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Diversity and Resilience to Socio-Ecological Changes of Smallholder Lagune Cattle Farming Systems of Benin

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Abstract: The indigenous smallholder Lagune breed and the production systems in which it is embedded in Southern Benin have received very little research or policy attention. Consequently, very little information exists on the diversity of these production systems or on their capacity to adapt to ongoing socio-economic and environmental changes. This study aimed to explore and characterize the diversity of Lagune cattle production systems along with farmers' local knowledge and resilience strategies. A questionnaire was administered to 417 Lagune cattle farmers across two agro-ecological zones: Ouémé Valley (OVZ) and Pobe (PZ). It included, inter alia, questions related to households' socio-economic conditions, their cattle herd characteristics, and management practices. Categorical principal component analysis and the two-step clustering method were used to classify the production systems which were then compared using the chi-square and ANOVA procedures. Four distinct farm types were identified. This study revealed the important role of agroecology in the diversity of farmers' breeding practices. Controlled mating was more common in tethering systems whereas uncontrolled mating, widespread in free-roaming systems, has favored Lagune breed admixture with zebu. Opportunities for conserving the genetic diversity within the Lagune breed might be greater in PZ where breed admixture was almost inexistent.

Keywords: adaptive strategies; livestock systems; management of local genetic resources; sustainability

1. Introduction

In sub-Saharan Africa, the keeping of indigenous cattle resources plays important socio-economic and cultural roles [1,2], but also constitutes one of the major sources of income and means of poverty reduction [3,4]. In Benin, it represents the main activity in the livestock sector which contributes about 5.8% to the country's gross domestic product (GDP) [5]. Throughout the country, cattle farmers keep a diversity of cattle genetic resources to sustain their livelihoods. The national cattle herd is composed of the taurine (*Bos Taurus*) breeds of Lagune and Somba, of diverse zebu breeds, and of Borgou breed (Sanga cattle). The latter is a stabilized crossbred between taurine and zebu, and represents, in terms of number, the largest cattle population of the country while the populations of the local taurine breeds of Lagune and Somba are decreasing [6,7]. These local taurine cattle were widely distributed in their geographical area in south and north west regions, respectively [8], and kept in various traditional production systems [9,10]. With the increasing climate variability and human population growth, which affect fodder availability, livestock survival, and farmers' access to market [11–13], and induce some social and agro-ecological upheavals, zebu cattle herders have increased their mobility from the semi-arid regions towards the humid regions in search of pasture and water. This encroachment of indicine cattle in the natural habitat of taurine breeds have brought significant changes in the breed

composition and management of the resident herds [14]. This is particularly true of Southern Benin, known as the natural distribution area of the Lagune breed in Benin [15,16], where crossbreeding and progressive replacement of the Lagune cattle by zebu have occurred. These changes have put the genetic diversity of this small-bodied but trypanotolerant breed [17] under threat, compromising its sustainable use.

The Lagune cattle breed has been traditionally kept in small herds [18]. In the current context of rapid demographic growth and shrinkage of grazing resources, these small farms could play a significant role in sustaining local and global food systems [19–21] by adopting agro-ecological and climate-smart practices that enhance their resilience [22–25]. The resilience of farming systems is defined as their ability to cope with external shocks and to adapt [26–28]. According to Darnhofer et al. (2010) [29], adopting a systemic approach to assess the resilience of farming systems provides a better understanding of the interdependence between social and ecological systems, an important step towards the evaluation of farms sustainability. Meuwissen et al. (2019) [30] differentiated between specified resilience and general resilience, distinguished three resilience capacities (robustness, adaptability, and transformability), and developed a framework for their assessment in specific contexts of farming systems in Europe.

Agroecology is seen as an alternative to improve the resilience to climate changes and sustainability of agroecosystems [24,25,31] whereby ecological, social, and economic concepts and principles are applied taking into account farmers' local knowledge [32,33]. Agro-ecological practices not only enhance the sustainability and resilience of farming systems but maintain or increase incomes at an acceptable level [34]. Tichit and Dumont (2016) [35] further argued that agroecology promotes and maintains the diversity of mixed livestock farming systems; the latter are particularly important for livelihoods and food security in sub-Saharan Africa [36].

So far, all previous studies on the Lagune cattle were conducted under improved on-station conditions, except the recent investigation of Assogba (2017) [37] and of Ahazonlin et al. (2019) [38]. But both studies were limited to the Ouémé Valley agro-ecological zone, one of the two agro-ecological zones where most of the Lagune cattle of Benin are kept, and therefore failed to account for the potential role of agro-ecological conditions in shaping the diversity of agricultural production systems [39,40]. Hence, its results could not be generalized to the distribution area of this breed in Southern Benin. Furthermore, the conclusions and recommendations drawn from these studies are so far insufficient for setting up a well-designed program for the sustainable use and conservation of this breed, that must take into account the diversity of its production systems as well as the local knowledge and resilience strategies of the farmers. Against this background, the main objective of this study was to explore and characterize the diversity of Lagune cattle production systems together with the local knowledge and resilience strategies of the farmers in the context of ongoing socio-economic, cultural, and environmental changes.

2. Material and Methods

2.1. Study Areas

The study was carried out in the Guinea-Congolian (GCZ) vegetation zone of Southern Benin, which was subdivided into four phytogeographical districts including the Pobe (PZ) and Ouémé Valley zones (OVZ) (Figure 1) where most of the Lagune cattle farms were found [15].

