented by internal deworming, with curative treatments applied for diarrhoea. Family members served as the primary labour force. The main constraint reported by herders in this cluster was financial difficulty ($v=3.39$; $p=6.938541e-04$).

Cluster 2: Wetland-adapted semi-sedentary system ($n=32$; Atlantique department). This was the largest cluster, comprising 55.2% of all farms. Herders resided predominantly in the mangrove and lakeside communes of the Atlantique department ($v=6.12$; $p=9.128252e-10$). Production was semi-sedentary, with animals grazing freely during the day and confined at night. River and lake water constituted the primary water sources ($v=5.88$; $p=4.032649e-09$), reflecting the hydrological character of the mangrove environment. Agricultural by-products were frequently used as feed supplements ($v=2.91$; $p=3.530420e-03$), particularly during flooding periods when natural grazing was restricted. Mating was

predominantly uncontrolled ($v= 4.25$; $p = 2.115112e-05$), raising concern for genetic introgression at communal grazing areas.

Cluster 3: Ranching system ($n=1$; Zou department). This cluster was represented by a single large-scale operation the Samiondji State Livestock Farm in the Zou department, with a herd of 147 animals. The farm practised a ranching system with improved pastures, organised feed supplementation, and structured health monitoring.

Figures and Tables

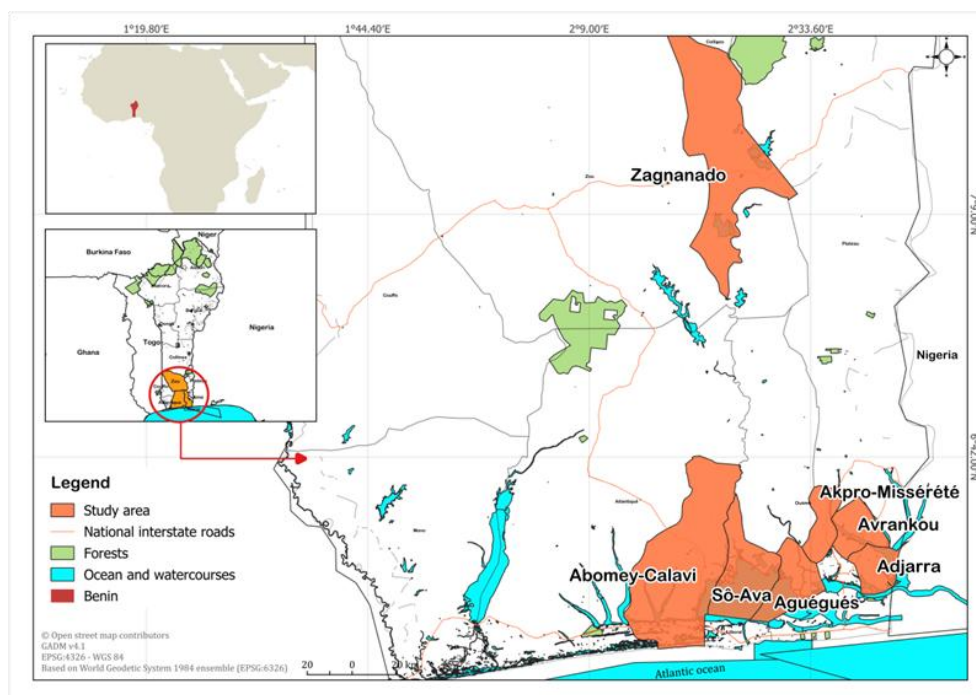


Figure 1. Geographic location of the study areas in Southern Benin. The highlighted zones indicate the specific surveyed municipalities within the Ouémé, Atlantique, and Zou departments where Mutura cattle production and herder interviews were assessed.



Figure 2: Visual representation of the three Mutura cattle production systems identified in Southern Benin: (a) Sedentary system with animals kept near the homestead, (b) Semi-Sedentary system characterized by daily guided grazing in wetland and mangrove ecosystems, and (c) Large-scale ranching system operating on enclosed pastures at the Samiondji State Farm.

