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Evaluation of zootechnical parameters of Azawak cattle based on data recorded in the secondary livestock multiplication centers (SLMC) of Toukounous, Bathé and Ibécetène

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Abstract

This study aimed to evaluate the zootechnical parameters of Azawak zebu cattle raised in Secondary Livestock Multiplication Centers (SLMCs) in Niger from 2012 to 2024, based on the analysis of annual reports. The comparative analysis of the three centers (Bathé, Ibécetène, and Toukounous) revealed significantly better performance from the Toukounous animals compared to the other two centers in terms of fertility rates, fecundity, and numerical herd productivity. However, annual variability was observed, with a trend starting in 2021 characterized by a decrease in reproduction and an increase in mortality, leading to a negative apparent growth rate.

Statistical modeling identifies the main factors influencing herd growth: mortality rate and numerical exploitation rate negatively and significantly impact the growth rate. These results indicate that improving the productivity and sustainability of livestock management centers (SLMCs) relies primarily on reducing animal mortality and optimizing herd transfer management. The Toukounous center's management model is recommended for other centers to improve the performance of Azawak zebu livestock farming and contribute to pastoral security in Niger.

Keywords: Secondary Livestock Multiplication Centre; Zootechnical parameters; Numerical herd productivity; Growth rate; Mortality rate; Herd management; Azawak Zebu; Niger

1. Introduction

Niger, a Sahelian country covering 1,267,000 km^2, relies primarily on agriculture and livestock farming. This sector employs nearly 87% of the active population and contributes approximately 11% to the national GDP and 35% to agricultural GDP [2; 12; 19]. The cattle herd was estimated at over 15 million head in 2020. [11; 17] consists of five breeds, including four zebu (Azawak, Bororo, Djelli, Goudali) and one taurine breed, the Kouri. Among these breeds, the Azawak zebu, originating from the Azawak Valley straddling Niger, Mali, and Burkina Faso, is particularly well-adapted to the harsh climatic conditions of the Sahel [22]. It is distinguished by its large size (128-135 cm at the withers), its hardiness, its resistance to heat, and by its appreciable performance in milk and beef production [5]. This breed plays a major economic, social, and cultural role by providing milk, meat, and labor, but its productive potential remains limited by the constraints of extensive livestock farming, food shortages, and uncontrolled crossbreeding [10]. Furthermore,

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the FAO [6], it was emphasized that phenotypic and zootechnical characterization is an essential step in the sustainable management of animal genetic resources. In this context, the evaluation of the zootechnical parameters of the Azawak zebu is of paramount importance for its optimal use and conservation. This study aimed to contribute to the improvement of the management of Secondary Livestock Multiplication Centers (SLMCs) in Niger. Specifically, it aimed to evaluate the zootechnical parameters of the Azawak zebu according to the center, analyze the evolution of these parameters in the SLMC throughout the year, and determine the zootechnical factors influencing the growth rate of the Azawak herd.

2. Materials and methods

2.1. Animal breeding sites

The animals are raised in the secondary livestock multiplication centers of Toukounous, Ibécetène and Bathé. These centers are located respectively between 14°30'8.7" North latitude and 3°17'53.1" East longitude; 15°19'47.52" North latitude and 5°52'53.1" East longitude; 14°58'5.04" North latitude and 7°53'11.88" East longitude.

In these areas, the climate is Sahelian-Saharan, with an average rainfall of 300 mm. The vegetation is steppe-like, and the main herbaceous species found are: *Cenchrus biflorus, Dactyloctenium aegyptium, Cenchrus preurii, Aristida mutabilis, Alysicarpus ovalifolius, Zornia glochidiata, Eragrostis Tremula and Tribulus terrestris. As for woody species, we find Balanites aegyptiaca, Ziziphus mauritiana, Maerua crassifolia, Sclerocarya birrea, Acacia seyal, Acacia nilotica, Acacia senegal, Calotropis procera, Bauhinia rufescens and Boscia senegalensis*.

The farming methods used in these centers are semi-intensive, with minimal inputs. The animals' diet is based primarily on natural pastures, supplemented during the dry season with cottonseed meal or wheat bran at an average rate of 2 kg per cow. The animals are watered with well water, and external and internal deworming is carried out twice a year. The animals are vaccinated against contagious bovine pleuropneumonia, symptomatic and bacterial anthrax, and bovine pasteurellosis [18].