The Ouémé Valley zone (OVZ) is characterized by an average temperature and humidity index of 4.9, and an annual precipitation that varies between 1100 and 1300 mm [41]. The soil is of hydromorphous type with sandy loam to clay loam texture [42]. The vegetation is made of a marshy forest of *Xylopia rubescens* and *Mitragyna ciliata*, a forest of *Dialium guineense* and *Berlinia grandiflora* which periodically get flooded, and of sections of dense semi-deciduous forest of *Triplochiton scleroxylon* and *Celtis zenkeri* [41–43]. Some localities of this area are known for hosting, for a few months in the year, transhumant zebu cattle herds [43]. The Pobe zone (PZ) is characterized by a temperature and humidity index which varies from 4.0 to 5.8 and an annual precipitation varying from 1100 to 1300 mm. The soil is

ferralitic and without concretions. The vegetation is a dense humid semi-deciduous forest of *Triplochiton scleroxylon* and *Celtis zenkeri* with the variant of *Strombosia pustulata* and *Piptadeniastrum africanum* [41]. Other characteristics distinguishing the two zones are presented in Table 1. Crop farming is the main livelihood activity in both zones and staple food crops are grown along with oil palm plantations.

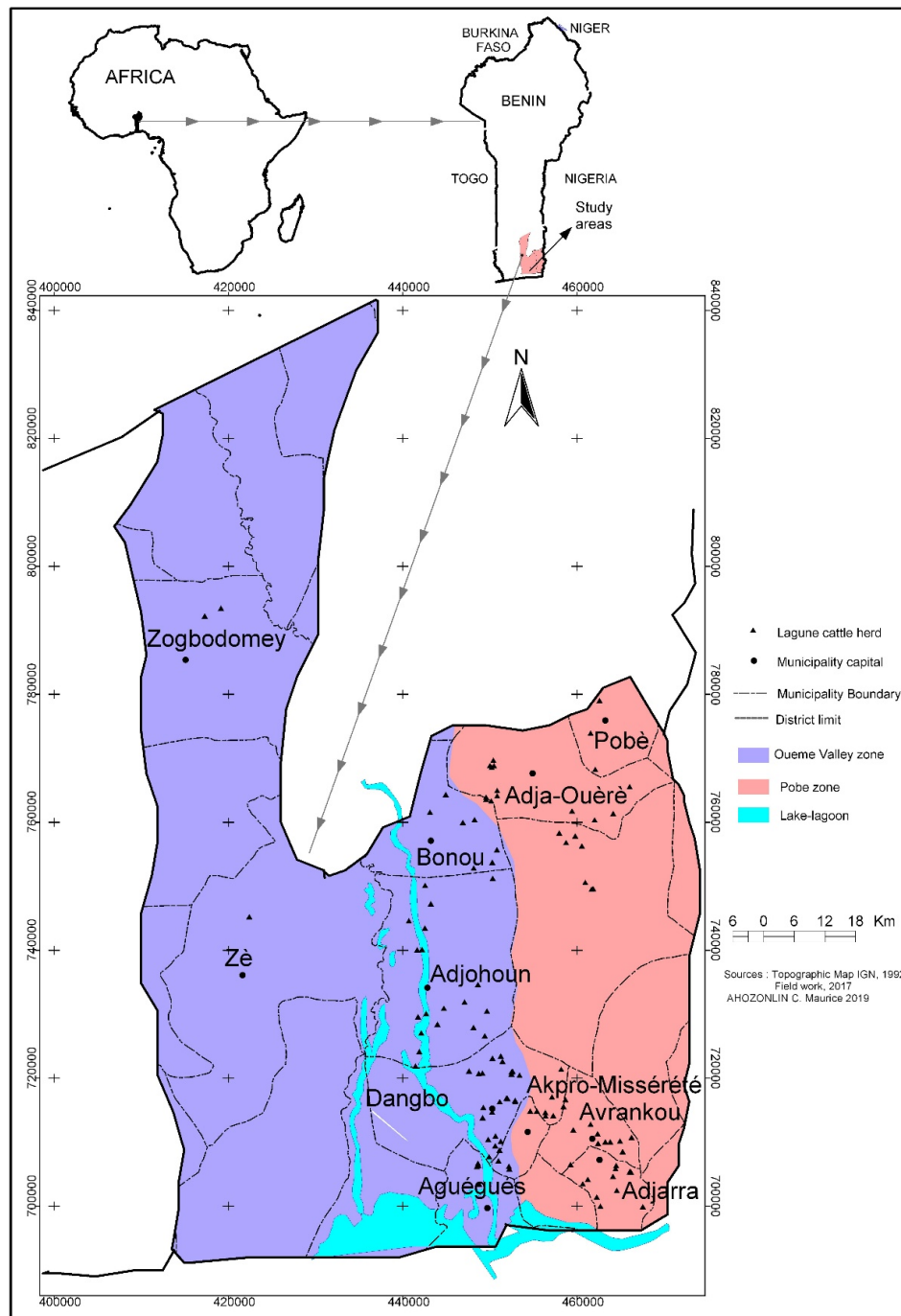


Figure 1. Map of study area in Southern Benin showing the two agro-ecological zones (AEZs).

Table 1. Characteristics of the study areas in Southern Benin, West Africa.

Other Characteristics	Agro-Ecological Zone	
	Ouémé Valley	Pobe
Hydrography ^a	Ouémé River (seasonal flood between August and October) Zone under strong influence and is regular destination of transhumant herds (Bonou and Zogbodomey)	- Transit zone of transhumant cattle herds (Pobè and Adja-Ouèrè)
Transhumance and fodder resources availability ^b	Zone under weak influence and accommodates transhumant herds but in intermittent way (Adjohoun and Dangbo). Abundant fodder availability in all seasons	No transhumance (Akpro-Missereté, Avrankou, Adjara) Abundant fodder availability in only wet season
Area (Km ²) ^c	1606	972
Population density (people/Km ²) ^c	327	1019.2
Estimated population of cattle (n) ^{c,d}	27,500	17,185

^a: Ali et al. (2014) [44], ^b: Alimi et al. (2015) [43], ^c: INSAE (2015) [45], ^d: FAOSTAT (2016) [46].

2.2. Sampling and Data Collection

The choice of the study locations was done through the review of available literature and group discussions with officers from the local extension services responsible for livestock production. The following 10 locations were chosen in these two zones: Bonou, Adjohoun, Dangbo, Aguégués, and Zogbodomey in the OVZ, and Pobè, Adja-Ouèrè, Akpro-Missereté, Avrankou, and Adjara in the PZ (Figure 1).