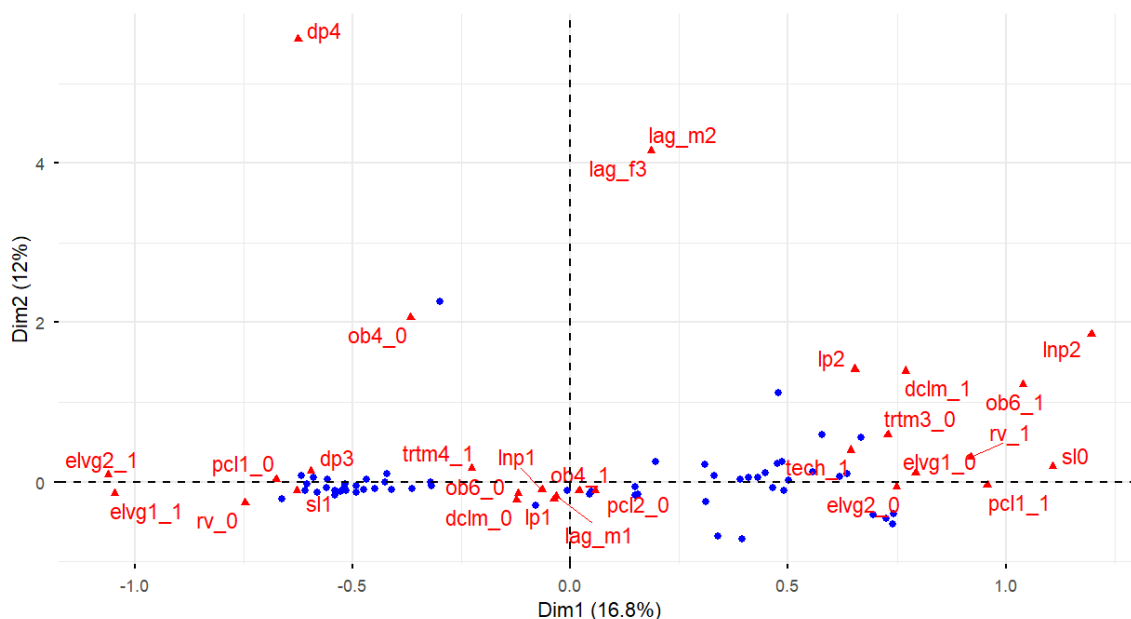


Figure 3 : Overlay of the MCA of the surveyed farms (blue dots) considering farming systems, farming practices, farming objectives, herd size, location, and difficulties encountered (red triangles). This graph shows the individual profiles of the farmers (n=58) according to the two main management dimensions. The first axis (horizontal) opposes the respondents on rangeland characteristics with a strong representation of sedentary and semi sedentary systems to the left of this axis (e.g. elvg2_1 and elvg2_0). The second axis (vertical) primarily opposes farmers according to the size of their holdings with the largest herds in the positive part of this axis (e.g. lag_m2 and lag_m1).

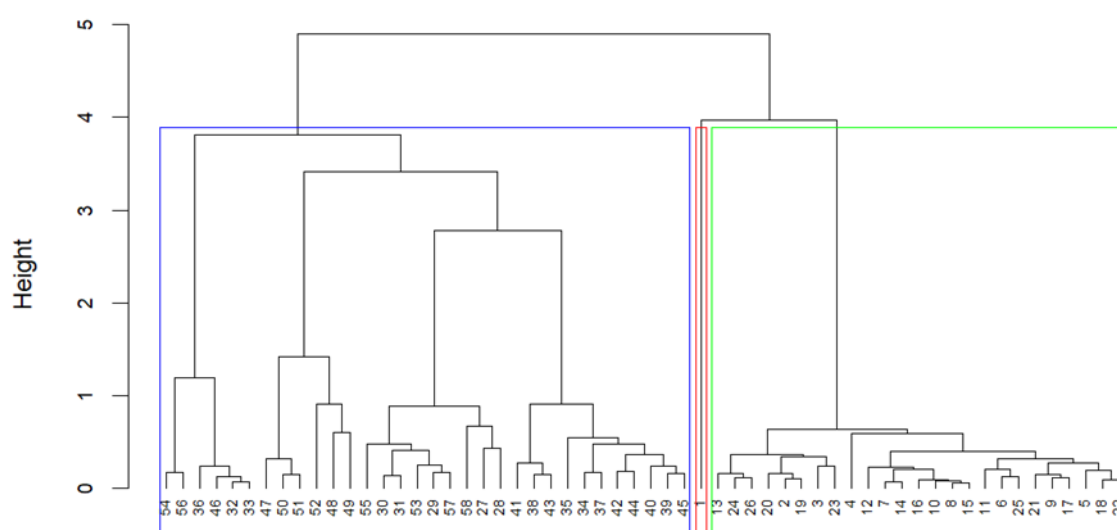


Figure 4: Hierarchical Ascending Clustering (HAC) dendrogram classifying the 58 Muturu cattle farms into three distinct structural typologies. Partitioning is based on individual farm similarities regarding livestock systems, herd sizes, geographic constraint, and production challenges.

