Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Factors Improving Production and Reproduction Performance of Cattle Herds in South Kivu, Democratic Republic of Congo

VICTOR NTWALI MITUGA

vickymituga@gmail.com

University of Lubumbashi: Universite de Lubumbashi https://orcid.org/0009-0002-7221-7324

Abdallah Idi Ngona

Université de Lubumbashi: Universite de Lubumbashi

Dieudonné Musale Katunga

University of Cinquantenaire Lwiro: Universite du Cinquantenaire de Lwiro

Salvius Amuri Bakari

Université de Lubumbashi: Universite de Lubumbashi

Christian Hanzen

University of Liege: Universite de Liege

Research Article

Keywords: cattle, reproduction, crossbreeding, synchronization, South Kivu

Posted Date: November 19th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11132481/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Factors Improving Production and Reproduction Performance of Cattle Herds in South Kivu, Democratic Republic of Congo

Victor Ntwali Mituga [1,2]*0009-0002-7221-7324 , Abdallah Idi Ngona [1], Dieudonné Musale Katunga [2,5], Salvius Amuri Bakari [3], Christian Hanzen[4]

[1]Faculty of Veterinary Medicine, University of Lubumbashi, Democratic Republic of Congo
[2] Faculty of Veterinary Medicine, University of Cinquantenaire, Democratic Republic of Congo

[3]Faculty of Pharmaceutical Sciences, University of Lubumbashi, Democratic Republic of Congo
[4]Faculty of Veterinary Medicine, University of Liège, Belgium

[5]National Institute for Agricultural Study and Research (INERA/ Mulungu) DS

Email corresponding*: vickymituga@gmail.com

Ngona Idi Abdallah <idin@unilu.ac.cd>,

Katunga Musale <katungamusale@yahoo.fr>

Salvius Bakari Amuri <bakari.amuri@unilu.ac.cd>

Hanzen Christian christian.hanzen@uliege.be

Abstract

This study evaluated the reproductive and zootechnical performance of local Ankole cows subjected to artificial insemination (AI) and examined environmental, demographic, and husbandry factors associated with these performances in four territories of South Kivu Province, Democratic Republic of Congo. A total of 806 cows were inseminated, of which 337 were monitored until calving and included in the analysis. The mean cow age was 7 ± 3 years. The mean interval from calving to conception was 200 ± 120 days, and the mean calving interval was 474 ± 119 days, indicating prolonged reproductive intervals. Mean gestation length was 275 ± 2 days, within the physiological range for cattle, while mean calf birth weight was 46 ± 3 kg.

Growth assessment of 687 calves showed a mean heart girth of 114.2 cm and mean wither height of 96.7 cm at approximately seven months of age. Heart girth was positively correlated with live weight, while wither height reflected skeletal development. The relationships among age, live weight, heart girth, and wither height indicated progressive growth during the monitoring period.

Factor Analysis of Mixed Data (FAMD) highlighted differentiation according to environmental and geographical conditions, although these associations were exploratory rather than causal. The

distribution of introduced sire breeds varied across agro-ecological zones: Jersey predominated at low altitudes, Friesian at medium and high altitudes, and Sahiwal across low- and medium-altitude zones. Overall, improved reproductive monitoring, postpartum management, nutrition, and AI practices could enhance cattle productivity in smallholder systems in South Kivu.

Keywords: cattle, reproduction, crossbreeding, synchronization, South Kivu

1. Introduction

Artificial insemination (AI) allows rapid genetic improvement, particularly for introducing high-performing breeds (Eulmi et al. 2024). In rural areas, adoption is limited by constrained access to semen, AI equipment, skilled personnel, low farmer awareness, and poor heat synchronization, especially under extensive systems (Mruttu et al. 2017). Weak government support further limits implementation.

Calving season significantly affects reproductive performance. In tropical regions, estrus is often less visible during dry seasons due to thermal and nutritional stress, lowering conception rates. Optimal calving periods typically follow the rainy season, when feed resources are abundant, improving body condition and resumption of reproductive cycles (Mwacharo & Drucker 2005). Bovine homeothermy uses behavioral and physiological control mechanisms to manage heat exchange between the body and the environment to cope with heat stress (Hanzen et al. 2024; Ferag et al. 2025).

The absence of reproductive monitoring prevents accurate characterization of reproductive performances. Without proper tracking, female animals risk infertility, as critical reproductive events remain undocumented. Livestock management, combined with unimproved pastures, often lacks structured mating strategies that consider female energy balance, estrus synchronization, or AI with improved bulls.

Several avenues exist to enhance reproduction: hormonal synchronization of estrus to optimize AI timing (Grimard et al. 2003; PICAGL report 2021), regular reproductive monitoring (gynecological exams, estrus observation) (Hanzen 2015), improved feeding to prevent postpartum anestrus (Abeygunawardena & Dematawewa 2004), and seasonal planning of inseminations (Marquezini et al. 2011; Chagunda et al. 2016).

Pastoral communities are encouraged to adopt herd management strategies that enhance both production and reproduction, overcoming constraints that limit fecundity. Effective reproductive management can ensure numerical, weight-based, and milk production productivity, generating income for cattle farmers in Kabare, Kalehe, Uvira and Walungu .

Evaluating infecundity and infertility using monthly reproductive follow-up allows identification and correction of functional reproductive issues, which directly affect herd productivity. Increasing herd productivity and farm profitability is essential for food security, financial self-sufficiency, and sustainable adoption of innovations in rural cattle systems.

Empirical management of local cows requires a more assisted reproductive approach to increase production and farm profitability (Negrón-Pérez et al. 2019). Implementing assisted reproduction can improve farmer incomes and overall rural livelihoods (Zamukulu et al. 2018 ; M'She et al. 2026). The study also explores the underlying causes of low adoption of assisted reproduction (hormonal synchronization, reproductive disease management, capacity building) and potential solutions.

Estrus synchronization is a critical preparatory step for AI or natural mating, ensuring effective management of reproductive females (Bisinotto et al. 2010). Promoting this practice can enhance reproductive performance and, consequently, production efficiency and profitability (Bounouala 2025). Improved reproductive outcomes also contribute to food self-sufficiency in rural communities, with income generation helping reduce poverty among pastoral populations.

The aim of this study is to characterize reproduction and production performances in local female cattle through natural and artificial insemination results, to identify influencing factors (breed, sex, altitude/geographical administrative units) and to evaluate zootechnical outcomes following crossbreeding of local Ankole cattle with imported semen or mating with Friesian, Jersey and Sahiwal bulls.

2. Material et methods

2.1. Study Area

The map shows the geographic position of South Kivu within the DRC and highlights its 4 main administrative territories: Kabare (1 960 km²), Kalehe (5 057 km²), Uvira (3081 km^2) and Walungu(1800

km^2). This regional context situates the study area relative to national boundaries and major landscape features (Fig. 1).

Fig. 1 Map of South Kivu Province in the Democratic Republic of Congo (DRC) and its Territories. (Source: adapted from ResearchGate, consulted 10 June 2025 - original at http://www.researchgate.net)

South Kivu Province is located in the eastern part of the Democratic Republic of Congo, between 1°36′ and 5°00′ South latitude and 26°47′ and 29°20′ East longitude. It covers approximately 69,130 km², representing about 3% of the national territory. The province borders Rwanda, Burundi, and Tanzania to the east, North Kivu to the north, Maniema to the west, and Maniema and Tanganyika to the south. This strategic transboundary position partly explains the diversity of production systems, livestock movements, and market linkages observed in the region.

The topography is highly heterogeneous and constitutes a major structuring factor for agricultural and livestock systems. The eastern part is predominantly mountainous, with high elevations associated with the Mitumba mountain chain, culminating at Mount Kahuzi (3,308 m). In contrast, the central and western zones are characterized by a mosaic of high, medium, and low plateaus.

The Ruzizi Plain, a low-altitude zone (around 746 m at Lake Tanganyika), extends from Uvira to Kamanyola and represents a distinct agroecological unit marked by higher temperatures and seasonal water stress. Medium-altitude zones (1,200–1,800 m) are mainly found in Walungu and Kabare, as well as in Idjwi and parts of Kalehe (Buloho). High-altitude areas (>1,900 m) correspond to the highlands of Kabare, Walungu (Mulume-Munene), Kalehe (Kalonge), Fizi, and eastern Mwenga. These sharp altitudinal gradients strongly influence forage availability, disease pressure, and the suitability of cattle breeds.

Climate in South Kivu is largely altitude-driven, resulting in marked contrasts over relatively short distances.

High-altitude areas (>1,900 m) experience a cool and humid climate, with mean temperatures around 10 °C, abundant rainfall (~1,800 mm/year), and a short dry season (June–August). Vegetation is dominated by mountainous grasslands and forest formations, including those of the Kahuzi-Biega National Park.

Medium-altitude zones (1,200–1,900 m) have a warm temperate and humid climate, with temperatures ranging from 12 to 20 °C, and landscapes shaped by hills and valleys. The abundant rainfall (1800 mm)

is evenly distributed throughout the rainy season.

Low-altitude zones (<1,000 m), such as the Ruzizi Plain (Uvira, Kamanyola), are characterized by a tropical dry climate, lower annual rainfall (~1,000 mm), and savanna vegetation ranging from grass-dominated to thorny formations.

In the western and central territories (Shabunda, Mwenga), the climate becomes equatorial, hot and humid, with abundant rainfall (800–1,500 mm/year) and dense evergreen forest cover. Bukavu, the provincial capital, has a mean annual temperature of approximately 19 °C. These climatic contrasts impose differentiated constraints on cattle nutrition, reproduction, and health management.