2.2. Data Collection

Data collection consisted of using the annual zootechnical monitoring reports of the three secondary livestock multiplication centers from 2012 to 2024. The information sought includes the number of animals (number of head), the number of females of reproductive age, abortions, stillbirths, weanings, births, purchases, donations received, additional transfers, mortalities, slaughters, sales, donations made, transfers under, thefts, losses, and the numbers at the beginning and end of the year.

2.3. Data Analysis

2.3.1. Calculation of Zootechnical Parameters

The different parameters were calculated according to the formulas used by Amadou [1].

$$\text{Birth rate (\%)} = \frac{\text{Number of births x 100}}{\text{Number of females of reproductive age}}$$

$$\text{Prolificacy rate (\%)} = \frac{\text{Number of live births x 100}}{\text{Number of females that gave birth}}$$

$$\text{Fecundity rate (\%)} = \frac{\text{Number of live births x 100}}{\text{Number of females of reproductive age}}$$

$$\text{Mortality rate (\%)} = \frac{\text{Number of deaths x 100}}{\text{Average number of people present}}$$

$$\text{True fertility rate (\%)} = \frac{\text{Number of pregnant females x 100}}{\text{Number of females of reproductive age}}$$

With:

Number of pregnant females = number of females that gave birth + number of females that aborted

Number of females that gave birth **=** number of females that produced live offspring + number of females that produced dead offspring

$$\text{Apparent fertility rate (\%)} = \frac{\text{Number of females that have given birth x 100}}{\text{Number of females of reproductive age}}$$

$$\text{Abortion rate (\%)} = \frac{\text{Number of abortions x 100}}{\text{number of females of reproductive age}}$$

$$\text{Stillbirth rate (\%)} = \frac{\text{Number of stillbirths x 100}}{\text{Number of females of reproductive age}}$$

$$\text{Numerical Exploitation Rate} = \frac{\text{Total number of animals removed from the herd x 100}}{\text{Average herd size}}$$

With:

$$\text{Total number of animals removed from the herd} = \text{slaughter, sale, transfer, donation, etc.}$$

$$\text{Average number} = \frac{\text{Initial number} - \text{Final number}}{2}$$

$$\text{Gross growth (GG)} = \frac{(\text{Year end workforce} - \text{Year beginning workforce) x 100)}}{\text{Average workforce}}$$

$$\text{Numerical Herd productivity} = \frac{\text{number of weaned animals x 100}}{\text{number of females of reproductive age}}$$

2.3.2. Statistical Analysis

The database, consisting of parameters calculated for the Azawak, was subjected to the GLM (General Linear Model) procedure of SPSS 20.0. Throughout the analyses, the calculated parameters were considered as dependent variables and race and center as fixed variables.

A linear regression was performed with XLSTAT 2014 to determine the parameters that significantly influence the growth rate of the herd.

3. Results

3.1. Evaluation of the zootechnical parameters of the cattle herd according to the center

Table 1 compares the zootechnical parameters of the three centers (Bathé, Ibécetène, and Toukounous). Highly significant differences ($p < 0.001$) are observed for True Fertility Rate, Apparent Fertility Rate, Fecundity Rate, Numerical Herd Productivity, and Numerical Exploitation Rate. These zootechnical parameters are significantly better for the Toukounous herd compared to the other two centers.

No statistically significant difference was observed for abortion rates ($p=0.101$) and stillbirth rates ($p=0.556$). However, relatively high rates were noted in Ibécetène for abortion (2.14%) and in Toukounous for stillbirth (1.88%). The mean mortality rates were not statistically different ($p=0.334$) between the centers, ranging from 5.5% (Ibécetène) to 9.24% (Bathé). Regarding the apparent growth rate, no significant difference was also found ($p=0.239$). Nevertheless, negative values were noted for Bathé (-6.4%) and Toukounous (-9.9%), and a slightly positive value for Ibécetène (3.4%).