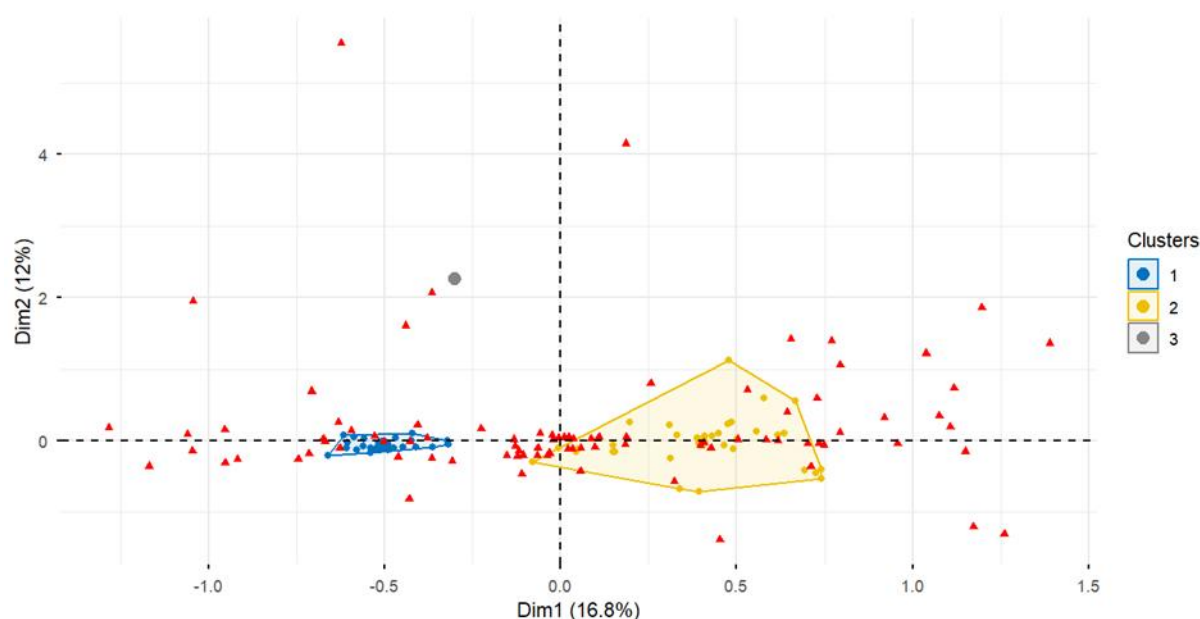


Figure 5: Spatial distribution and clustering of the 58 Muturu cattle farms within the first two dimensions of the MCA space. Cluster 1 (blue) represents the sedentary family-based system in Ouémé; Cluster 2 (yellow) denotes the wetland-adapted semi-sedentary system in Atlantique; Cluster 3 (grey) isolates the single large-scale ranching operation in Zou.

Table 1. Codes of the different modalities.

Variables	Modality	Code
Description of the plot	Mangrove	pcl1_0 and pcl1_1
	Others	pcl2_0 and pcl2_1
Household area in m ²	[200;1000[	sm1
	[1000;2000[	sm2
	[2000;3000]	sm3
Number of lagoon cattle owned by the household	[1;10]	lp1
	[11;47]	lp2
Many of those who do not belong to the household	[1;10]	lnp_1
	[11;47]	lnp_2
Pet accommodation available	Yes	logm1
	No	logm2
Main source of water	River	rv_0 and rv_1
	Drilling	fg_0 and fg_1
Objective of livestock farming	Food source	ob1_0 and ob1_1
	Cultural status	ob3_0 and ob3_1
	Prestige	ob4_0 and ob4_1
	Leisure	ob6_0 and ob6_1
Production method	Sedentary	elvg1_1 and elvg1_0
	Semi-sedentary	elvg2_1 and elvg2_0
	Ranching	elvg3_1 and elvg3_0
Type of food do you give your animals	Cultivated pasture	alm1_1 and alm1_0
	Crop residues	alm4_1 and alm4_0
Number of intact males	[0;7]	lag_m1
	[8;21]	lag_m2
Number of females (females of all ages included)	[0;5]	lag_f1
	[6;50]	lag_f2
	[50;→[	lag_f3