The hydrographic network is dominated by two major lakes: lake Kivu and lake Tanganyika. Lake Kivu, with a maximum depth of about 1,470 m, is the second deepest lake in the world after lake Baikal, while lake Tanganyika (773 m deep) is renowned for its high biological productivity. The two lakes are connected by the Ruzizi River (IPPEL rapport 2023).

Territories covered by the study

The study focused on four territories: Kabare, Kalehe, Uvira and Walungu. Together, they encompass low-altitude areas (Uvira, Kamanyola), medium-altitude areas (Walungu/Burhale, Kabare), and high-altitude areas (Mulume-Munene in Kabare and Walungu; Kalonge and Mbinga-Sud in Kalehe). This deliberate selection captures the agroecological diversity of South Kivu and allows comparison of cattle reproductive performance across contrasting environments. Data were collected between March 2020 and November 2024.

2.2. Livestock

The data used in this study comes from the analysis of the artificial insemination campaign conducted in rural communities in the territories of Kabare, Kalehe, Uvira, and Walungu from March to November 2024. Of the 806 cows inseminated, only 337 could be followed to calving and formed the basis for the analysis of fecundity parameters. Data on growth was collected from June to August 2024. A total of 687 cattle were bred from Ankole females crossed with Friesian, Jersey, and Sahiwal semen or bulls. The age groups considered were newborns, 2 months, 7 months, 12 months, and 15 months.

2.3. Methods

138 Data collection and artificial insemination

139 The data analyzed in this study were derived from an artificial insemination (AI) campaign conducted in
140 rural communities of the Kabare, Kalehe, Uvira and Walungu territories.

141 Critically, the relatively low proportion of cows monitored until calving reflects structural limitations in
142 longitudinal herd monitoring, which remains a key constraint for robust reproductive performance
143 evaluation in traditional cattle systems of South Kivu.

144 Due to the absence of systematic monitoring of returns to estrus, the study could not assess fertility in
145 the strict sense (i.e., conception rate). The analysis consequently focused on fecundity, defined here as
146 the necessary time to obtain a successful establishment of pregnancy (and/or calving) following
147 insemination. This methodological limitation reflects the structural constraints of field conditions in
148 smallholder systems, where continuous reproductive monitoring is rarely feasible.

149 The AI campaign was implemented by Vétérinaires Sans Frontières (VSF) and was designed around
150 three main steps: estrus synchronization, artificial insemination, and pregnancy diagnosis. Although
151 pregnancy control was initially planned, its implementation remained limited because of the lack of
152 diagnostic tools such as ultrasonography, leading to reliance on later-stage confirmation methods.

153 Estrus synchronization protocol

154 Estrus was synchronized using hormonal protocols based on prostaglandin F2α (Syncro-part-500,
155 Enzaprost T), gonadotropin-releasing hormone (GnRH; Cysterline), and progestins (PRID). The most
156 frequently used protocol was the Cysterline-Enzaprost protocol, administered over a period of 7 or 9
157 days without the second dose of Cysterline .

158 From a critical standpoint, the predominance of this protocol reflects both its operational simplicity and
159 its adaptability to field conditions, but it also underscores the need for better standardization and follow-
160 up to optimize reproductive outcomes in low-input cattle systems (Table 1).

161 **Table 1** Hormonal synchronization protocol applied for artificial insemination

162 Note: Insemination was performed using imported semen from Friesian, Jersey, and Sahiwal bulls, using
163 one straw per cow. The insemination were perfomed by 13 trained private veterinary inseminators
164 distribuated among the study area.

Zootechnical data collection

Pregnancy was confirmed by rectal palpation from the fourth month onward. Information recorded by community health workers on insemination and calving dates in the different agro-climatic areas (low, medium, and high altitude) allowed for the calculation of the calving-to-pregnancy interval (DO:days open), the calving interval (CI), and gestation length at the time the calf's weight at birth was recorded using a scale (100kg) (0-2 weeks). During the growth of the young animals, their weight was measured using a perimeter tape. The age groups considered were newborns (0-2 weeks), 2 months, 7 months, 12 months, and 15 months.

Due absence of individual records, the age at first calving could not be determined. Body condition scores for the cows were not recorded; animal nutrition was primarily focused on existing forage resources, followed by high-biomass forage crops with good nutritional value. The low altitude (Ruzizi Plain) with pastures dominated by *Brachiaria ruziziensis*, the medium and high altitude (Bukavu Hinterland) with pastures dominated by *Pennisetum clandestinum* (Kikuyu grass).

Statistical analysis

The initial statistical analyses were performed using Microsoft Excel. The focus was on calculating the standard deviation, in order to assess the dispersion of values around the mean; the standard error, indicating the accuracy of the mean estimate based on the sample size and, if necessary, visualizing the distribution of variables and detecting any extreme values.

Analysis of factors influencing reproductive performance

Factors considered for reproductive parameters (DO, CI) included altitude (low, medium, high), geographical administrative unit below the Kingdom, which is also below the territory, and age of the female at AI. Birth weight was included as a production indicator, particularly in crossbreeding between exotic breeds and Ankole cattle.

Multivariate analysis: FAMD

A Factor Analysis for Mixed Data (FAMD) was performed using the FactoMineR package in R, with visualization via factoextra, to simultaneously explore quantitative and qualitative variables. The FAMD requires that each variable have a total weight of 1. Dimensions 1 and 2 correspond to axes (1 on the x-

192 axis and 2 on the y-axis), which are factorial axes representing the most influential biological and
193 geographic gradients.

194 Quantitative variables are the DO, the age, the calf birth weight and the gestation length. The qualitative
195 variables are the altitude, the geographical administrative unit and the calf sex.

196 Numeric variables were centered and scaled, while categorical variables were transformed into binary
197 indicators and weighted to prevent artificial dominance. FAMD enabled the identification of reproductive
198 profiles of females, visualization of individuals according to their farming environment, and extraction
199 of factorial axes representing the most influential biological and geographical gradients.

200 **3. Results**

201 **3.1. Fecundity parameters**

202 The inseminated cows were generally young to middle-aged, with a mean age of 7 ± 3 years. The
203 moderate standard deviation indicates a heterogeneous herd structure, reflecting the coexistence of
204 primiparous and multiparous females, which is typical of traditional mixed-age herds.

205 The mean number of days open was 200 ± 120 days, which is clearly prolonged and highly variable.
206 Similarly, the calving interval (CI) averaged 474 ± 119 days, equivalent to roughly 16 months. In contrast,
207 gestation length was remarkably stable (275 ± 2 days) and fully consistent with bovine physiological
208 norms. Likewise, mean birth weight (46 ± 3 kg) falls within the expected range for large-frame cattle and
209 crossbreds, suggesting satisfactory fetal development and acceptable maternal nutritional conditions
210 during gestation (Table 2).

211 **Table 2** Reproductive parameters of inseminated females (n = 337)

212 Legend: DO = days open i.e. calving-to-conception interval (CCI) ; CI = calving interval.

213 **3.2. Growth parameters: chest circumference and height at the withers**

214 The average chest circumference is 114.2 cm, corresponding to an estimated weight of 161.5 kg, while
215 the average height at the withers is 96.7 cm, indicating a young and growing population 7 months,
216 corresponding to the average for the age groups (Table 3).

217 **Table 3** Growth parameters according to calf age and sex

The overall sex ratio (0.38) indicates a predominance of females. The chi-square test reveals a significant difference between the geographical administrative unit ($\chi^2 = 36.68$; $p < 0.001$), demonstrating a non-uniform distribution. Luberizi (0.27) and Itara (0.32) have a lower sex ratio, while Bugorhe (0.56) and Bushumba (0.58) have a higher sex ratio.

Correlations between age, sex, and body measurements

The increasing age is accompanied by an increase in various body measurements, with varying degrees of intensity depending on the parameters considered. Chest circumference appears to be a relevant indicator of weight status, while height at the withers reflects skeletal development more closely, and this is true according to sex. There is a slight differentiation according to sex from a threshold of approximately 130 cm, corresponding to a slowing of growth. The skeletal development tends to stabilize from a height at the withers between 110 and 120 cm, chest circumference without marked distinction between the sexes.

The correlations highlight consistent positive relationships between age and weight ($r = 0.994$; very strong correlation), age and chest circumference ($r = 0.728$; moderate to strong correlation), age and height at the withers ($r = 0.572$; moderate correlation), weight and chest circumference ($r = 0.750$; strong correlation), weight and height at the withers ($r = 0.590$; moderate correlation), and chest circumference and height at the withers ($r = 0.689$; moderate to strong correlation). Chest circumference is a factor in assessing body weight, while height at the withers reflects skeletal development more closely (Fig. 2).

Fig. 2 Correlations between age (weight), chest circumference and height at the withers

3.2.1. Influence of altitude, age, and geographical administrative units

Altitude emerged as the primary factor determining variation in reproductive and growth performance, influencing both the level and stability of results. Age and group-specific management practices acted as secondary modifiers, refining performance within the broader environmental context imposed by altitude.

The factor map derived from the FAMD analysis highlighted the predominant influence of altitude on the structure of the observations.

At high altitudes, herd compactness resulted in significant internal stability for both reproductive and growth parameters. Conversely, farms at low altitudes exhibited marked heterogeneity, demonstrating a high sensitivity to environmental constraints and variations in agricultural practices.

The role of herd groups again appears as a complementary influence, acting primarily within each altitude class without altering the overall structure.

For reproduction, Dim1 (19.3%) primarily expressed internal variability within each altitude, with a particularly marked dispersion of individuals at low altitudes. This variability is associated with combined differences in growth, reproduction, and the age structure of the herds. Dim2 (15.3%) showed a clear discrimination between the three altitudinal levels: individuals at high altitudes are strongly clustered in the lower part of the plane, those at medium altitudes are concentrated in the upper part, and those at low altitudes are widely spread along the horizontal axis, revealing a strong dispersion (Fig. 3).