During group discussions with officers of local extension services responsible for livestock production in each of the research locations, a list of villages and of cattle farmers per village was drawn. From this list, five smallholder cattle farmers were randomly pre-selected per village. Subsequently, the data for this study was collected between June 2016 and March 2017 through individual interviews of the pre-selected cattle farmers (n = 417) who agreed to participate. The farmers were distributed in 87 villages across the 10 selected locations (Table 2). For this purpose, a questionnaire was used and encompassed questions on the socio-economic characteristics of the cattle farmers, the characteristics of their cattle herds (size, structure, and breed composition), their management practices (feeding, reproduction, selection, health), the use and marketing of livestock products. The questionnaire also included questions related to the farmers' perceptions of zebu breeds and to their willingness to introduce them in their Lagune cattle herds.

Table 2. Locations, number of villages, and Lagune cattle herds surveyed in Southern Benin, West Africa.

Agro-Ecological Zone	Locations	Villages (n)	Lagune Cattle Herds (n)
Ouémé Valley (OVZ)	Bonou	14	45
	Adjohoun	11	48
	Dangbo	9	44
	Aguégués	4	20
	Zogbodomey	5	11
	Total	43	168
Pobe (PZ)	Pobè	2	2
	Adja-ouèrè	17	96
	Akpro-Missereté	8	50
	Avrankou	9	51
	Adjara	8	50
	Total	44	249
Overall		87	417

2.3. Statistical Analysis

All statistical analyses were performed with the statistical software package IBM SPSS version 23.0 [47]. The distribution frequencies of the categorical variables across agro-ecological zones were calculated using Pearson chi-square (χ^2) and the Z tests for comparisons between and within agro-ecological zones. The means with standard deviations of the continuous variables were determined and compared between and within zones using the Kruskal–Wallis test and/or Mann–Whitney U test where appropriate. Subsequently, a categorical principal component analysis (CATPCA) was performed for the reduction of the original variables into a smaller group of uncorrelated components representing most of the information found in the original variables. The four significant variables retained for the CATPCA (manure collection, cattle herd size, feed supplementation, and breed composition) with loadings equal or higher than 0.5 on one of the two principal dimensions were selected for the classification of the 417 Lagune cattle farms surveyed. This classification was performed using the two-step clustering approach [48,49]. Discriminant and multinomial logistic regressions analyses were used to assess the validity and stability of the cluster solutions through a set of variables that were not used in the cluster analysis [10,49,50].

3. Results

3.1. Socio-Economic Characteristics of Lagune Cattle Smallholder Farmers and Production Objectives

Table 3 presents the socio-economic characteristics of Lagune cattle smallholder farmers in the two agro-ecological zones. Significant ($p < 0.001$) differences were observed between agro-ecological zones for certain variables such as the ethnic groups of the smallholder farmers, their sex, main occupation, and source of income. The ethnic group *Goun* predominated in the two zones, but with a higher proportion (92.2%) in OVZ, whereas other ethnic groups such as the *Tori*, *Adjarra*, and *Nago* were only met in PZ. Irrespective of agro-ecological zone, the majority of the smallholder Lagune cattle farmers were married. Crop farming was their main occupation. However, the size of land and number of fields cultivated were significantly greater ($p < 0.001$) in OVZ than in PZ (Table 3). Diverse staple crops, such as cereals (maize mainly), leguminous plants (peanut, cowpea), starchy roots and tubers (yam, cassava, and sweet potato), and vegetables (pepper, tomato, leafy vegetables, and okra) were grown in both zones. In addition, cotton was also grown at Zogbodoméy in OVZ.

Irrespective of zone, the main objectives and reasons for keeping Lagune cattle were their use as means of savings and of income diversification. Nevertheless, other reasons such as culture, prestige, and provision of manure were reported in the OVZ. In addition to cattle, small ruminants, poultry, pigs, and rabbits were also raised. However, these species fulfilled other social roles or functions different from those mentioned for Lagune cattle.

3.2. Herd Sizes, Structure, and Breed Composition

The average cattle herd size was 4.4 ± 4.5 animals with significant differences ($p < 0.01$) between agro-ecological zones. Similarly, there were significant differences between agro-ecological zones with regard to herd size distribution and structure (Table 4). Small herds (<5 heads) dominated as they represented 64.5% of Lagune cattle herds surveyed. Cows represented 55.3% of the animals in the herds against 5.6% for breeding bulls with significant variations between the two zones.

Table 3. Socio-economic characteristics of smallholders' Lagune cattle farmers in southern Benin.

Agro-Ecological Zone				
Variable	Total	Ouémé Valley	Pobe	χ^2
	(n = 417)	(n = 168)	(n = 249)	
Frequency (% of Farmers)				
Sex				5.402
Male	95.2	92.2 ^a	97.2 ^b	
Female	4.8	7.8 ^a	2.8 ^b	
Level of formal education				5.646
None	89.7	86.2 ^a	92.0 ^a	
Some primary	06.2	4.8 ^a	02.8 ^a	
Some secondary and more	4.1	9 ^a	5.2 ^a	
Ethnic group				469.37
Goun	59.3	92.2 ^a	37.3 ^b	
Tori	16.1	0.0 ^a	26.9 ^b	
Adjarra	8.4	0.0 ^a	14.1 ^b	
Nago	4.1	0.0 ^a	19.3 ^b	
Fon	4.1	7.2 ^a	0.0 ^b	
Peulh	0.5	0.6 ^a	0.4 ^a	
Main occupation				26.282
Crop farming	77.5	89.9 ^a	69.1 ^b	
Livestock farming	04.3	03.5 ^a	5.2 ^a	
Trade	4.1	2.4 ^a	5.2 ^a	
Other	14.1	04.8 ^a	20.5 ^b	
Main source of income				13.345
Crop farming	59.8	65.3 ^a	56.1 ^b	
Livestock farming	21.5	24.6 ^a	19.5 ^b	
Other	18.1	10.1 ^a	24.4 ^b	
		mean \pm SD		<i>p</i> -value
Age (years)	47.3 \pm 12.48	46.1 \pm 12.57	48.3 \pm 12.35	0.163
Estimated cultivated land size (ha)	2.2 \pm 1.56	4.0 \pm 3.59	1.9 \pm 1.18	0.001
Number of fields cultivated (n)	2.8 \pm 2.66	4.5 \pm 3.66	1.3 \pm 0.64	0.001
Experience in cattle farming (years)	15.4 \pm 11.01	15.9 \pm 10.72	14.9 \pm 11.26	0.289

^{a, b} Within a row, values with different superscript letters are significantly different at $p \leq 0.001$ level (chi-square test).