Table 1 Zootechnical parameters of the Azawak cattle herd according to the centers

	Centers				
Settings	**Bathé**	**Ibécetene**	**Toukounous**	**Average**	**p-Value**
True fertility rate	37.87 ± 16.34 [b]	29.72 ± 12.76 [b]	54.71±14.13 [a]	40.77±17.60	0.000
Apparent fertility rate	37.22 ± 16.31 [b]	27.57 ± 11.65 [b]	53.52 ± 13.82 [a]	39.44±17.46	0.000
Fecundity rate	36.09 ± 16.21 [b]	26.10 ± 10.83 [b]	51.64 ± 13.39 [a]	37.94±17.03	0.000
Abortion rate	0.65±0.86 [a]	2.14±2.78 [a]	1.19±0.82 [a]	1.33±1.81	0.101
Stillbirth rate	1.13±1.61 [a]	1.48±2.02 [a]	1.88±1.63 [a]	1.50±1.74	0.556
Mortality rate	9.24 ± 5.62 [a]	5.50±3.30 [a]	8.31 ± 9.43 [a]	7.68±6.64	0.334
Numerical Exploitation Rate	17.31 ± 6.76 [a]	8.95 ± 4.56 [b]	22.62 ± 8.12 [a]	16.29 ± 8.62	0.000
Numerical herd productivity	30.86 ± 9.08 [b]	18.90 ± 17.38 [b]	45.37±13.69 [a]	31.71±17.35	0.000
Apparent Growth Rate	-6.42±17.16 [a]	3.36±19.84 [a]	-9.91±23.44 [a]	-4.32±20.57	0.239

3.2. Evaluation of the zootechnical parameters of the cattle herd according to the year

Table 2 presents the zootechnical parameters over 13 years (2012-2024) of the cattle herds in the Secondary Livestock Multiplication Centers (SLMCs) of Bathé, Ibécetène and Toukounous.

The true fertility, apparent fertility, and fecundity rates show moderate average values (around 40%), but with very high individual variability (large standard deviations). There is no significant difference between years for these parameters (p-value > 0.05). However, a worrying drop in values is noted starting in 2021, which intensifies in 2023 and 2024, reaching very low levels (true fertility at 21.04%). The average abortion rate is low (1.33%) and stable (p>0.05), which is a positive point. The stillbirth rate is low on average (1.50%), but shows a statistically significant variation (p=0.016). The year 2018 stands out with a very sharp peak (5.43%). An average mortality rate of 7.68% was noted. This rate shows a highly significant increase (p=0.023) over the years, rising from approximately 3-6% before 2020 to more than 16-18% after 2023.

Numerical Exploitation and Productivity Rates are stable (p>0.05) at around 16% and 32% respectively. Regarding the apparent growth rate, which is the most revealing parameter, the 13-year average is negative (-4.32%). and its variation is significant (p=0.017). Recent years (2021-2024) show extremely sharp declines, up to -40.97% in 2023.

Table 2 Zootechnical parameters of the Azawak cattle herd according to the center