Mating control	Yes	ctrl1
	No	ctrl 0
Method of mating	control	SL1
	uncontrolled	sl 0
Workforce	Other people	mo3
	Household member	mo2
	Knowledge	mo1
Most frequent symptoms in case of illnesses	Wounds	p laie _0 and plaie _1
	Stomach bloating	ball _0 and ball _1
	Hair loss	hairs _0 and hairs _1
	Diarrhea	diarh _0 and diarh _1
	Weight loss	amgr _0 and amgr _1
Difficulties encountered by livestock farmers	Financial difficulties	df _0 and df _1
	Difficulties with food	da _0 and da _1
	Ineffectiveness of animal health technicians	dts _0 and dts _1
	Jealousy	djls _0 and djls _1
	Lack of administrative follow-up	dadm _0 and dadm _1
	Flood and ebb	dclm _0 and dclm _1
	Lack of livestock facilities	dl _0 and dl _1
	Cadet agent	frame _0 and frame _1
	Technician	tech _0 and tech _1
Department	Atlantic	dp1
	Mono	dp2
	Ouémé	dp3
	Zou	dp4
Prophylaxis	Vaccination	trtm3 _1 and trtm3 _0
	Curative treatment	trtm4 _1 and trtm4 _0
	Internal parasite removal	trtm1 _1 and trtm1 _0

Table 2. Gender of respondents and household sizes of Muturu cattle herders in southern Benin.

Variables	n	Frequency %	95% CI	p-value
Gender	Male	57	98.27 ^a	3.35
	Female	1	1.72 ^b	3.35
Household size	[0-5[	8	13.79 ^a	8.875
	[5-10[	44	75.86 ^b	11.01
	[10-15]	6	10.34 ^a	7.838

Intraclass frequencies followed by different letters are significantly different ($p < 0.05$); n: number of observation

Table 3: Reasons and objectives for breeding

Variables	n	Frequency%	95% CI	p-value
Hardiness	58	100 ^a	0	
Sources of income	55	94.82 ^a	5.70	
Labor	8	13.79 ^b	8.87	
Use of cow manure	6	10.84 ^b	7.84	
Traditional ceremonies	6	10.34 ^b	7.84	
Consumption	5	8.62 ^b	7.22	
Prestige	2	3.44 ^b	4.70	
Conservation	2	3.44 ^b	4.70	

< 2.2e-16

Frequencies followed by different letters are significantly different ($p < 0.05$); n: number of observation

Table 4: Description of the herd

Variables		n	Frequency %	95% CI	p-value
Herd size	[1-10]	53	91.37 ^a	7.22	< 2.2e-16
	]10-20]	2	3.44 ^b	4.70	
	]30-40]	1	1.72 ^b	3.35	
	]40-50]	1	1.72 ^b	3.35	
	> 50	1	1.72 ^b	3.35	
Number of animals not belonging to the household	]0-10]	55.00	94.83 ^a	5.70	< 2.2e-16
	]10-20]	1.00	1.72 ^b	3.35	
	]30-40]	1.00	1.72 ^b	3.35	
	]40-50]	1.00	1.72 ^b	3.35	
Total number of animal in the visited herd presented by sex	Males	72.00	17.06 ^b	3.59	< 2.2e-16
	Females	350.00	82.94 ^a	3.59	

Intraclass frequencies followed by different letters are significantly different s ($p < 0.05$); n:

number of observation

Table 5: Rearing systems for Muturu cattle in southern Benin

Variables		n	Frequency %	95% CI	p-value
Production method	Sedentary	36	62.07 ^a	12.49	4.08e-11
	Semi-sedentary	21	36.21 ^b	12.37	
	Ranching	1	1.72 ^c	3.35	

Intraclass frequencies followed by different letters are significantly different ($p < 0.05$); n: number of observation