With regards to the breed composition of the herds, significant differences ($p < 0.01$) were observed between the two zones (Table 4). While herds of Lagune cattle breed only predominated (92.0%) irrespective of zone, the proportion of herds with a mix of breeds (Lagune, zebu, Lagune \times zebu) was higher in the Ouémé Valley (19.3%) and had likely increased over time as all respondents reported that they set up their initial breeding stock with Lagune cattle only.

3.3. Sources of Stock Foundation

With significant ($p < 0.001$) differences across locations, the Lagune cattle herds were set up either with purchased (73.4%), or inherited animals (7.3%). In addition, a practice called “Hodononkon”, which consists of handing over 100,000 FCFA (USD 172) to a Lagune cattle farmer as a guarantee in exchange for a cow was reported by 3.2% of the respondents in the OVZ. After the cow successfully calves two times, the owner of the cow returns the amount and takes back his cow. Some herds were also gradually set up through entrustment practices. For example, 14.3% of respondents indicated that they kept animals entrusted by friends (56.1%) and parents (43.9%). The animals were often kept in exchange for offspring (92.9%) and cash (7.1%).

Table 4. Average Lagune cattle herd size (mean and SD), distribution (%) of herd size, structure, and breed composition in two agro-ecological zones of South Benin.

Parameters	Total (n = 417)	Agro-Ecological Zone		χ^2
		Ouémé Valley (n = 168)	Pobe (n = 249)	
Average herd size (heads, n)	4.4 ± 4.5	5.3 ± 5.6 ^a	3.8 ± 3.26 ^b	-
Class (%) of cattle herd size				124.246
<5 heads	64.5	63.5 ^a	65.2 ^a	
5–10 heads	29.2	25.6 ^a	31.7 ^b	
>10 heads	6.3	10.9 ^a	3.1 ^b	
Herd structure (%)				5.864
Calves	18.6	20.4 ^a	16.4 ^a	
Heifers	12.2	10.2 ^a	14.7 ^a	
Bull-calf	8.2	6.9 ^a	9.8 ^b	
Cows	55.3	56.6 ^a	53.7 ^b	
Bull	5.6	5.8 ^a	5.3 ^a	
Breeds (% of herds)				
Current breeds in herds				49.397
Lagune only	92.0	80.7 ^a	100.0 ^b	
Lagune, zebu, and Lagune × zebu	8.0	19.3 ^a	0.0 ^b	
Breeds in the herds five year ago				48.136
Lagune	92.8	82.1 ^a	100.0 ^b	
Lagune, zebu, and Lagune × zebu	7.2	17.9 ^a	0.0 ^b	

^{a, b} Within a row, values with different superscript letters are significantly different at $p \leq 0.001$ level (Kruskal–Wallis and chi-square test).

3.4. Herd Management Practices

3.4.1. Housing and Feeding

Farmers' herd management strategies varied significantly ($p < 0.001$) between agro-ecological zones. While tethering (81.0%) and free roaming in the presence of a herder or partial free roaming (1.7%) were common practices in the two zones, total free roaming herds without being monitored (17.3%) were observed only in the OVZ. Furthermore, 17.8% of cattle farmers, mainly located in the PZ, alternated between tethering and partial free roaming. The practice of tethering consisted of attaching the animals to a stake in a grazing area close to the farmer's homestead where the animals were conducted early in the morning (06–07 a.m.) and stayed the whole day, whereas in the partial free-roaming practice, the animals were conducted to grazing either from 09 a.m. to 6 p.m. or from 12 p.m.–6 p.m.

Irrespective of agro-ecological zones, most Lagune cattle herds (90.6%) were housed at night around their keepers' or owners' homestead. However, 17.6% of herds surveyed in OVZ were freely roaming in permanence, except during periods of floods when they were housed in enclosures built with precarious materials.

3.4.2. Feeding and Crop-Livestock Integration

Extensive grazing on communal lands was the most common feeding practice among Lagune cattle farmers in both agro-ecological zones. The main forage species present on these grazing lands and known to the respondents were *Panicum maximum*, *Imperata cylindrica*, *Cynodon polystachus*, *Centrosema pubescens*, *Aspilla africana*, and *Elaeis guineensis*. In addition, feed supplementation was practiced by 45.1% of respondents and was essentially based on crop residues such as corn residues (99.7%), groundnut hays (17.5%), cowpea haulms (71.3%), cassava leaves (27.8%), and leaves of cotton plant. The latter was only reported in Zogbodomey (OVZ). Stubble grazing was reported with significantly ($p < 0.0001$) higher frequency in the PZ (100%) compared with the OVZ (91.6%). Drinkable water was offered to the herds after their return from grazing. In the dry season, when fodder resources are scarce, 20.1% of smallholder farmers in Adjara and Avrankou in PZ allowed their animals

to partially free-roam while few of them (6.5%) reported that they moved their animals towards the backwater of Ouémé River or entrusted them to other farmers in areas where feed resources were available. The main causes of fodder shortage, as perceived by the respondents, were drought (99.3%) related to climate variability, expansion of crop fields at the expense of fallows and grazing lands (87.6%), recurring floods (36.0%), and presence of transhumant herds (9.7%) reported in the OVZ only. In addition to crop residues, some smallholders (43.2%) occasionally used wild herbs and branches of oil palm tree (*Elaeis guineensis*) as feed supplements in the PZ. Mineral supplementation was only reported by very few (7.1%) farmers.