Fig. 3 Projection of Individuals (FAMD–Individuals) and Variable map (FAMD–Variables)

Legend : DO : days open (CCI), DO_log : days open logarithm, GAU : Geographical Administrative Unit

Regarding weight and age as factors influencing production performance, FAMD revealed a clear structuring of calves according to biological and environmental variables.

The projection of individuals integrating race and sex in relation to altitude and geographical administrative unit of which dimension 1 (10.1%), reflected a biological gradient of growth and dimension 2 was dominated by altitude and geographical administrative unit (9.1%), indicating a marked spatial and ecological organization (Fig. 4).

Fig. 4 Projection of Individuals (FAMD–Individuals) and Variable map (FAMD–Variables)

3.2.2. Influence of Altitude and Breed on Zootechnical Performance

Analysis of correlations between altitude classes, across all breeds, reveals low and negative coefficients: -0.21 between high and medium altitude, -0.20 between high and low altitude, and -0.17 between medium and low altitude. These results indicate a differentiated distribution of cattle according to ecological conditions, with each altitude favoring certain breeds. This highlights the ecological specialization of

breeds. The Jersey breed is mainly observed at low altitude : -0.42 between high and medium altitude, -0.34 between high and low altitude, and -0.30 between medium and low altitude ; the Friesian at medium and high altitude : -0.27 between high and medium altitude, -0.25 between high and low altitude, and -0.22 between medium and low altitude, while the Sahiwal shows a more flexible distribution between low and medium altitude : -0.21 between high and medium altitude, -0.21 between high and low altitude, and -0.16 between medium and low altitude (Fig. 5).

Fig. 5 Influence of Altitude and Breed on Zootechnical Performance

4. Discussion

4.1. Fecundity parameters

The inseminated cows showed a mean age of 7 ± 3 years, corresponding to animals that are still within their active reproductive phase but already approaching the latter part of their productive life. This age structure is comparable to that reported by Touré et al. (2017), who observed a mean age of 6 years and 7 months ± 1 year and 6 months. Such heterogeneity is typical of extensive and semi-intensive cattle systems, where replacement rates are irregular and productive lifespan is often extended beyond optimal reproductive efficiency (Eulmi et al. 2022).

The CCI of 200 days is markedly longer than the recommended 90 days for optimal reproductive performance. The very high variability (SD = 120 days) highlights major inconsistencies in herd management, nutritional status, and possibly underlying reproductive disorders (Kibwana et al. 2016). The wide dispersion points to strong individual differences in reproductive performance, likely driven by uneven nutritional status, postpartum anoestrus, variable estrus detection efficiency, and inconsistent reproductive follow-up. Such a long CCI indicates that, although conception eventually occurs, the system is inefficient in terms of reproductive rhythm.

Similar delays have been observed in extensive herds in Central Africa, reflecting the impact of limited husbandry and monitoring practices compared to intensive dairy farms in the North (Fodor et al. 2018). In the dairy sector, traditional approaches to reproductive management and the use of artificial insemination include either visual observation of estrous behavior or the use of fixed-time insemination protocols (Crowe et al. 2018).

The mean calving interval (CI) of 474 days largely exceeds the recommended standard of 365 days. Touré et al. (2017) reported a comparable average of 16 ± 5 months, with extremes ranging from 10 to 31 months, while Chapaux (2013) suggested an optimal interval of 380–390 days for dairy cows. Such prolonged calving intervals reflect cumulative reproductive failures, delayed resumption of ovarian activity, unsuccessful inseminations, and nutritional constraints.

The positive correlations observed between cow age and CI indicate that older cows tend to experience longer reproductive cycles, likely due to reduced physiological resilience and less rigorous reproductive monitoring. Breed composition further exacerbates this pattern. For instance, Manzi et al. (2018) showed that Ankole × Friesian crosses exhibited calving-to-first and calving-to-last insemination intervals as long as those observed in pure Ankole cattle, confirming a significant breed effect on reproductive efficiency.

Gestation length (275 ± 2 days) was remarkably stable and close to the biological norm for cattle (≈280 days), despite genetic and environmental diversity (Echternkamp & Thallman 2011; Grimard et al. 2017). This consistency suggests that gestation duration is largely conserved physiologically, although it may still be influenced by cow nutrition during pregnancy (Royen 2021). However, heat stress can lead to shorter gestation periods. Hanzen et al. (2025) emphasizes that exposing pregnant cows to heat stress shortens gestation. While physiologically consistent despite the genetic and environmental diversity of the herd (Echternkamp and Thallman, 2011; Grimard et al. 2017), gestation can be influenced by the cow's diet during gestation (Royen 2021) and the level of stress, as is the case in Algeria (Ferag et al. 2025).

Overall, these results depict a reproductive system that is biologically functional but operationally inefficient. The main bottlenecks lie not in gestation or fetal growth, but in the lengthening of the reproductive cycle before conception and between calvings. Substantial gains in productivity could be achieved by improving postpartum nutritional management, strengthening estrus detection and reproductive monitoring, and ensuring closer veterinary and technical supervision around insemination. Reducing CCI and CI remains the most critical leverage point for improving herd productivity and management efficiency.

The mean birth weight (46 ± 3 kg) falls within a normal range and indicates generally satisfactory fetal development. However, it appears higher than values reported for several local and crossbred

populations. Boukar et al. (2015) reported lower birth weights for Aku (17.9 kg), Djafoun (19.1 kg) and Gudali zebus (19.4 kg) in Cameroon, while Manzi et al. (2019) found significantly lower birth weights in Ankole–Jersey calves (25.8 kg) compared with other crosses (27.5–28.4 kg). Conversely, Ankole–Friesian calves showed superior growth at weaning (182 kg), illustrating the strong effect of sire breed on postnatal performance.

Survival rates reported elsewhere 88% up to 42 months (Blagna et al. 2019) highlight that birth weight alone does not determine productivity, as management system and season exert strong effects. In contrast, crosses between two indigenous breeds (Ituri Zebu × N'dama) produced much lighter calves (15–18 kg) (Joachim et al. 2023), emphasizing the substantial genetic contribution of improved dairy breeds. Touré et al. (2017) reported calf weights at 30 days for males (39 ± 10 kg) and females (32 ± 4 kg) that appear lower than our results.

The sex ratio can deviate due to influences exerted at three stages: oocyte maturation, fertilization, and embryonic development. It can vary under the effect of several factors including biological mechanisms which explain the variations observed in the resulting offspring. Regarding the origin of the oocytes, the sex ratio differs between the left and right ovaries, with the latter reportedly yielding a high proportion of males; the uterine horn carrying the fetus has no influence; Y-chromosome-bearing spermatozoa are thought to be faster but less resilient than X-chromosome-bearing spermatozoa; and the timing of insemination relative to ovulation and embryo survival also plays a role (Hanzen et al., 2016a). The secondary sex ratio defined as the proportion of males at birth varies between 46% and 57% across the populations studied, with an average of 52% (Hanzen et al., 2016 b).

In this study, only 337 of the 806 inseminated cows—representing 41.8%—could be monitored through to calving. In other words, 58.2% of the inseminated cows lacked a complete record documenting their reproductive outcome through to the end of the cycle. This relatively low rate of longitudinal monitoring poses a significant challenge for evaluating reproductive performance, as estimating parameters such as the calving interval, gestation length, or the interval between insemination and calving relies on the availability of reliable, sequential reproductive dates for each animal. This highlights the importance of systematically recording these events within the herd (Allan et al. 2024).

This situation can be partly attributed to herd management practices in traditional systems, where record-keeping is limited. The lack of permanent reproductive records can lead to the loss of information regarding inseminations, returns to estrus, pregnancy diagnoses, abortions, and calvings data that are nonetheless essential for effective herd management (Nkadimeng et al. 2022).

In the context of South Kivu, this difficulty may be compounded by animal movements between farms, sales or transfers of animals, and a lack of continuous monitoring following insemination. The 58.2% of animals that were not monitored through to parturition should not be directly interpreted as a reproductive failure.

. This distinction is crucial, as a lack of information regarding a cow's outcome does not necessarily mean she was not pregnant or did not produce a calf.

Methodologically, this loss of follow-up data is liable to introduce selection bias into the estimation of reproductive performance. The 337 cows successfully tracked through to calving represent a subsample of the initially inseminated population. Parameters calculated based solely on the tracked cows may not be fully representative of the entire group of 806 inseminated cows. Indeed, literature on African cattle systems highlights the importance of data quality and completeness for reliable comparisons of reproductive performance across populations and farming systems (Romero-Zúñiga et al. 2026).

The 41.8% follow-up rate should therefore be viewed as an indicator of the current difficulty in maintaining longitudinal reproductive monitoring on the farms studied. It highlights not only a limitation of the present study but also a weakness in the livestock management systems found in the traditional farming setups examined. Developing simple individual identification systems, using standardized reproductive records, and regularly monitoring cows after insemination could help reduce data loss. Involving livestock farmers, inseminators, and community agents in recording reproductive events would notably improve monitoring continuity and, ultimately, the accuracy of fertility and reproductive productivity estimates.

4.2. Factors influencing reproduction and growth parameters

4.2.1. Influence of altitude, age, and geographical administrative unit

Depending on altitude, the factorial projection of individuals clearly reveals a strong structuring of reproductive and growth performance. Altitude appears as the dominant organizing gradient. Herds located at high altitudes form a compact and well-defined group. A homogeneity is observed, with constant climatic conditions and forage availability, which tends to attenuate individual variability and result in more uniform reproductive outcomes.