Table 6: Feeding, watering, and habitat management

Variables		n	Frequency%	95% CI	p-value
Water sources	Boreholes	46	79.31 ^a	10.43	3.423e-14
	River	26	44.82 ^b	12.80	
	Lake	26	44.82 ^b	12.80	
	Tap water	18	31.03 ^{bc}	11.91	
	Collected rainwater	15	25.86 ^c	11.27	
	Dam	4	6.89 ^d	6.52	
Watering method (rainy season)	Animals walk to the water source	31	53.44 ^a	12.84	1
	Water is collected and supplied	31	53.44 ^a	12.84	
Watering method (dry season)	Water is supplied	32	55.17 ^a	12.80	0.3532
	Animals walk to the water source	26	44.82 ^a	12.80	
Types of feed	Natural grazing	58	100 ^a	0	< 2.2e-16
	Agricultural byproducts	46	79.31 ^b	10.43	
	Forage (hay)	43	74.14 ^b	11.27	
	Crop residues	40	68.96 ^b	11.91	
	Cultivated pasture	13	22.41 ^c	10.73	
	Others	2	3.45 ^d	4.70	
Animal housing	No	51	87.93 ^a	8.384	1.406e-15
	Yes	7	12.07 ^b	8.384	

Intraclass frequencies followed by different letters are significantly different ($p < 0.05$); n: number of observation, variable «Others» concern Concentrate and Forest species

Table 7: Breeding management of Muturu cattle in southern Benin

	Variables	n	Frequency %	95% CI	p-value
Mating practice	Controlled	37	63.79 ^a	12.37	0.005346
	Uncontrolled	21	36.21 ^b	12.37	
Calf abundance period	All year round	56.00	96.55 ^a	4.70	< 2.2e-16
	Rainy season	1.00	1.72 ^b	3.35	
	Dry Season	1.00	1.72 ^b	3.35	
Selection of breeding males	No	41	70.69 ^a	11.71	1.946e-05
	Yes	17	29.31 ^b	11.71	
Criteria for selecting breeding male	Conformation	17	27.87 ^a	11.71	0.003852
	Mating performance	16	26.23 ^a	11.50	
	Color	15	24.59 ^a	11.27	
	Size	11	18.03 ^a	10.09	
	Temperament	2	3.28 ^b	4.70	
Origin of the breeding male	Borrowed	9	52.94 ^a	23.73	0.009189
	Purchased	6	35.29 ^{ab}	22.72	
	Self-bred male	5	29.41 ^{ab}	21.66	
	Collective male for the area	3	17.64 ^b	18.12	

Intraclass frequencies followed by different letters are significantly different ($p < 0.05$); n: number of observation

Table 8: Identified relationships and parentage within the herd

	Variables	n	Frequency %	95% CI	p-value
Relationships identified within the herd	Father-Daughter	26	44.82 ^a	12.80	0.2839
	Brother and sisters	26	44.82 ^a	12.80	
	Mother-Son	23	39.65 ^a	12.59	
	Half-siblings	21	36.20 ^a	12.37	
	No relation	16	27.58 ^a	11.50	
Distinction of parentage	Coat color	50	86.20 ^a	8.87	< 2.2e-16
	Body conformation	50	86.20 ^a	8.87	
	Body markings	45	77.58 ^a	10.73	
	Maternal lineage	43	74.13 ^a	11.27	
	Appearance	36	62.06 ^{ab}	12.49	
	Back type	28	48.27 ^b	12.86	
	Shape of horns	6	10.34 ^c	7.84	
	Shapes	3	5.17 ^c	5.70	
	Loops	1	1.72 ^d	3.35	

Intraclass frequencies followed by different letters are significantly different ($p < 0.05$); n: number of observation

Table 9: Veterinary care and common symptoms in cases of illness

	Variables	n	Frequency %	95% CI	p-value
Public health measures	Vaccination	41	70.68 ^a	11.71	0.06961
	Internal deworming	33	56.89 ^{ab}	12.75	
	External deworming	29	50 ^b	12.87	
Common symptoms of illness	Diarrhea	27	46.55 ^a	12.84	< 2.2e-16
	Weakness	26	44.82 ^a	12.80	
	Weight loss	22	37.93 ^a	12.49	
	Watery eyes	13	22.41 ^{ab}	10.73	
	No idea	10	17.24 ^b	9.72	
	Runny nose	10	17.24 ^b	9.72	
	Paralysis	9	15.51 ^b	9.32	
	Abdominal bloating	8	13.79 ^b	8.87	
	Skin wounds	4	6.89 ^c	6.52	
	Hair loss	4	6.89 ^c	6.52	
	Others	10	17.24 ^b	9.72	