Settings									
Years	**True fertility rate**	**Apparent fertility rate**	**Fecundity rate**	**Abortion rate**	**Stillbirth rate**	**Mortality rate**	**Numerical Exploitation rate**	**Numerical productivity rate**	**Apparent growth rate**
2012	53.19±30.5 a	52.74±30.17 a	50.47±28.40 a	0.46±0.79 a	2.27±3.39 ab	6.53±2.50 c	16.01±7.80 a	37.01±26.93 a	-1.80± 8.79 ab
2013	45.83±21.5 a	44.86 ±21.10 a	44.01±22.15 a	0.97±0.60 a	0.86± 1.21 b	3.35±1.69 c	14.21 ± 8.22 a	28.36±12.72 a	2.47± 3.18 ab
2014	43.42±26.58	43.04±26.57 a	43.04±26.57 a	0.38±0.66 a	0.00 b	4.57±3.09 c	13.87±3.01 a	29.42±26.47 a	-0.58± 7.64 ab
2015	37.91±17.55	36.79±17.58 a	35.88±16.75 a	1.12± 0.98 a	0.91± 0.83 b	6.14±4.18 c	15.30 ±7.56 a	30.03±23.80 a	15.72±37.11 a
2016	39.52±21.47	38.00±21.32 a	36.47±20.20 a	1.52± 0.87 a	1.53±1.15 ab	4.63±1.48 c	15.92 ±4.20 a	30.97±21.92 a	-1.47±3.15 ab
2017	37.30±15.84	36.79 ±15.53 a	35.80±15.40 a	0.51±0.46 a	0.99± 0.40 b	3.18±1.71 c	14.30±6.62 a	28.83±18.63 a	1.84±5.41 ab
2018	54.64±5.75 a	50.88±3.73 a	45.45±5.50 a	3.76±4.34 a	5.43± 1.91 a	4.47± 0.71 c	11.18±12.49 a	33.73±12.14 a	12.35± 13.63 a
2019	43.50±16.8 a	42.55±15.86 a	41.84±15.73 a	0.94±1.24 a	0.71± 0.62 b	4.41±1.71 c	17.53±13.50 a	39.19±16.42 a	5.41±8.04 ab
2020	47.06±7.46 a	46.28 ± 8.13 a	44.74±9.47 a	0.77±0.67 a	1.55±1.34 ab	8.12± 4.05 b c	18.57±16.02 a	30.15±7.81 a	-2.04±18.88 ab
2021	34.29±19.24	32.41 ±19.52 a	30.47±19.65 a	1.87±1.20 a	1.94±0.58 ab	11.61± 7.87 abc	23.34± 13.07 a	28.89±25.98 a	-19.80±10.66 ab
2022	44.58±16.4 a	43.57±15.69 a	42.33±15.01 a	1.01±0.88 a	1.25± 1.19 b	7.46 ± 2.20 c	12.80 ±6.23 a	48.28±13.60 a	-1.18±11.00 ab
2023	27.67±11.8 a	25.09±11.80 a	23.46±11.35 a	2.59±3.74 a	1.62± 1.55 ab	16.89±15.12ab	22.97±6.69 a	28.62±20.38 a	-40.97±33.48 b
2024	21.04±3.90 a	19.69±1.62 a	19.29±0.99 a	1.35±2.34 a	0.40± 0.70 b	18.54±5.42 a	15.77±8.59 a	18.72±10.62 a	-26.14±8.64 ab
Average	40.77±17.60	39.44±17.46	37.94±17.03	1.33±1.81	1.50±1.74	7.68±6.64	16.29 ±8.62	31.71±17.35	-4.32±20.57
p-Value	0.641	0.606	0.657	0.674	0.016	0.023	0.938	0.956	0.017

3.3. Determination of zootechnical parameters that influence the gross growth rate of the Azawak cattle herd

The model is statistically highly significant ($p < 0.0001$). The R^2 of 0.75 means that it explains 75%. of the variability in the apparent growth rate of the herd. The adjusted R^2 of 0.72 confirms the good explanatory quality of the model (Table 3).

The Mortality Rate ($\beta = -1.89$; (standardized $\beta = -0.61$; $p < 0.0001$) is the most influential parameter on the apparent growth rate of the Azawak cattle herd in the SLMCs of Toukounous, Bathé, and Ibécetène, with a strong negative impact. The Numerical Exploitation Rate ($\beta = -1.02$; standardized $\beta = -0.43$; $p < 0.0001$) also significantly influences the apparent growth rate of the herd with a moderate negative impact. The fecundity rate ($p = 0.066$) has a positive, but not significant, effect. The Numerical Productivity Rate ($p = 0.492$) also has a non-significant effect.

The VIFs are all less than 3, indicating the absence of collinearity problems between the variables (Table 4).

Figures 1, 2, 3, and 4 below show that normality, linearity, and homoscedasticity are verified. The model is therefore reliable.

The formula for the model is:

Apparent growth rate = 18.10569 + 0.33067 x Fecundity rate -1.88947 x Total mortality -1.02272 x Numerical exploitation rate -0.11963 x Numerical productivity rate

Table 3 Model characteristics

Model	R-two	R-two adjusted	Standard error of the estimate	p-value
1	0.75	0.72	10.94	< 0.0001