Conversely, herds at low altitudes exhibit a wide dispersion along the main factorial axis. This heterogeneity reflects highly variable reproductive and growth performance. This may be due to environmental constraints: high temperatures, water stress, and seasonal fluctuations. Management practices in these areas also appear less standardized, amplifying individual differences. Herds at mid-altitudes occupy an intermediate position, with less restrictive ecological conditions than those at low altitudes.

From a statistical point of view, dimension 1 is strongly associated with the combined differences in body condition score (BCS) and cow age, evident in low-altitude systems where reproductive performance is highly heterogeneous. Dimension 2 constitutes the main axis of discrimination between altitude classes: tight clustering at high altitude, a sharper separation with moderate dispersion at mid-altitude, and wide dispersion at low altitude. The effect of clustering appears to be secondary, as does age.

Dimension 2 shows the three altitudinal levels. This vertical segregation reflects the existence of a dominant altitudinal gradient in the organization of livestock performance. Dimension 1 expresses the internal variability at each altitude associated with combined differences in growth, reproduction, and herd age structure.

Correlation analyses reveal two dominant patterns. First, a positive relationship between cow age and CI was observed in specific geographical administrative unit (Irhambi-Katana, Mutarule, Kitemesho), indicating that older cows tend to experience longer reproductive cycles. This aligns with findings by Sokouri et al. (2010) and Chapaux et al. (2013), who demonstrated that age and body condition strongly influence postpartum reproductive recovery.

Second, a strong inter-geographical administrative unit variability was evident. In some areas (Bugorhe, Kibirizi), correlations between age and CCI were weak or absent, suggesting that reproductive

performance is not driven by age alone. Local management practices, veterinary support, and feed availability likely play a decisive role (Azine et al. 2025).

Slight increases in gestation length among older cows confirm the general physiological stability of pregnancy duration, while younger cows tend to exhibit marginally shorter gestations (Soukouri et al. 2022). These variations remain biologically minor and do not represent a major constraint to productivity.

Breed group has a significant effect on the intervals between calving and the first or last insemination, the calving interval, and the conception rate (Manzi et al., 2018). Estimates of phenotypic correlation between productive and reproductive traits were low, ranging from 0.13 to 0.22. A strong association (0.99) was observed between the lower lactation interval (LCI) and a longer calving interval (382, 450, and 498 days) (Domiguez et al., 2020). The postpartum interval is influenced by various factors, including lactation, nutrition, age, dystocia, genetic variation, stress, and disease (Perry et al. 2022). Diseases occurring early in lactation lead to decreased cow performance and increased risks of mortality and culling (Pinedo et al. 2019).

The Ankole being a zebu, this is consistent with results obtained in Côte d'Ivoire, which show that the interval between two successive calvings was significantly shorter in Baoulé cows, with an average of 435 days, and in N'Dama cows, with an average of 428 days, ranging from 400 to 470 days. In zebu cows, it averages 474 days (Sokouri et al. 2010). Indeed, age and body condition influence the waiting period (Chapaux et al. 2013). Traditional opinion holds that the calving interval until the first ovulation is an important indicator of reproductive health (Berry et al. 2016).

4.2.2. Zootechnical performance after crossbreeding

Crossbred cattle involving Friesian, Jersey and Sahiwal sires displayed higher body weight and thoracic girth than local Ankole cattle, confirming the expected impact of artificial insemination and crossbreeding on body size and growth potential (Manzi et al. 2018). The extremely strong correlation between age and body weight ($r = 0.994$) indicates near-linear growth up to more than 750 days. Withers height and thoracic girth showed moderate to strong correlations with age, reflecting a balanced skeletal and muscular development.

Consistent with Manzi et al. (2018), Ankole–Jersey calves had significantly lower birth weights, whereas Ankole–Friesian calves outperformed all other crosses at weaning. Sex-related differences, particularly pronounced in Friesian crosses, reflect well-known sexual dimorphism in bovine growth.

Multivariate FAMD analysis clearly identifies sire breed, age, and environment (altitude and geographical administrative unit) as the main drivers of morphological and weight variation. These findings are consistent with Touré (2017), who reported very strong correlations between body weight and thoracic girth ($r = 0.95$) and withers height ($r = 0.94$).

An examination of the ecological specialization of breeds shows (at high, medium and low altitudes) that the Jersey breed is mainly observed at low altitudes, the Friesian at medium and high altitudes, while the Sahiwal exhibits a more flexible distribution between low and medium altitudes.

Despite the genetic gains achieved through crossbreeding, several structural weaknesses continue to limit reproductive and growth performance. Prolonged waiting periods, insufficient reproductive monitoring, and seasonal nutritional deficits remain major constraints (Kibwana et al. 2016). Addressing these issues requires urgent action: reducing the postpartum waiting period, strengthening assisted reproductive management, improving cow monitoring, and implementing coherent national livestock policies (Miteyo et al. 2025) in a mosaic of diverse Sanga and Zenga ecotypes (Yamboué et al. 2025). Fertility and fecundity must be tackled holistically, integrating nutritional, zootechnical, and pathological factors (Moussa Garba et al. 2014).

Conclusion

This study provides a clear assessment of bovine fecundity under natural and artificial insemination systems in South Kivu. Reproductive performance remains below expected standards, primarily due to weak technical support, suboptimal management of artificial insemination, seasonal feed shortages, and limited health monitoring.

Nevertheless, significant improvements are achievable. Promoting heat detection techniques, strengthening the technical capacity of farmers and field agents, improving feeding strategies through forage development and dry-season supplementation, and establishing effective preventive health systems would substantially enhance productivity.

Ultimately, effective control of bovine reproduction, combined with improved nutrition and animal health management, represents a cornerstone for increasing meat and milk production, thereby improving household income and food security among agropastoral communities in South Kivu.

Author contributions

VNM: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing original draft, Writing review & editing. AIN: Conceptualization, Methodology, Supervision, Writing review & editing. DMK: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Supervision, Writing – review & editing. CH: Conceptualization, Methodology, Formal analysis, Data interpretation, Supervision, Writing review & editing.

Study limitations

This study has four main limitations : (i) Although 806 cows were inseminated, only 337 were monitored through to calving, which may have introduced selection bias and limited the representativeness of the reproductive results; (ii) Certain potentially important factors such as body condition, nutritional status, health status, estrus detection, semen quality, and timing of insemination were not systematically recorded, thereby limiting the identification of factors determining reproductive performance; (iii) The associations identified via Factor Analysis of Mixed Data (FAMD) between animal performance, bull breed, altitude, and geographical location were exploratory in nature and should not be interpreted as cause-and-effect relationships; (iv) finally, as the study was conducted in four territories of South Kivu under specific agroecological and husbandry conditions, the results should be generalized with caution to other cattle production systems in the Democratic Republic of the Congo.

Acknowledgements

The authors gratefully acknowledge the support of the Integrated Project for Agricultural Growth in the Great Lakes Region (PICAGL) for facilitating this study. We sincerely thank VSF Belgium, the project's technical partner for the livestock component, for its technical assistance during the implementation of the cattle production and reproduction activities. We are also grateful to all participating farmers, veterinarians, extension officers, and field staff whose collaboration made this study possible.

Funding

485 This research did not receive any specific grant funding from public, commercial, or non-profit sector
486 funding bodies.

487 **Data availability**

488 The datasets used in this study can be obtained from the corresponding author upon request.

489 **Declaration**

490 Confict of interest The author declares that there are no financial interests or personal relationships that
491 could have infuenced the content or outcomes of this paper.

492 **Statement of Animal Rights**

493 This study involved observational surveys of cattle farmers and the non-invasive collection of
494 information on livestock management practices. No experimental procedures or interventions involving
495 animals were conducted specifically for this study. Data collection complied with institutional ethical
496 standards, and informed consent was obtained from all participants before each interview.

497 **References**

498 1. Abeygunawardena H & Dematawewa C M B (2004) Pre-pubertal and postpartum anestrus in tropical
499 Zebu cattle. Animal Reproduction Science, 82, 373-387. DOI: 10.1016/j.anireprosci.2004.05.006

500 2. Allan F K, MacVicar I S, Peters A R, Schnier C (2024) Systematic map of recent evidence on
501 reproductive performance of cattle in Africa. Tropical Animal Health and Production, 56(7),
502 218.https://doi.org/10.1007/s11250-024-04074-z

503 3. Azine P C, Mugumaarhahama Y, Mutwedu VB, Baenyi SP, Kunde EA, Mwanga Mwanga JCI,
504 Bacigale SB, Karume K, Ayagirwe RBB (2025) Livestock feeding practices in South Kivu, Eastern
505 Democratic Republic of Congo: challenges and opportunities, Discover Animals.
506 https://doi.org/10.1007/s44338-025-00053-2

507 4. Berry D P, Friggens N C, Lucy M & Roche J R (2016) Milk production and fertility in cattle. Annual
508 review of animal biosciences, 4(1), 269-290. doi: 10.1146/annurev-animal-021815-111406

5. Bisinotto R S, Ribeiro E S, Martins L T, Marsola R S, Greco L F, Favoreto M G, ... & Santos J E P (2010) Effect of interval between induction of ovulation and artificial insemination (AI) and supplemental progesterone for resynchronization on fertility of dairy cows subjected to a 5-d timed AI program. Journal of dairy science, 93(12), 5798-5808. https://doi.org/10.3168/jds.2010-3516

6. Blagna S, Koté B, Tellah M, Djalal A K, Ouédraogo J, Logtené Y M, & Boly H (2020) Survie et aptitudes des veaux issus de croisements entre Brunes des Alpes et Zébus Peuls dans la région des Cascades au Burkina Faso. Revue d'Elevage et de Médecine Vétérinaire des Pays Tropicaux, 73(4), 239-246. DOI:10.19182/remvt.31942

7. Bounouala M (2025). Analyse des facteurs limitants de l'insémination artificielle Chez les bovins dans la région de Tiaret (Doctoral dissertation, Université Ibn Khaldoun–Tiaret).