Intraclass frequencies followed by different letters are significantly different ($p < 0.05$); n: number of observation, variable «Others» concern: Vomiting, Loss of appetite, None, Agalactia, Tremors, Anorexia

Table 10: Animal-source food/by-product used

Variables	n	Frequency %	95% CI	p-value
Meat	56	96.55 ^a	4.70	< 2.2e-16
Skin	56	96.55 ^a	4.70	
Milk	2	3.45 ^b	4.70	

Frequencies followed by different letters are significantly different from one another ($p < 0.05$); n: number of observation

Table 11: Constraints faced by herders

Variables	n	Frequencies%	95% CI	p-value
Conflicts with farmers	24	41.38 ^a	12.68	4.544e-15
Financial problems	21	36.21 ^a	12.37	
Reptile bites	4	6.89 ^b	6.52	
Lack of veterinary staff for animal health monitoring	4	6.89 ^b	6.52	
Labor shortage	3	5.17 ^b	5.70	
Calf mortality	3	5.17 ^b	5.70	
Animal feeding issues	3	5.17 ^b	5.70	
Lack of time to care for animals	2	3.44 ^b	4.70	

Frequencies followed by different letters are significantly different ($p < 0.05$); n: number of observation

Discussion

Sociodemographic profile and breed preference

The data collected through this study indicate that cattle ownership was almost exclusively men, consistent with finding from previous studies on Muturu cattle production in Benin (Adoligbe et al., 2022; Tobada et al., 2018) and with broader patterns of livestock ownership across West Africa. This finding may be linked to the sociocultural norms that govern the distribution of productive resources in rural societies in West Africa, and in Benin in particular. In most rural African societies, large animals represent productive capital and social status, historically associated with male household authority, while women's roles in livestock production are predominantly limited to marketing and secondary tasks (Soro et al., 2015 ; Roessler, 2019) (Adoligbe et al., 2020). All surveyed herders cited hardiness as their primary reason for keeping the Muturu breed, reflecting the breed's established reputation for trypanotolerance and ecological resilience in the humid and subhumid zones of West Africa (Berthier et al., 2015; Mwai et al., 2015). Several studies have confirmed that African cattle breeds, and the Muturu in particular, possess a unique capacity to resist African Animal Trypanosomiasis and maintain productive performance under high parasite pressure. An adaptive trait of exceptional value in low-input systems where chemoprophylaxis is economically inaccessible to most herders (Ahozonlin et al., 2022; Marshall et al., 2019; Dotché et al., 2025). The capacity to utilize natural forage in tropical wetland ecosystems further reinforces the breed's fitness for the extensive production context of southern Benin (Ahozonlin and Dossa, 2020).

Production objectives, herd structure, and feeding practices

In the present study, Muturu cattle are primarily raised for meat production, while milk production remains marginal. This strong meat orientation reflects both the limited biological dairy potential of Muturu cows and the absence of organized milk collection or processing infrastructure. The high consumer appreciation for Muturu beef, driven by its premium organoleptic quality and favorable carcass yield, reinforces the commercial logic of a meat-oriented production strategy (Kassa et al., 2016; Salifou et al., 2013). In this context, cattle function primarily as a mobile financial reserve, liquidated

when households face severe economic shocks a cash-security role that is well documented in agropastoral systems across the Sahel and sub-Saharan Africa.

The clear predominance of small herds, typically consisting of one to ten animals, is consistent with the family-based, low-input character of Muturu cattle production in southern Benin, and directly reflects the land and capital constraints inherent to sedentary agropastoral systems. This profile contrasts sharply with the mean herd size of 46.0 head reported by Fatondji et al. (2025) in peri-urban areas of northern Benin, where cattle are predominantly managed by Fulani pastoralists maintaining large dairy and replacement herds. In the Ouémé Valley specifically, the absolute dominance of agricultural activity and high soil fertility encourage an integrated crop-livestock system in which cattle numbers are kept deliberately low to minimize the risk of crop damage and subsequent farmer-herder conflict. Natural grazing was confirmed as the universal primary feed source, which is highly consistent with Ahozonlin et al. (2022). The supplementary use of crop residues and agricultural by-products particularly within the mangrove zone of the Atlantique department during flood-induced pasture scarcity is an adaptive response to seasonal forage unavailability rather than a deliberate system intensification strategy.