Overall, the integration of crop and cattle farming, whereby the crop residues were used to feed the animals and the manure used to fertilize the crop fields, was reported by 75.1% of the respondents irrespective of agro-ecological zone. The frequency of manure collection varied significantly ($p < 0.01$) between zones and seasons.

3.4.3. Reproduction and Selection

Natural mating was the only mating method practiced by all surveyed cattle farmers. Nevertheless, it was controlled in tethered herds (81.0%), and more especially in herds that had no breeding bull. These herds represented 52.4% of the surveyed herds. The keepers of these herds borrowed bulls in their neighborhood to mate cows in their herds. The borrowing was either free of charge or against the payment of a fee varying between 1000 CFA (USD 1.72) to 3000 CFA (USD 5.17).

Some farmers (21.5%) were able to detect cows in heat by their behavior (agitation, overlap, lack of appetite) and other signs such as flush vulva and the flow of the cervical mucus. The farmers perceived that all cows have to calve once a year. Many practices were implemented to mate cows with variations among farmers. Generally, cows were mated 2 or 3 months after a calving while some farmers (21.5%) preferred to mate them successively the 22nd, 23rd, and 24th day after calving.

The average age of heifers at first mating was 32.52 months and varied from 30 to 42 months. Most of the farmers adopted a simple practice, to mate the heifer and its dam in the same period after the latter has given birth twice after the one that gave birth to the heifer. The management practices of cows' career varied significantly ($p < 0.01$) across agro-ecological zones. The average life-time number of calving per cow also varied significantly ($p < 0.01$) across zones, and was greater (9.7 ± 3.89) in OVZ than in the PZ (5.8 ± 2.03). Breeding females were kept longer in the herds than male animals in the OVZ. The latter were quickly sold whenever cash was needed, but also to avoid their theft. The age of the male calves at first service varied from 9 to 12 months.

Habitually, Lagune cows were not milked, but in herds composed of more than one breed and kept by professional herdsmen, mainly in the locations of Bonou and Zogbodomey (OVZ) and of Pobe (PZ), Lagune cows were milked and the milk turned into cheese.

There was no record keeping. Most of the farmers relied on their memory to identify individual animals in their herds. In addition to this method, some farmers (16.9%) in the Dangbo and Aguégues locations (OVZ) used ear marks.

To improve Lagune cattle growth performance, smallholder farmers practiced various selection methods. Seven (07) criteria were often used for the selection of both male and female animals and the frequency of their mentions varied significantly ($p < 0.01$) depending on the sex of the animal. These criteria were general body conformation, resistance to parasitic diseases, growth performances, parents' performances, robustness, and coat color (Figure 2). The selection intensity depended also on the sex and the origin of the animals. Selection was especially more rigorous for males and animals acquired from neighboring herds.

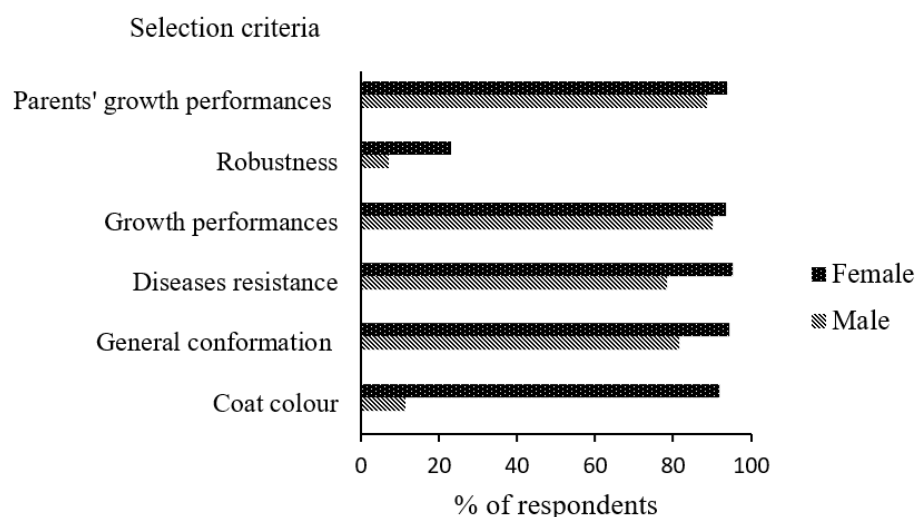


Figure 2. Criteria used by farmers for selecting breeding female and male animals in smallholder Lagune cattle production systems.

As mentioned by most of the respondents, reproductive disorders were an important factor affecting herd productivity. But only very few farmers (3.5%) from OVZ reported the use of ethnoveterinary practices (pharmacopoeia) to treat sick animals, persistent anestrus in multiparous cows, mastitis, and agalactia.

3.5. Farm Typology

The CATPCA performed on the variables that were statistically significant in the univariate analyses showed two dimensions that accounted for about 66.8% of the total variance (Table 5). The Cronbach's alpha value for the overall model was 0.874, very close to 1, confirming the reliability of the model. The variables that formed the two dimensions and of which loadings were >0.5 were cattle herd size, breed composition of the herd, manure collection and use as fertilizer, and feed supplementation (Table 5). These four variables were used in the two-step cluster analysis that generated four clusters with a satisfactory average silhouette measure (0.8). The multinomial logistic regression analysis performed on further five explanatory variables (cultivated land size, use of crop residues for feeding, farmers' ethnicity, farmers' main occupation, and herd management mode) showed a 78.6% correct classification. The Cox and Snell pseudo R-square of the model was 0.879. The model chi-Square was statistically significant at $p < 0.001$ and the goodness-of-fit equals to 1, indicating a good fit.