8. Chagunda M G, Mwangwela A, Mumba C, Dos Anjos F, Kawonga B S, Hopkins R, & Chiwona-Kartun L (2016) Assessing and managing intensification in smallholder dairy systems for food and nutrition security in Sub-Saharan Africa. Regional environmental change, 16, 2257-2267. http://dx.doi.org/10.1007/s10113-015-0829-7.

9. Chapaux P, Glorieux G, & Hanzen C (2013) Impact des périodes d'attente et de reproduction sur la fécondité de la vache laitière. Wallonie Elevages. 33-35.

10. Crowe M A, Hostens M, & Opsomer G (2018) Reproductive management in dairy cows-the future. Irish veterinary journal, 71(1). DOI 10.1186/s13620-017-0112-y

11. Echternkamp S E & Thallman R M (2011) Factors affecting pregnancy rate to estrous synchronization and fixed-time artificial insemination in beef cattle. Journal of animal science, 89(10), 3060-3068. DOI:10.2527/jas.2010-3549

12. Eulmi H, Daghnouch K, & Gherissi D E (2022, December) Caractéristiques socio-économiques et performances de reproduction des exploitations bovines laitières dans la région aride de Biskra, au sud est de l'Algérie. In 3R2022: 26èmes Rencontres autour des Recherches sur les Ruminants. https://hal.science/hal-04734548

13. Ferag A, Gherissi D E, Khenenou T, Boughanem A, Moussa H H, Maamour A, & Hanzen C (2025) Fertility of indigenous “Atlas Brown” Algerian cattle under different heat stress levels. International Journal of Environmental Studies, 82(4), 1797-1817. Https://doi.org/10.1080/0027233.2025.2507444

14. Fodor I, Abonyi-Tóth Z, & Ózsvári L (2018) Management practices associated with reproductive performance in Holstein cows on large commercial dairy farms. Animal, 12(11), 2401-2406. DOI:10.1017/S1751731118000101

15. Grimard B, Agabriel J, Chambon G, Chanvallon A, Constant F F, & Chastant-Maillard S (2017) Particularités de la reproduction des vaches allaitantes de races françaises. INRA Productions Animales, 30(2), 125-138.

16. Grimard B, Humblot P, Ponter A A, Chastant S, Constant F, & Mialot J P (2003) Efficacité des traitements de synchronisation des chaleurs chez les bovins. INRAE Productions Animales, 16(3), 211-227.

17. Haou A, Miroud K & Gherissi D E (2021) Impact des caractéristiques du troupeau et des pratiques d’élevage sur les performances de reproduction des vaches laitières dans le Nord-Est algérien. Revue d’élevage et de médecine vétérinaire des pays tropicaux, 74(4), 183-191. DOI: 10.19182/remvt.36798

18. Hanzen C (2015) Pathologies: L’infertilité dans l’espèce bovine: un syndrome. http://orbi.ulg.ac.be. Consulted at “ 3th march 2026”

19. Hanzen C, Chastant-Maillard S, Rao A S, & Theron L (2016) Le sexe ratio chez les bovins: mécanismes potentiels. Le Point Vétérinaire, 367. http://www.lepointveterinaire.fr/bdd/165/165_4693

20. Hanzen C, Chastant-Maillard S, Rao A S, & Theron L (2016) Le sexe ratio chez les bovins: facteurs de variation. Point Vétérinaire: Expert Rural, 367. http://www.lepointveterinaire.fr/bdd/165/165_4692

21. Hanzen C, Delhez P, Knapp E, Hornick J L, & Gherissi D E (2024) Le stress thermique environnemental dans l’espèce bovine: 1. Caractéristiques générales et méthodes d’évaluation. Revue d'Élevage et de Médecine Vétérinaire des Pays Tropicaux, 77. DOI: 10.19182/remvt.37379

22. Joachim U D M B, Lazare M P, Darius B S, Charles K N, & Claude L L J (2023) Essai de croisement des races Zébu et N'dama à la ferme agropastorale de Ngondi pour une performance en viande et en trypanosomiase en RD Congo.https//doi.org/10.35759/JAnmPISci.v57-2.4

23. Kibwana D K (2016) Contribution à l'amélioration de la production laitière et de la reproduction des vaches Ankole et croisées Ankole x Frisonne en territoire de Beni, République Démocratique du Congo (Doctoral dissertation, Université de Liège (Belgium)). http://orbi.ulg.ac.be. Consulted at «2023»

24. Garba M M, Issa M, Marichatou H, Okouyi M W M, Kamga-Waladjo A R, & Hanzen C (2014) Caractéristiques et performances de reproduction du Zébu. Le cas du Niger. Revue Africaine de Santé et de Productions Animales, 12(3-4), 135-141.

25. Manzi M, Rydhmer L, Ntawubizi M, Karege C, & Strandberg E (2018) Growth traits of crossbreds of Ankole with Brown Swiss, Holstein Friesian, Jersey, and Sahiwal cattle in Rwanda. Tropical animal health and production, 50(4), 825-830.. https://doi.org/10.1007/s11250-017-1501-7

26. Manzi M, Rydhmer L, Ntawubizi M, Karege C, & Strandberg E (2019) Reproductive performance of Ankole cattle and its crossbreds in Rwanda. Tropical Animal Health and Production, 51(1), 49-54. https://doi.org/10.1007/s11250-018-1658-8

27. Marquezini G H L, Dahlen C R, Bird S L, & Lamb G C (2011) Administration of human chorionic gonadotropin to suckled beef cows before ovulation synchronization and fixed-time insemination: replacement of gonadotropin-releasing hormone with human chorionic gonadotropin. Journal of animal science, 89(10), 3030-3039. doi: 10.2527/jas.2010-3455

28. Miteyo B, Kabamba M W, Tshikung D, Litutala B, & Pongombo C (2025) Politiques de production bovine en République Démocratique du Congo de 1960 à 2023. Revue Marocaine des Sciences Agronomiques et Vétérinaires, 13(1), 33-40.https://doi.org/10.5281/zenodo.15027019

29. Mruttu H, Ndomba C, Gebru G, & Stapleton J (2017) Animal breeding and genetics in the Tanzania livestock master plan.

30. Mwacharo J M, & Drucker A G (2005) Production objectives and management strategies of livestock keepers in South-East Kenya: Implications for a breeding programme. Tropical Animal Health and Production, 37, 635-652. DOI: 10.1007/s11250-005-4253-8

585 31. M'She W K, Hornick J L, Hatungumukama G, Ntwali V M, & Musale D K (2026) Le bushi comme
586 milieu d'étude pour la caractérisation des systèmes d'élevage bovin et leurs impacts environnementaux:
587 une approche monographique (territoires de Walungu et Kabare, Sud-Kivu, RD Congo). Revue
588 Internationale de la Recherche Scientifique (Revue-IRS), 4(2), 2048-2084. https://orcid.org/0009-0003-
589 6666-4766

590 32. Negrón-Pérez V M, Fausnacht D W, & Rhoads M L (2019) Invited review: Management strategies
591 capable of improving the reproductive performance of heat-stressed dairy cattle. Journal of dairy science,
592 102(12), 10695-10710. https://doi.org/10.3168/jds.2019-16718

593 33. Nkadimeng, M, Van Marle-Köster E, Nengovhela N B, Ramukhithi F V, Mphaphathi M L, Rust J M,
594 & Makgahlela M L (2022) Assessing reproductive performance to establish benchmarks for small-holder
595 beef cattle herds in South Africa. Animals, 12(21), 3003.https://doi.org/10.3390/ani12213003

596 34. Pinedo P, Santos J E P, Chebel R C, Galvão K N, Schuenemann G M, Bicalho R C, ... & Thatcher W
597 W (2020) Early-lactation diseases and fertility in 2 seasons of calving across US dairy herds. Journal of
598 dairy science, 103(11), 10560-10576. https://doi.org/10.3168/jds.2019-17951

599 35. Romero-Zúñiga J J, Galina C S, Geffroy M, Corro M D, & Maquivar M (2026) Productive and
600 Reproductive Record Keeping in Low-to-Middle-Income Tropical Livestock Systems: Challenges and
601 Perspectives. Animals, 16(11), 1691. https://doi.org/10.3390/ani16111691

602 36. Royen J (2021) Impact d'un régime de gestation hyperglycémiant sur la macrosomie fœtale chez la
603 vache allaitante. http://hdl.handle.net/2268.2/12393

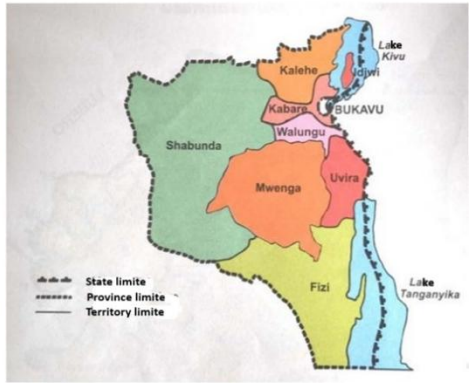
604 37. Sokouri D P, Yapi-Gnaore C V, N'guetta A S P, Loukou N E, Kouao, B J, Toure G, ... & Sangaré A
605 (2010) Performances de reproduction des races bovines locales de Côte d'Ivoire. J. Appl. Biosci, 36(1),
606 2353-2359.