Table 4 Model parameters

Source	Coefficient (β)	Standard error	β standardized	p-value	Lively	Lower limit (95%)	Upper limit (95%)
Constant	18.11	5.76		0.003		6.40	29.81
Fecundity rate	0.33	0.17	0.27	0.066	2.79	-0.02	0.68
Mortality Rate	-1.89	0.29	-0.61	< 0.0001	1.17	-2.48	-1.30
Numerical Exploitation Rate	-1.02	0.22	-0.43	< 0.0001	1.16	-1.47	-0.57
Numerical Productivity Rate	-0.12	0.17	-0.10	0.492	2.83	-0.47	0.23

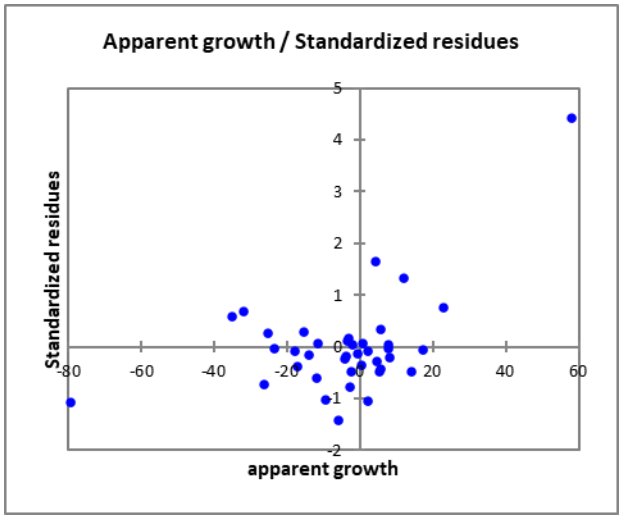

Figure 1 Normalized residuals as a function of the growth rate

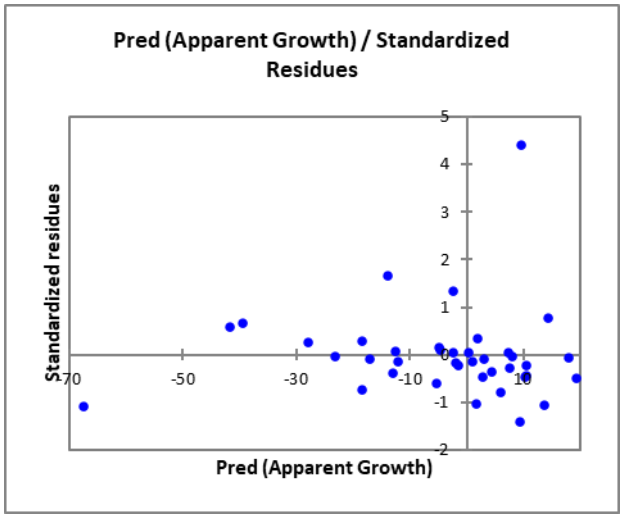

Figure 2 Normalized residuals as a function of growth rate predictions

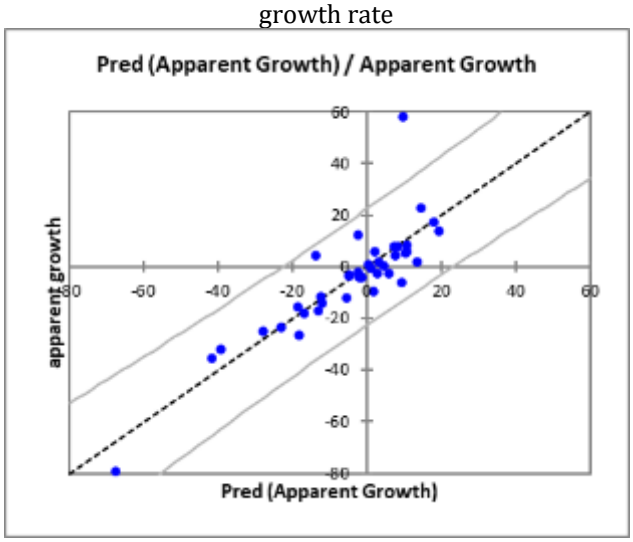

Figure 3 Growth rate as a function of growth rate predictions

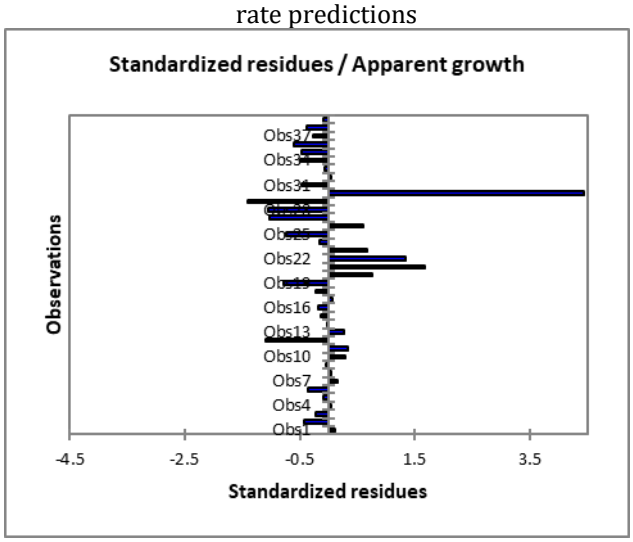

Figure 4 Prediction of the growth rate as a function of the growth rate

4. Discussion

4.1. Analysis of the zootechnical parameters of the cattle herd according to the centers

Fertility and fecundity are key indicators of reproductive efficiency. They are influenced by genetics, nutrition, animal health, and breeding management. The observed discrepancies suggest major differences in rearing conditions between centers. The performance of Toukounous is remarkable and could be explained by better nutrition, a better-adapted genetic strain, or more effective veterinary management practices. Such values are often associated with well-managed intensive farming systems [8]. The poor results recorded at Ibécetène highlight potential constraints such as nutritional stress (mineral deficiencies, insufficient feed, etc.), health problems (reproductive diseases such as brucellosis), or deficiencies in breeding management [14].

Regarding abortion and stillbirth rates, the lack of significant difference suggests that the causes of abortion and stillbirth (infections, trauma, stress, congenital anomalies) are relatively similar and probably at a low endemic level in all three centers. The slightly higher abortion rate at Ibecetène could be a further indication of underlying health or nutritional problems [23]. The stillbirth rate at Toukounous, although the highest, could be an indirect consequence of a greater number of births, without the specific cause being identified.

Mortality rates, although statistically similar between centers, are concerning from an economic point of view. An acceptable mortality rate in well-managed livestock systems is generally less than 5%. The values observed, particularly