Reproductive management

Fewer than one third of herders practised formal male selection, and breeding bull selection criteria were predominantly phenotypic: conformation, mating performance, coat colour and body size. The preference for borrowing bulls from neighbours of those practising selection reflects both the limited availability of high-quality breeding males at the farm level and the social capital networks that structure livestock management in rural communities. However, Ahozonlin et al. (2020) noted that herders in similar systems, tend to retain breeding males across multiple generations and mate them with closely related animals, a practice that promotes inbreeding. The present study provides direct evidence of this phenomenon by demonstrating that, despite the selection criteria employed, introgression remains evident in certain individuals, thereby underscoring the risk of genetic dilution of the breed. In addition, father–daughter, mother–son and full-sibling relationships, together with matings between half-siblings, were detected among the herds investigated.

The conservation significance of these findings cannot be overstated. In small closed populations, such as the predominant 1–10 animal herds of Cluster 1, random genetic drift accelerates allelic diversity loss and increases the probability of identity by descent, leading to inbreeding depression expressed as reduced fertility, higher calf mortality, and compromised immune function (Parreira et al., 2025). The concurrent prevalence of uncontrolled mating at shared communal grazing areas and watering points further amplifies this risk by enabling random crosses with animals of unknown or non-Muturu origin, potentially introducing genetic introgression that erodes the breed's adaptive distinctiveness. Organised bull rotation programmes and community-level mating plans, supported by molecular parentage verification, are therefore a priority intervention for Clusters 1 and 2.

Health management and production constraints

Regarding health management, vaccinations and antiparasitic treatments (both internal and external deworming) were the most widely practiced health interventions, though differences in adoption frequency among these measures were not statistically significant. Tobada et al. (2018) reported similar health practices among herders in the Ouémé Valley. In contrast, Dotché et al. (2025) found that vaccination was barely practiced in the communes of Sô-Ava and Aguégoués in the Ouémé and Atlantique departments. This divergence likely reflects local differences in proximity to veterinary services, herd size, and economic capacity, which are major factors known to drive variable adoption of preventive health measures across West African smallholder livestock systems (Eeswaran et al., 2022). The symptom profile observed in this study, dominated by diarrhea, general weakness, and weight loss, is clinically consistent with the combined burden of African Animal Trypanosomiasis and gastrointestinal helminthiasis, which remain the principal health challenges in the tsetse-endemic wetland environments of southern Benin.

Farmer-herder conflicts were the dominant constraint reported, followed closely by financial difficulties. The primacy of farmer-herder conflict reflects growing competition for land and water in a region where agricultural expansion progressively encroaches on traditional cattle corridors and communal grazing

areas. This dynamic is not unique to southern Benin: across West Africa, the intensification of crop agriculture and population growth are accelerating the erosion of pastoral space, with documented increases in the frequency and severity of farmer-herder conflicts (Benjaminsen et al., 2012; FAO, 2023). Financial constraints, reported by more than one third of herders, relate directly to the cost of veterinary care, dry-season feed supplementation, and the near-total absence of accessible rural credit facilities for livestock producers in the study area.

Farming system diversity and conservation implications

This study identified three distinct Muturu cattle farming systems in southern Benin: a sedentary/semi-sedentary family-based system in the Ouémé floodplain (Cluster 1), a wetland-adapted semi-sedentary system in the Atlantique mangrove zone (Cluster 2), and a large-scale ranching system in the Zou department (Cluster 3). Methodologically, Cluster 3 represents an (n=1) outlier consisting solely of the Samiondji State Livestock Farm. While a single-herd cluster cannot support a generalized community typology in the same manner as Clusters 1 and 2, its isolation is highly informative for breed conservation. It exposes a severe institutional and structural divide in southern Benin's livestock landscape. Rather than representing a widespread commercial farming strategy, Cluster 3 serves as an isolated institutional baseline. It demonstrates the production potential of the Muturu breed under optimized, controlled conditions, highlighting the sharp contrast with the fragmented, resource-constrained smallholder production systems that dominate the region.