Table 5. Summary of the final categorical principal component analysis (CATPCA) model and component loadings for 382 Lagune cattle farms in Southern Benin.

Parameters	Dimensions	
	1	2
Cronbach's alpha	0.464	0.361
Total eigenvalues	1.534	1.371
Total variance explained (%)	41.131	25.672
Variables	Component loadings	
Breed composition of the herd	0.616	−0.556
Use of crop residues for feeding	0.063	0.362
Feed supplementation	0.812	0.343
Manure collection and use as fertilizer	0.507	0.737
Cultivated land size crop	−0.277	−0.331
Cattle herd size	−0.488	0.633

Four Lagune cattle farm types were distinguished (Table 6) as follows: Improved traditional Lagune cattle farms (ITLF, $n = 159$; 41.6%); mixed Lagune, zebu, and crossbreed cattle farms (MIXF, $n = 38$; 10%); partially integrated traditional Lagune cattle-crop farms (PITLF, $n = 97$; 25.4%); and conventional traditional Lagune cattle farms (CTLF, $n = 88$; 23%).

Table 6. Comparative profile of the different types of Lagune cattle farms differentiated by the two-step clustering algorithm performed on 382 farms in Southern Benin.

Lagune Cattle Farm Types						
Variables	Overall (n = 382)	ITLF (n = 159)	MIXF (n = 38)	PITLF (n = 97)	CTLF (n = 88)	χ ²
Frequency (% of herds)						
Breed composition						316.2
Lagune only	91.6	100.0 ^a	15.8 ^b	100.0 ^a	100.0 ^a	
Mixed (Lagune, zebu andcrossbreds)	8.4	0.0 ^a	84.2 ^b	0.0 ^a	0.0 ^a	
Feed supplementation						338.5
Yes	44.8	100.0 ^a	5.3 ^b	0.0 ^c	11.4 ^b	
No	55.2	0.0 ^a	94.7 ^b	100.0 ^c	88.6 ^b	
Collection and use of manure						358.4
Yes	75.7	100.0 ^a	86.8 ^b	100.0 ^a	0.0 ^c	
No	24.3	0.0 ^a	13.2 ^b	0.0 ^a	100.0 ^c	
Means ± SD						p-value
Cattle herd size	4.4 ± 0.2	3.7 ± 0.18 ^a	10.9 ± 1.26 ^b	3.8 ± 0.26 ^a	3.3 ± 0.27 ^a	0.000

^{a, b, c} Within a row, values with different superscript letters are significantly different at $p \leq 0.001$ level; ITLF = Improved traditional Lagune cattle farms; MIXF = Mixed Lagune, zebu, and crossbreed cattle farms; PITLF = Partially integrated traditional Lagune cattle-crop farms; and CTLF = Conventional traditional Lagune cattle farms.

Farm type 1: Improved traditional Lagune cattle Farms (ITLF).

This type gathered 63.6% and 12.7% of farms in PZ and OVZ respectively. The animals (3.7 ± 2.27 heads) were tethered at stake on fallows or under oil palm trees and supplemented with crop residues. Agriculture was the main occupation of 64.2% of their owners who collected and valued manure as fertilizer in their crop fields. The average cultivated land was significantly ($p < 0.0001$) the smallest (1.7 ± 1.57 ha) compared with average size of land cultivated by farmers of other groups.

Farm type 2: Mixed Lagune, zebu and crossbreed cattle farms (MIXF).

This group was only found in OVZ where it encompassed 21.2% of herds. The cattle herd size was significantly ($p < 0.0001$) larger compared with other farm types and averaged 10.9 ± 7.78 heads of cattle. In contrast to the other three farm types, the herds were composed of Lagune cattle mixed with either zebu or their crossbreeds. The animals were kept in a free-roaming system and were not provided with any feed supplementation. However, their manure was collected and valued as fertilizer as most (92.1%) of their owners/keepers had crop farming as main occupation. The average cultivated land was the largest (2.5 ± 2.17 ha) compared with the three other groups.

Farm type 3: Partially integrated traditional Lagune cattle-crop farms (PITLF).

Similar to the ITLF group, this group consisted of farms keeping an average of 3.8 ± 2.53 heads of Lagune cattle in the tethering system. This group gathered 33.3% of herds in OVZ and 19.4% of herds in PZ. No supplementation feeding was provided to the animals, but the manure was collected and valued as fertilizer and 4.2% of farmers in OVZ used ethnoveterinary practices. Agriculture was the main occupation of 88.7% of the farmers who cultivated a size of land that averaged 2.4 ± 1.16 ha.

Farm type 4: Conventional traditional Lagune cattle farms (CTLF).

This group was mainly made of traditional tethered Lagune cattle herds. Found in both agro-ecological zones, it gathered 32.7% of herds in OVZ and 15.7% of herds in PZ. No feed supplementation was provided to the animals. In contrast to all other three farm types, the manure was

not collected and used as fertilizer although crop cultivation was reported by 91% of the cattle farmers in this group as their main occupation. They cultivated a size of land that averaged 2.5 ± 1.62 ha.

Reproduction management and selection practices were compared among different types of Lagune cattle farms (Table 7).

Table 7. Comparative profile of the different types of Lagune cattle farms using the variables of reproduction management and selection practices on 382 farms in Southern Benin.