at Bathé, indicate significant losses, potentially linked to neonatal diseases, nutritional deficiencies, or housing problems [21].

The exploitation rate reflects the economic efficiency of the center. A low rate, as at Ibécetène, means that few animals are sold or given away, which may be due to low demand, conformity issues, or a herd conservation strategy for breeding. Numerical productivity herd is the most important composite parameter: it represents the number of weaned offspring produced per 100 females put to breeding. The value of 18.9% at Ibécetène is critical and reflects the combination of low fertility and significant mortality. Conversely, the performance of Toukounous (45.4%) is indicative of an efficient production system [15].

For the growth rate, which measures the change in herd size, negative values indicate a reduction in livestock over the period. This is consistent with the high exploitation rates of Bathé and Toukounous, which harvest more animals than are born and survive. The slightly positive value for Ibécetène is logical given its very low exploitation rate. A negative growth rate is not necessarily bad if it results from a deliberate, aggressive marketing strategy, but it is not sustainable in the long term without an external supply of breeding stock.

4.2. Analysis of the zootechnical parameters of the cattle herd according to the year

True and apparent fertility and fecundity rates around 40% are considered low for controlled systems such as CSMB. Under optimal cattle farming conditions in the Sahel, fertility rates exceeding 60–65% would be expected [7]. This low performance is most likely linked to nutritional, health, and climatic stress factors**.** Undernutrition, common in the Sahel, delays puberty, prolongs postpartum anestrus, and reduces the conception rate. The work of Lhoste et al. [16], have clearly established the link between energy deficit and decreased fertility in cattle in sub-Saharan Africa.

A low abortion rate generally indicates relatively effective disease control against major abortive pathogens (Brucellosis, Rift Valley Fever, etc.). The peak in stillbirths in 2018 is alarming. It may be linked to: i) Acute nutritional stress caused by drought or a forage shortage specific to that year. ii) The emergence of an infectious disease (such as Rift Valley Fever during heavy rains) or severe nutritional deficiencies affecting calves at birth. iii) Difficulties during calving.