These clusters, derived from MCA and HAC on 58 herder profiles, reflect the ecological heterogeneity of the study area and the diversity of management strategies adopted by Muturu cattle keepers. Similar typological diversity has been documented in West African cattle systems more broadly, where farming system types are consistently structured by geographic location, ecological constraints, and production objectives (Adebambo, 2001). The existence of three ecologically differentiated clusters underscores that no single conservation or development intervention will be appropriate for all Muturu cattle herders, and that targeted approaches calibrated to each system type are needed.

For Cluster 1, the critical risk is not breed mixing, but severe genetic drift. Our empirical data shows that 91.37% of these herds contain fewer than 10 animals, and father-daughter or brother-sister pairings are actively occurring in 44.82% of them. This high rate of inbreeding requires immediate community-based bull rotation programs to minimize inbreeding depression.

Conversely, for the wetland-adapted Cluster 2, the primary threat is genetic introgression. Because 36.21% of herders practice uncontrolled mating on shared communal pastures, the unique adaptive traits of the Muturu are vulnerable to dilution through accidental crossbreeding. A critical finding of this study is the molecular validation of the genetic purity of the sampled populations, which directly informs conservation priorities. The successful amplification of the *MSTNdel16* locus in 165 individuals confirms the retention of core *Bos taurus* genomic features within these traditional farming systems. However, the detection of five individuals exhibiting dual amplification for both *MSTNdel16* and the *Bos indicus*-specific *MSTNins16* locus provides definitive molecular evidence of active zebu introgression. This genetic dilution aligns with the high prevalence of uncontrolled mating observed at shared communal pastures and watering points, particularly within the wetland adapted smallholder systems of Cluster 2. Left unmanaged, this bidirectional crossbreeding threatens to erode the unique evolutionary adaptations of the Muturu, such as trypanotolerance, which make the breed ecologically resilient in humid environments. Conservation actions here must focus on establishing community pasture boundaries and synchronized seasonal breeding blocks.

The third cluster (Cluster 3), represented by the Samiondji State Farm, offers the most favourable conditions for maintaining genetic diversity, with a herd of 147 animals, organised health management, improved pastures, and structured breeding infrastructure. These various factors can positively influence the animals' muscular and skeletal development and contribute to the cattle breed conservation (Yougharé et al., 2020; Adjahoutonon et al., 2024). This system is most consistent with the conditions needed to sustain an effective population size above the critical threshold of $N_e \geq 50$ recommended to prevent short-term inbreeding accumulation (FAO/UNEP, 1981). However, the large size of breeding

herds can sometimes constitute a risk factor for mortality in cattle in this system, particularly due to the complexity of individual monitoring. Radostits (2007) emphasized, in his clinical summary of bovine diseases, that an increase in herd size is often associated with a rise in neonatal mortality, due particularly to unsupervised calving, delays in intervention, and difficulties in calf care. However, individual smallholders cannot replicate this intensive model unaided. A community-based ranching programme in which the State Farm functions as a nucleus herd supplying certified breeding males to Cluster 1 and 2 herders would successfully combine the genetic diversity advantages of the ranching system with the social and ecological embeddedness of smallholder production (Darmawan et al., 2023).

Conclusion

This study established a clear micro-regional typology for the endangered indigenous Muturu cattle population of southern Benin, identifying three distinct management profiles. Production remains predominantly extensive and family-based, split between small-scale sedentary systems in the Ouémé floodplain (Cluster 1) and wetland-adapted semi-sedentary systems in the Atlantique mangrove zone (Cluster 2), alongside a single institutional ranching system (Cluster 3). Each system faces distinct threats to survival: Cluster 1 is highly vulnerable to inbreeding drift due to small herd sizes and documented parent-offspring pairings, while Cluster 2 faces genetic erosion from uncontrolled communal mating. This risk of genetic erosion is further confirmed by allele-specific PCR diagnostics, which revealed active zebu introgression (MSTN^{ins16}) within the herds, highlighting that genetic dilution is an immediate threat alongside structural management constraints. Effective conservation cannot rely on a single policy approach; it requires targeted actions, including community bull rotation networks for smallholders and utilizing the state ranch as a source for purebred genetic distribution.

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Author's Contributions

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Ethics

The authors declare that they will address any ethical issues that may arise after publication in accordance with journal policies.

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