Lagune Cattle Farm Types						
Variables	Overall (n = 382)	ITLF (n = 159)	MIXF (n = 38)	PITLF (n = 97)	CTLF (n = 88)	χ^2
Frequency (% of herds)						
Selection practice for male						84.909
Yes	75.3	93.1 ^a	34.2 ^b	79.2 ^c	56.8 ^d	
No	24.7	6.9 ^a	65.8 ^b	20.8 ^c	43.2 ^d	
Selection practice for female						45.288
Yes	95.3	96.9 ^a	73.7 ^b	96.9 ^a	100.0 ^a	
No	4.7	3.1 ^a	26.3 ^b	3.1 ^a	0.0 ^a	
Presence of bull in herd						44.216
Yes	47.5	39.4 ^a	97.4 ^b	47.9 ^a	39.5 ^a	
No	52.5	60.6 ^a	2.6 ^b	52.1 ^a	60.5 ^a	
Ethnoveterinary practices						12.043
Yes	1.1	0.0 ^a	0.0 ^{a, b}	4.2 ^b	0.0 ^{a, b}	
No	98.9	100.0 ^a	100.0 ^{a, b}	95.8 ^b	100.0 ^{a, b}	
Ear marks method						231.579
Yes	6.8	0.0 ^a	65.8 ^b	0.0 ^a	0.0 ^a	
No	93.2	100.0 ^a	34.2 ^b	100.0 ^a	100.0 ^a	
Means \pm SD						<i>p</i> -value
Age at first calving (month)	32.0 \pm 3.07	32.7 \pm 3.27	30.0 \pm 3.22	31.3 \pm 3.45	32.1 \pm 3.15	0.344
Average number calving	9.7 \pm 0.71	8.4 \pm 1.22	11.8 \pm 1.66	9.4 \pm 1.37	10.0 \pm 1.50	0.334

a, b, c, d Within a row, values with different superscript letters are significantly different at $p \leq 0.001$ level; ITLF = Improved traditional Lagune cattle farms; MIXF = Mixed Lagune, zebu and crossbreed cattle farms; PITLF = Partially integrated traditional Lagune cattle-crop farms; and CTLF = Conventional traditional Lagune cattle farms.

4. Discussion

4.1. Socio-Economic Characteristics of Lagune Cattle Farmers in Southern Benin

This study has revealed important socio-economic characteristics of the smallholder Lagune cattle farmers, such as their main occupation, main source of income, and production objectives, which influenced their herd management strategies. Similar findings have been reported by Houessou et al. (2019) [10] and Dossa et al. (2015) [49] in Benin and in Burkina Faso, respectively. In this condition, the management strategies implemented affect herd productivity [10]. This traditional management of Lagune cattle, consisting of keeping small herd sizes and using the locally available feed resources with least or zero external inputs, had facilitated the implication of women who are increasingly recognized for their important role in the safeguard of farm animal genetic resources [19,51–53].

Only the smallholder farmers from the ethnic group *Goun*, which represents respectively 33% and 12% of the human population in the Ouémé and Plateau regions in Southern Benin, perceived the Lagune cattle as an indigenous and locally adapted animal genetic resource. This positive perception towards and attachment to the breed have probably limited its indiscriminate crossbreeding and/or replacement with zebu cattle among farmers from this ethnic group. Similar observations were made by Dossa and Vanvanhossou (2016) [54] for the indigenous taurine Somba breed in Boukoumbe in the north west of Benin, by Mopaté et al. (2014) [55] for the Baoule cattle in southern Burkina Faso and by Musemwa et al. (2007) [56] in the Eastern Cape Province, South Africa.

In addition to crop production that was their main occupation, Lagune cattle farmers were involved in several other livelihood activities. They also kept other livestock species which certainly fulfilled different livelihood functions than cattle, given that livelihood diversification by households was one of the strategies to enhance resilience to shock [57].

4.2. General Management of Lagune Cattle Herds

Lagune cattle herds were generally set up through purchase, inheritance, and entrustment. The latter practice has played an important role in setting up small herds in all rural communities [54,58,59]. Interestingly, this study has documented another approach for setting up a new herd called “*Hodononkon*” and developed in Ouémé Valley zone (OVZ). This practice helped to tighten the social relations through the Lagune breed and the perpetuation of its traditional farming. It is also an original initiative which showed the level of attachment of smallholder farmers to this breed and could be an opportunity for its conservation.

Lagune cattle farmers’ management practices varied significantly between the two agro-ecological zones and were also influenced by their ethnic group. The herds managed by people from the Peulh ethnic group were composed of several cattle breeds although they were set up with Lagune cattle. The strong preference of Peulh people for zebu breeds has been extensively documented [60,61]. According to the latter authors, Peulh herders despised the taurine cattle breeds for several reasons including their low capacity to produce milk compared with zebras. Hence, the entrustment of their herds to Peulh herders by Lagune cattle absentee owners would likely facilitate the introduction of zebu cattle in the Lagune cattle herds and expose the Lagune breed to indiscriminate crossbreeding with zebu cattle.

Indiscriminate or poorly planned crossbreeding is one of the major threats to cattle breed diversity in sub-Saharan Africa [62,63]. This situation has spread throughout in the natural habitat of the Lagune cattle breed leading to its replacement by zebras and crossbred cattle. The dilution and erosion of genetic diversity in this local resource therefore becomes inevitable [64,65] in these farming systems, although its ability to adapt to local conditions is a good reason for its conservation [66]. An urgent action for the conservation of this genetic is thus necessary. However, several research works justify these practices of management of taurine cattle population by their low productivity and small format [67,68], market demand and higher market price paid for zebras and crossbred cattle [69], and substantial reduction of the tsetse flies burden and trypanosome prevalence [67,69,70].

Natural mating is the only mating method practiced by all Lagune cattle farmers. It was controlled in the tethering system and uncontrolled in free-roaming one. The same observations about the traditional taurine farming systems have been reported by Soro et al. (2015) [58] in Ivory Coast, by Mopaté et al. (2014) [55] and by Mopaté (2015) [59] in Burkina Faso. However, the permanent absence of bulls in several cattle herds is of concern as it certainly negatively affects the reproduction parameters and herd productivity. The mating of animals more closely related such as cows and their progeny regularly occurred. The parameters such as calving interval and age at first calving are determinants of the numerical productivity [71,72] and explain the low herd growth in small holdings despite the presence of high numbers of cows in these herds. Furthermore, in the tethering system where mating was not controlled, the smallholder farmers did not have the technical skills to appropriately detect the cows in heat. Similar observations were also made by Girma et al. (2016) [73]. Interestingly, Lagune cattle farmers practiced selection following criteria that respond to their needs such as productivity improvement, building resilience and adaptive capacity, and valorization of available marginal pastoral resources [74–76].