The literature, particularly the World Bank reports [4], on climate resilience in the Sahel, highlights the direct impact of climate shocks on zootechnical performance, which may explain such fluctuations.

A mortality rate exceeding 10% is critical in any livestock system. The figures for 2023 (16.89%) and 2024 (18.54%) are catastrophic and indicate a major crisis. This exponential increase is very likely due to multiple factors:

The intensification of droughts and the irregularity of rainfall, documented by the IPCC [9], for the region, this leads to degradation of pastures and water shortages, weakening the animals;

The increase in parasitic diseases (such as gastrointestinal strongylosis) and infectious diseases (such as pasteurellosis) in a context of stress is a classic cause of excess mortality [20].

In some SLMCs like Toukounous, the increasing insecurity since 2021 is disrupting access to pastures, water points and veterinary care, worsening the situation.

A negative growth rate means that the herd is shrinking faster than it is renewing itself. For breeding centers, this represents a failure of their fundamental mission. This decline is the mathematical consequence of the combination of stagnant fertility, rising mortality, and a maintained exploitation rate. The model has become unsustainable. As Lesnoff et al. [15] point out, in their models of Sahelian herd dynamics, a prolonged negative growth rate inevitably leads to the disappearance of the herd if it is not corrected by external inputs.

4.3. Analysis of the influence of zootechnical parameters of the Azawak cattle herd on the apparent growth rate

The pronounced negative effect ($\beta = -1.89$) confirms that mortality is the main constraint on herd growth. Each 1% increase in the mortality rate reduces the growth rate by approximately 1.89%. A counterintuitive effect was observed for the Numerical Productivity rate. Indeed, the negative impact (standardized $\beta = -0.10$) suggests that overly intensive management is detrimental to herd growth. This could indicate sales or slaughter practices that compromise future reproduction. This finding is consistent with that of Yahaya et al. [24]. which states that an increase in herd size is linked to low mortality and low exploitation. Also, according to Azalou et al., [3], a positive growth rate in an animal population

is linked to interventions aimed at improving survival and reproduction parameters, and a low growth rate, to poor reproduction and mortality parameters associated with high numerical exploitation.

In general, in livestock farming, management rates are reflected in the exploitation rate and the import rate carried out by farmers. The different types of exploitation practiced by farmers are essentially slaughtering, sales, loans, and donations [13]. The positive, but not statistically significant, effect ($p = 0.066$) warrants attention. This could suggest that the improvement in fertility might become significant with a larger sample size.

5. Conclusion

This study assessed the zootechnical parameters of Azawak zebu cattle in three Secondary Livestock Multiplication Centers (SLMCs) in Niger from 2012 to 2024. The analysis revealed a significant influence of the center on the main performance indicators. The Toukounous center showed the best results for fertility rates, fecundity, and numerical productivity, while Ibécetène recorded the lowest performance for these same parameters as well as for the exploitation rate. In contrast, abortion, stillbirth, and mortality rates did not show significant differences between the centers, suggesting that common management factors or similar environmental constraints may affect animal health in a homogeneous manner.

The temporal analysis revealed significant interannual variability for some parameters, including stillbirths, mortality, and apparent growth rate. The most recent years (2021–2024) are characterized by a worrying downward trend in reproductive indicators and an increase in mortality, resulting in a negative and significantly lower apparent growth rate in 2023. This deterioration could be linked to increased climatic, health, forage, or security pressures.

The regression model ($R^2 = 0.75$) identified that herd dynamics, represented by the apparent growth rate, are primarily negatively influenced by the mortality rate and the numerical exploitation rate. This means that to increase herd size, management efforts should focus primarily on reducing losses (mortality) and implementing a more reasoned and appropriate transfer policy (exploitation).

In conclusion, this study provides concrete levers for action to improve the management of livestock management centers (CSMBs). Improving the productivity of the Azawak zebu will require strengthening health and feeding practices to reduce mortality, as well as strategically optimizing animal sales. Replicating the management practices of the Toukounous center, which has demonstrated the greatest effectiveness, could serve as a model to improve the performance of other centers and thus contribute to national pastoral security.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no conflict of interest to declare.

Statement of informed consent

Informed consent was obtained from all study participants.

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