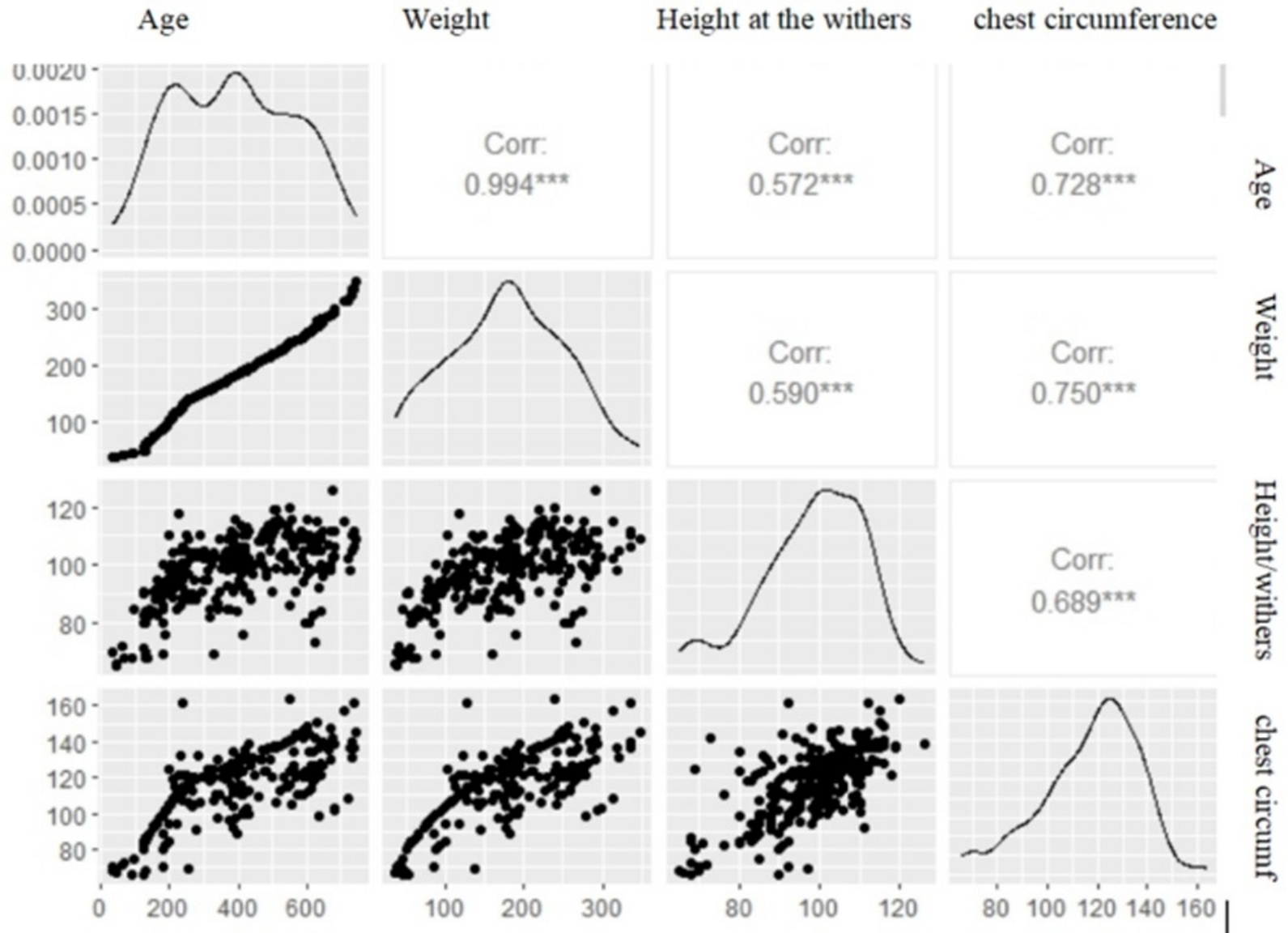
607 38. Touré A, Kouriba A, Leroy P, Antoine-Moussiaux N, & Moula N (2017) Caractérisation
608 zootechnique et formule barymétrique de la race zébu Azawak à Ménaka au nord du Mali. Revue
609 d'Elevage et de Médecine Vétérinaire des Pays Tropicaux, 70 (4) : 115-120. Doi: 10.19182/remvt.31528.

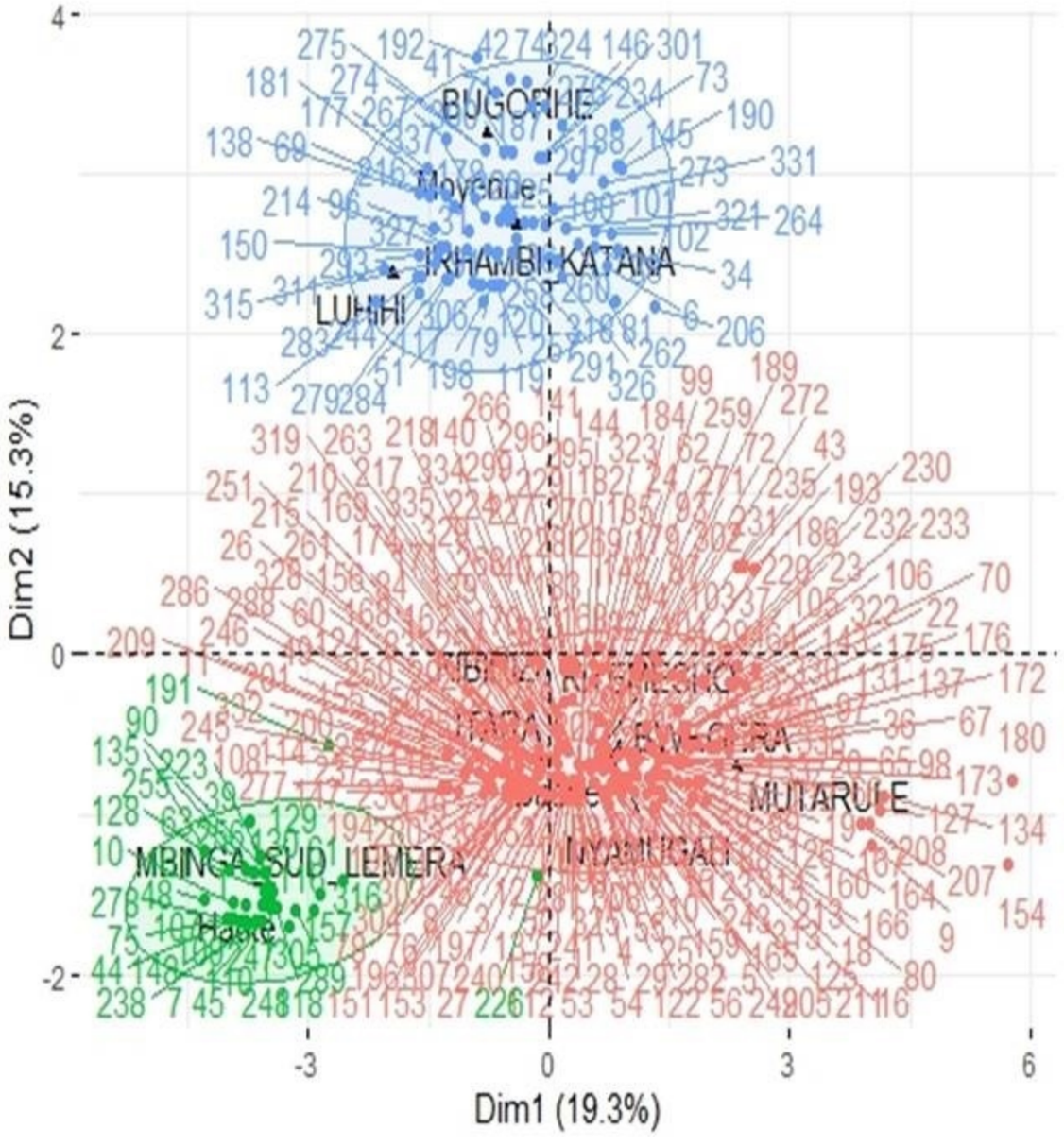
610 39. Zamukulu P, Ayagirwe R, Ndeko A, Bagula E, Mondo J, Ganza D, Musale D K, Mushagalusa G N
611 (2019) Contraintes et opportunités de l'intégration agriculture-élevage à Mushinga dans l'Est de la RD