4.3. Diversity of Lagune Cattle Farming Systems

In this study, four distinct Lagune cattle farm types were distinguished. The ITLF and PITLF integrated crop and livestock activities, whereby crop residues were used to feed the animals and manure used to sustain soil fertility. These two farm types are improved forms of the conventional

traditional Lagune cattle farm type (CTLF). The adoption of improved management practices observed in the first farm group, that gathered 63.6% of farms in the vicinity of the city of Porto-Novo (Adjarra, Avrankou, and Akpro-Missereté), is probably in response to shrinkage of pasture areas and fodder shortage in these locations due to the increasing human population density and fast growing urbanization. Faced with these constraints, farmers have intensified the association of their cropping and livestock activities by valuing the crop residues as feed supplements and recycling manure as fertilizer. Compared with ITLF, The PITLF still had access to abundant natural vegetation. This probably explains the lesser use of crop residues for feeding the animals in this farm type. However, with the ongoing rapidly increasing urbanization, this natural vegetation will become scarce and both PITLF and CTLF will likely shift to a full integrated system as observed in ITLF.

In contrast to the three other farm types identified in this study, MIXF consisted of mixed herds (zebu, Lagune, and crossbreed), and this admixture of breeds influenced the management strategies implemented by farmers which include the use of external inputs such as trypanocides, as the zebras and their crossbreeds are still insufficiently adapted to the prevailing environmental conditions (i.e., high humidity and presence of tsetse flies). This finding is in line with the previous finding of Houessou et al. (2019) [10]. Furthermore, zebras are more demanding in feed than Lagune cattle and are not adapted to the tethering, hindering the farmers of this group from adopting zero-grazing practices.

4.4. Resilience of Lagune Cattle Farms

With the exception of the CTLF farm type, all other farm types showed an increasing tendency towards integrated crop-livestock practices by using crop residues as feed supplement and recycling manure as fertilizer. While the integration of crop and livestock is not a new practice among cattle farmers in Benin [10] and in West Africa [77], because it is considered as one of the most promising options to face climate change [20,25,78] it is increasingly adopted by the smallholder farmers in the current context of socio-economic and environmental changes, confirming its important role in the resilience of these smallholder production systems. Similar to results of previous research [10,79], this study has shown that the degree of crop and livestock integration varied among cattle farming systems. In the African context, integrated crop and livestock systems are more resilient than specialized systems under global warming [80]. Livestock plays an important role in the process of this integration and in building resilience against external shock [81,82]. Animal manure management aims to combine profitable agricultural production with minimum nutrient losses from manure [83]. Hence, integrated farms are considered eco-efficient and sustainable [84–86]. In the agro-sylvo-pastoral systems, Lagune cattle were tethered under oil palm plantations where they grazed all the grasses, including weeds, and laid down manure which fertilizes the soil. Farmers have developed this management strategy to increase the profitability of farming systems mostly through agroforestry reducing clearing costs. Hence, the economic profitability of these integrated crop-livestock systems as defined by ecological principles is not related to the diversity of production or animal productivity, but to the low dependency on off-farm inputs [86,87]. Furthermore, the diversity of production enhances the farms' flexibility [88].

In addition to cattle, almost all surveyed farmers were keeping other livestock species. This diversification of agricultural activities could not only be considered as a resilience strategy but also as a means to improve the sustainability of livestock farms [89,90]. Even if some exhaustive studies are lacking to reveal the conditions under which multi-species livestock farms are more profitable [91], many economic advantages related to multi-species livestock farming are comparable to diversified farming systems [92,93].

Uses of crop residues and manure other than as feed and fertilizer, respectively, were also reported and contribute to sustain the livelihoods of Lagune cattle farmers. Most of CTLF farms in the OVZ were located in villages where soils are still fertile but exposed to recurrent flooding because of their closeness to the Ouémé River. Therefore, instead of using the crop residues for feeding their animals, most of the farmers in this group used it to protect soil against erosion, to maintain soil humidity,

and also as organic fertilizer. They also collected the manure but used it as a building material or burnt it to fight against mosquitos instead of using it to enhance soil fertility. The latter use of manure has also been reported by Roxburgh and Rodriguez (2016) [94] and Rodriguez et al. (2017) [95].

5. Conclusions

In this study, four distinct Lagune cattle farm types were identified based on the herd size, breed composition of the herd, manure use, and feed supplementation. All of them relied on natural feed resources. Consequently, increasing scarcity and difficult access to these resources were the major production constraints. These varied significantly within and between agro-ecological zones and were mainly related to drought, increasing expansion of crop cultivation, and rapid urbanization. To cope with these constraints, Lagune cattle farmers were progressively integrating their cattle husbandry with crop cultivation, whereby crop residues are valued for feeding animals and manure used to fertilize crop fields. However, the degree of crop and livestock integration varied significantly across farm types and agro-ecological zones. Farmers' local knowledge that underlie the resilience of the traditional Lagune cattle production systems are still not sufficiently documented. In the context of ongoing socio-economic and environmental changes, the application of agro-ecological principles to these smallholder production systems will likely play a key role in improving their resilience. Livestock development policies in West African countries in general, and in Benin especially, recognize the need to promote local production through the rational use of the indigenous animal genetic resources. However, no prompt action has been taken to conserve in situ the Lagune Cattle breed. The results of this study suggest that the risk of dilution of the Lagune breed could be reduced by raising awareness among breeders, improving their technical skills and herd management practices, and empowering them to develop legal institutions and collective actions for the sustainable management of the breed. The valorization of the breed in its natural ecosystem calls for further policy options that support the diversity of Lagune farming systems and include: (i) Facilitating participatory management/community-based initiatives; (ii) promoting agro-ecological innovations for more resilient production systems; (iii) providing infrastructure services for breed development (livestock markets and veterinary services) and a breed selection program for improving animal performances.

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