612 Congo. Journal of Animal & Plant Sciences, 41(3), 7000-7014. https://doi.org/10.35759/JAnmPlSci.v41-
613 3.4

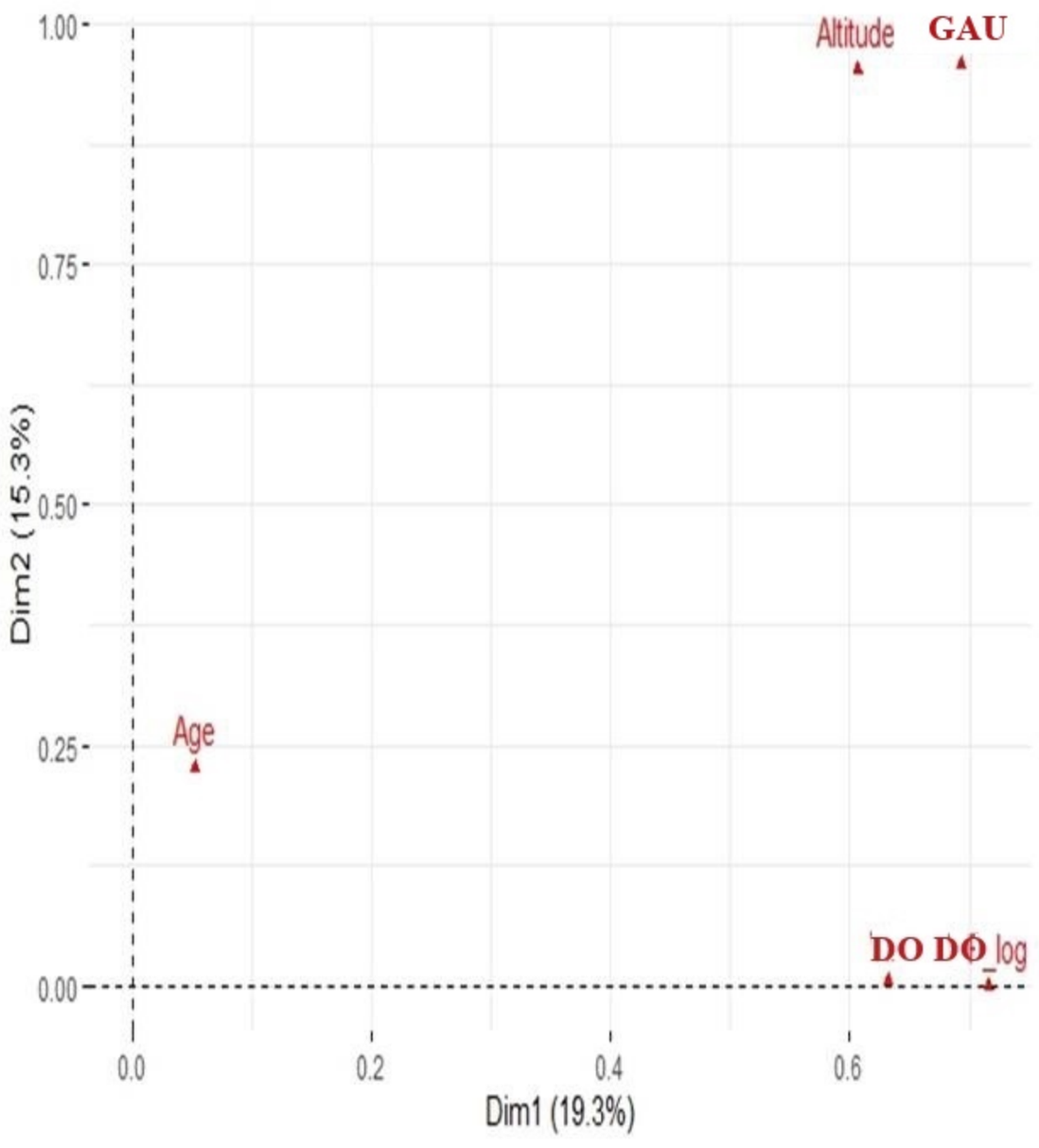


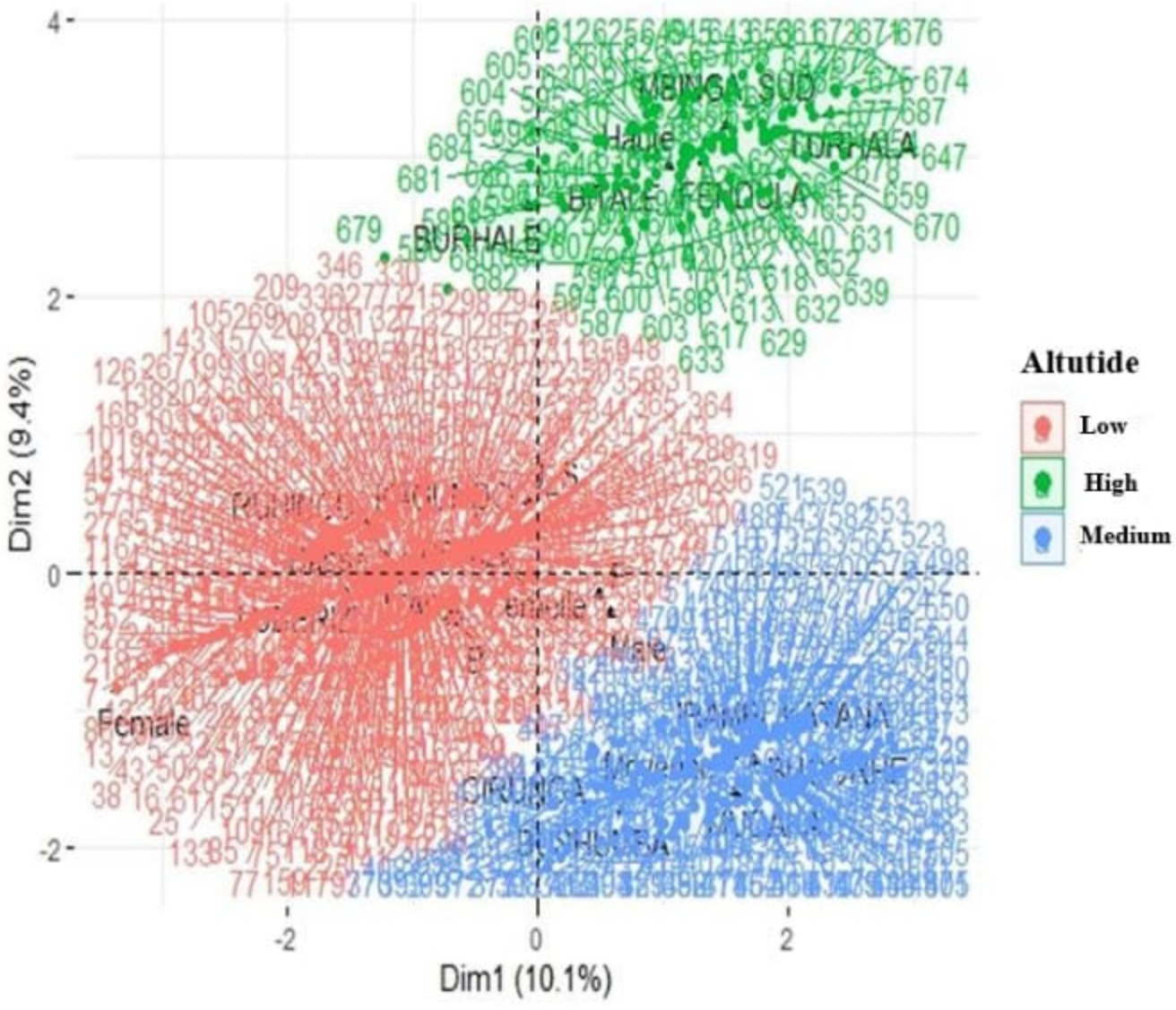

Lake
Kivu
Kalehe
Idjwi
Kabare
BUKAVU
Walungu
Shabunda
Mwenga
Uvira
Fizi
Lake
Tanganyika
State limite
Province limite
Territory limite


Age
Weight
Height at the withers
chest circumference
Corr:
0.994***
Corr:
0.572***
Corr:
0.728***
Corr:
0.590***
Corr:
0.750***
Corr:
0.689***
Age
Weight
Height/withers
chest circumf
0.0020
0.0015
0.0010
0.0005
0.0000
300
200
100
120
100
80
160
140
120
100
80
0
200
400
600
100
200
300
80
100
120
80
100
120
140
160

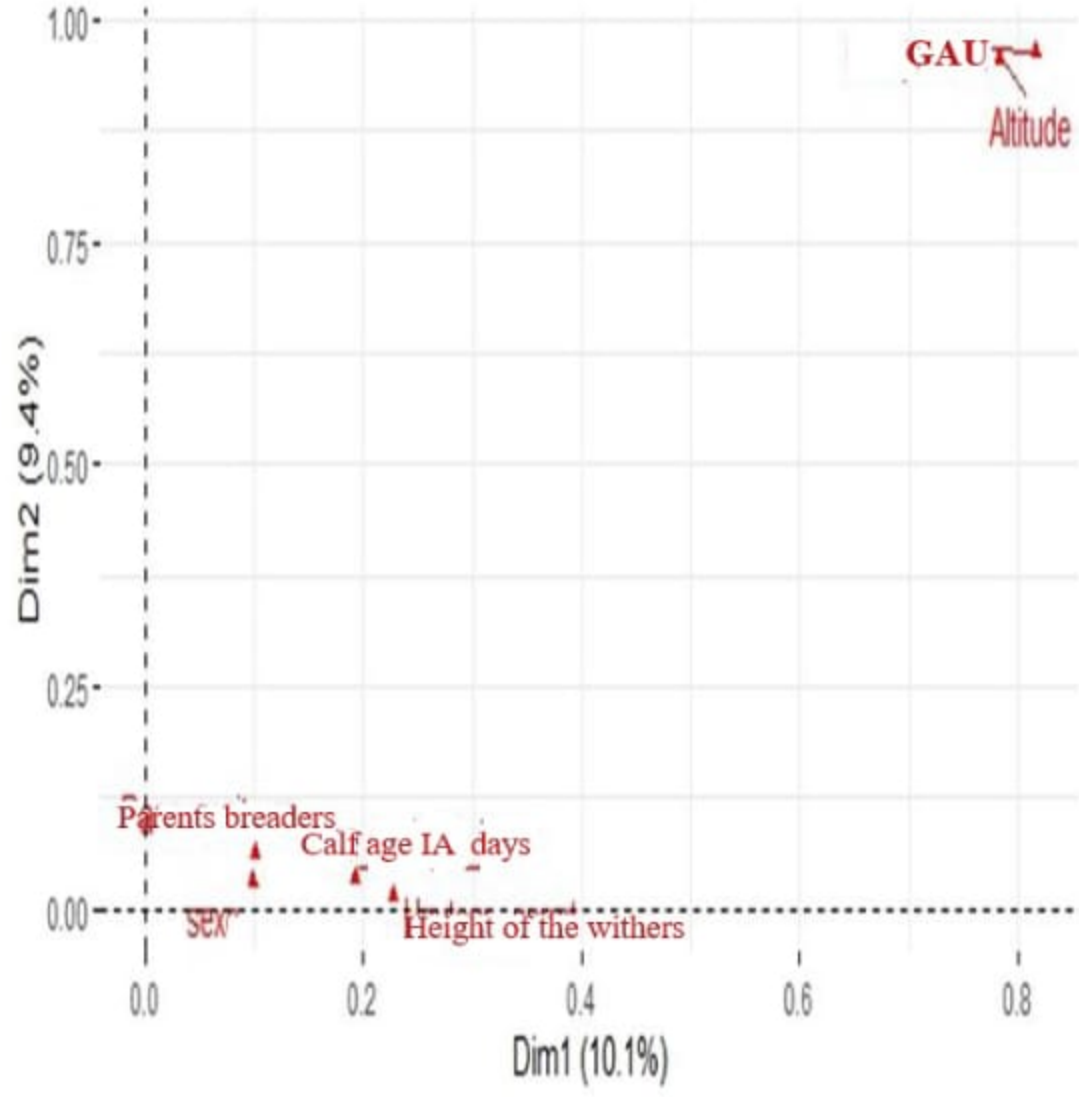

BUGORHE
Moyenne
IKHAMBI KATANA
LUHIHI
MUTARULE
MBINGA SUD LEMERA
Hauteur
Dim2 (15.3%)
Dim1 (19.3%)

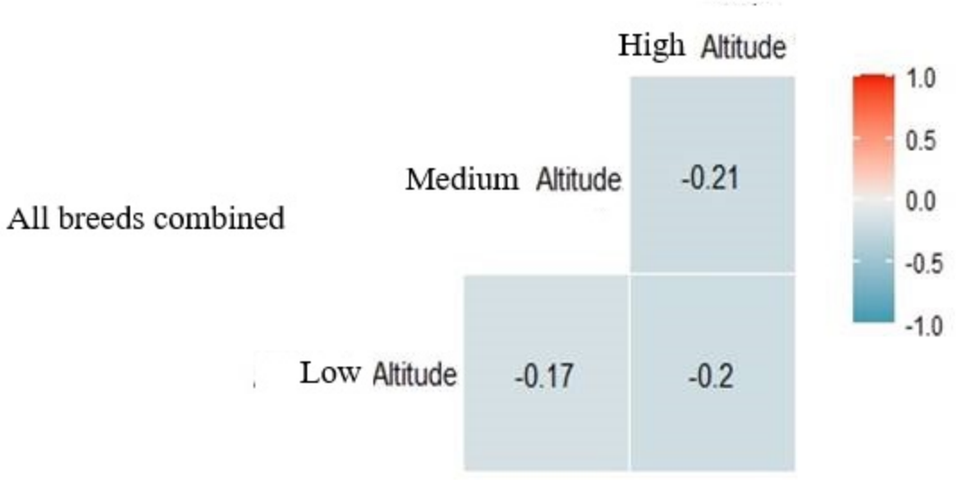

Altitude
Low
High
Medium

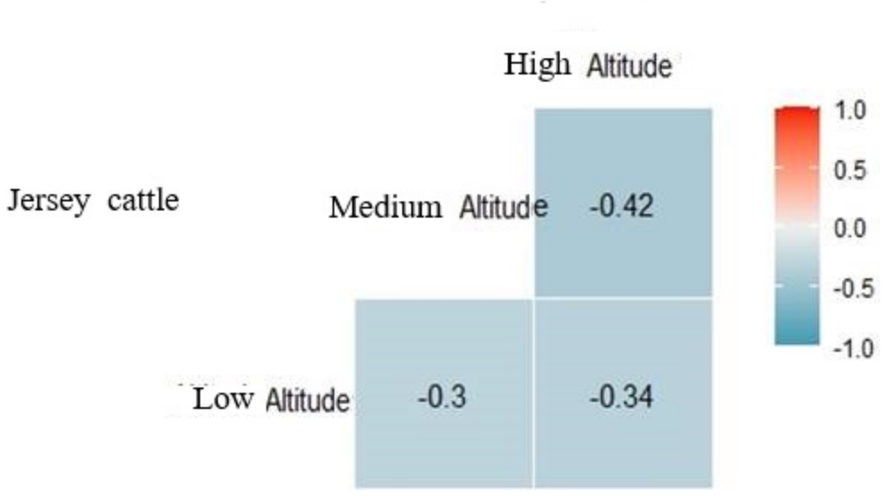

Altitude
GAU
Age
DO
DO_log
Dim2 (15.3%)
Dim1 (19.3%)

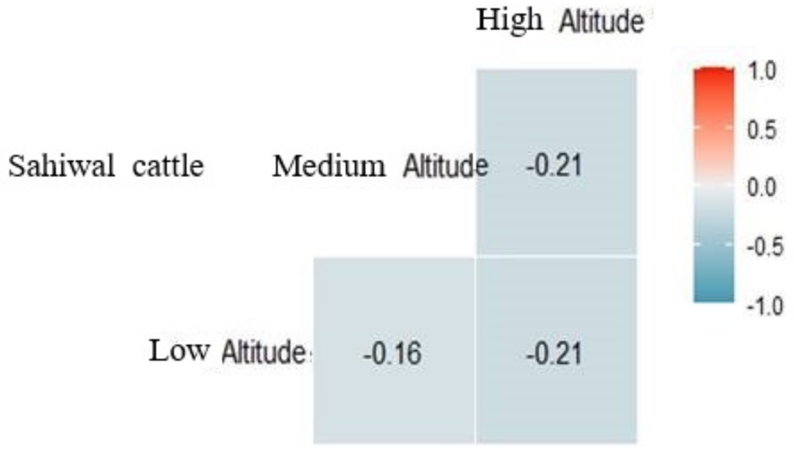

MBINGA SUD
Haute
TDRHALA
BRALE FENDOLA
BURHALE
Female
Male
CIRUNGA
Dim1 (10.1%)
Dim2 (9.4%)

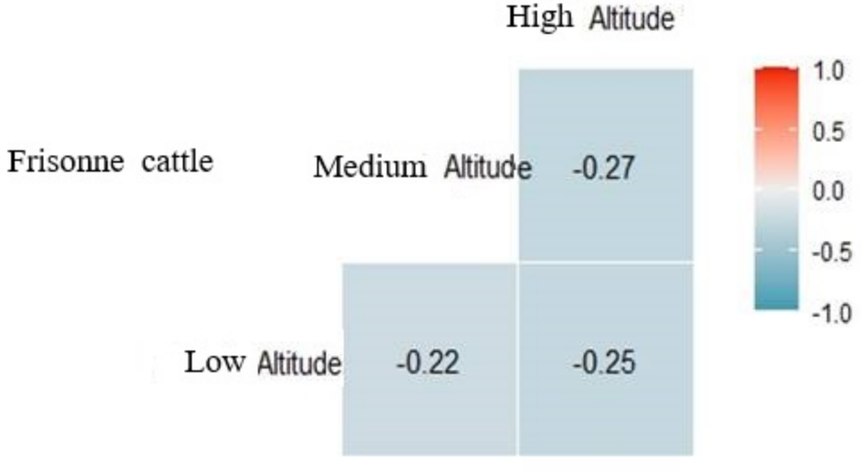
Altutide
Low
High
Medium


GAU
Altitude
Parents breaders
Calf age IA days
SEX
Height of the withers
Dim1 (10.1%)
Dim2 (9.4%)


All breeds combined
High Altitude
Medium Altitude
Low Altitude
-0.21
-0.17
-0.2
1.0
0.5
0.0
-0.5
-1.0


Jersey cattle
High Altitude
Medium Altitude
Low Altitude
-0.42
-0.3
-0.34
1.0
0.5
0.0
-0.5
-1.0


Sahiwal cattle
High Altitude
Medium Altitude
Low Altitude
-0.21
-0.16
-0.21
1.0
0.5
0.0
-0.5
-1.0


Frisonne cattle
High Altitude
Medium Altitude
Low Altitude
-0.27
-0.22
-0.25
1.0
0.5
0.0
-0.5
-1.0

TABLES

Table 1

Period	Hormone	Role
Day 1	100 µg GnRH (Cystoreline)	Luteinization/ovulation of the dominant follicle
Day 7 or 9	PGF2α (Enzaprost T)	Lysis of the corpus luteum and induction of a new estrous cycle
48–60 h after	100 µg GnRH	Triggering of the LH surge
12–24 h after	Insemination	Optimal fertility window (≈16 h)

Table 2

Variable	Min	Max	Mean	SD
Age (years)	3	19	7	3
DO (days)	56	741	200	120
CI (days)	347	821	474	119
Gestation length (days)	270	282	275	2
Birth weight (kg)	38	57	46	3

Table 3

Age class	Sex	n	Body weight (kg)	Chest circumference (cm)	Height at withers (cm)
0-2 weeks	Male	13	47.5	68.7	68.3
0-2 weeks	Female	22	44.8	67.4	68
2 months	Male	15	55.6	71.8	71.1
2 months	Female	28	55.2	70.9	71
7 months	Male	46	91,5	98,2	89,6
7 months	Female	99	91	94,6	88,2

12 months	Male	52	169	109,2	109,5
12 months	Female	74	163	106	108
15 months	Male	136	228	139,8	121
15 months	Female	102	226,5	137,4	118,3
Total/ average		687	161,5	114,2	96,7

7

8

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SUPPLEMENTARYMATERIALTABLESANDFIGURECAPTION.docx