



Integrating breeding, feeding and keeping systems in the Lowland Livestock-Crop Agriculture Developing Centre; perspectives from West Papua

Integración de los sistemas de cría, alimentación y mantenimiento en el Centro de Desarrollo de Agricultura Ganadera y de Cultivos de Tierras Bajas; perspectivas desde Papúa Occidental

Deny Anjelus Iyai^{1*}; Meky Sagrim²; Stepanus Pakage¹; Yubelince Y. Runtubo³; Andoyo Supriyanton¹; Bernadetha Wahyu Irianti Rahayu¹; Makarius Bajari⁴; Hieronymus Y. Chrisostomus¹; Trisiwi Wahyu Widayati¹; Diana Sawen¹; Siti Aisah Bauw⁴; Daniel Yohanes Seseray¹; Johan F. Koibur¹; Hans Mamboai²; Frandz Rumbiak Pawere¹

¹ Faculty of Animal Science. Papua University. Jl. Gunung Salju, Amban. Manokwari. Papua Barat.

² Faculty of Agriculture. Papua University. Jl. Gunung Salju, Amban. Manokwari. Papua Barat.

³ Faculty of Forest Science. Papua University. Jl. Gunung Salju, Amban. Manokwari. Papua Barat.

⁴ Faculty of Economic and Business Science. Papua University. Jl. Gunung Salju, Amban. Manokwari. Papua Barat.

ABSTRACT

The integration of breeding, keeping, and feeding practices is essential for improving livestock productivity and sustainability, particularly in lowland agricultural systems. This study investigates the integration of these practices in the Lowlands Agriculture Development Centre of Manokwari, West Papua. Using Principal Component Analysis (PCA) and hierarchical clustering, key factors influencing livestock performance were identified, including grazing systems, reproductive strategies, feeding types, and shelter management. The principle finding shown majority of livestock are of local breeds, followed by crossbred and wild types. This suggests a dominance of indigenous stock over improved or exotic breeds. The number of offspring/parents, births/parent/year, mating system, management system, feed type, and feeding frequency are significant factors influencing livestock outcomes. Wild livestock, natural mating, and artificial insemination significantly impact livestock performance. This result highlights the dominance of traditional practices such as natural mating and the use of local feeding resources, alongside significant variations in sheltering and grazing systems. Livestock relies mainly on agricultural or plantation products, while commercial feed and household waste are minimally used. Two distinct clusters of livestock management were revealed, indicating varying levels of efficiency and sustainability among farmers. This research emphasizes the importance of adopting integrated approaches to optimize livestock management, enhance productivity, and support sustainable agricultural development in tropical lowlands. The findings provide actionable insights for policymakers and practitioners in the region.

Keywords: Livestock management; Feeding strategies; Lowland agriculture; Sustainability; Agricultural development.

RESUMEN

La integración de las prácticas de cría, mantenimiento y alimentación es esencial para mejorar la productividad y la sostenibilidad del ganado, especialmente en los sistemas agrícolas de tierras bajas. Este estudio investiga la integración de estas prácticas en el Centro de Desarrollo Agrícola de Tierras Bajas de Manokwari, Papúa Occidental. Mediante el Análisis de Componentes Principales (ACP) y el análisis de conglomerados jerárquicos, se identificaron factores clave que influyen en el rendimiento del ganado, como los sistemas de pastoreo, las estrategias reproductivas, los tipos de alimentación y el manejo de los establos. El principal hallazgo mostró que la mayoría del ganado es de razas locales, seguido de los mestizos y los salvajes. Esto sugiere un predominio del ganado autóctono sobre las razas mejoradas o exóticas. El número de crías por progenitor, los nacimientos por progenitor al año, el sistema de apareamiento, el sistema de manejo, el tipo de alimento y la frecuencia de alimentación son factores significativos que influyen en los resultados del ganado. El ganado salvaje, el apareamiento natural y la inseminación artificial impactan significativamente en el rendimiento del ganado. Este resultado pone de relieve el predominio de prácticas tradicionales como el apareamiento natural y el uso de recursos alimenticios locales, junto con variaciones significativas en los sistemas de refugio y pastoreo. El ganado depende principalmente de productos agrícolas o de plantaciones, mientras que el alimento comercial y los residuos domésticos se utilizan mínimamente. Se identificaron dos grupos distintos de manejo ganadero, lo que indica diferentes niveles de eficiencia y sostenibilidad entre los agricultores. Esta investigación subraya la importancia de adoptar enfoques integrados para optimizar el manejo ganadero, mejorar la productividad y apoyar el desarrollo agrícola sostenible en las tierras bajas tropicales. Los hallazgos proporcionan información práctica para los responsables políticos y los profesionales de la región.

Palabras clave: Manejo ganadero; estrategias de alimentación; agricultura de tierras bajas; sostenibilidad; desarrollo agrícola.

1. Introducción

Indonesia's agricultural sector is predominantly characterized by smallholder mixed farming systems (Iyai et al., 2020; Pasandaran, 2006), where approximately 95% of livestock production is managed by small-scale farmers who integrate crop cultivation with livestock rearing (McCarthy, 2010; Clough et al., 2016; Hutabarat, 2017). This traditional approach is particularly prevalent in lowland regions, including areas like Manokwari in West Papua. In current conditions, the genetic improvement of livestock has been limited due to the absence of well-designed breeding programs (Gizaw et al., 2014; Winarso & Basuno, 2013; Argo et al., 2015; Frison et al., 2011; Bolowe et al., 2022). Crossbreeding efforts have often resulted in mixed-breed animals without clear genetic composition or enhanced productivity (Muhlisin et al., 2014; Boujenane, 2015). This challenge is compounded by the lack of access to quality breeding stock and insufficient dissemination of research findings to farmers. In animal husbandry, smallholder farmers typically employ low-input (Mezgebe et al., 2018; Marandure et al., 2020; Marie et al., 2023), low-output production systems, leading to suboptimal livestock productivity. Management practices are often conventional, with limited adoption of modern technologies and infrastructure, affecting animal health and growth rates. In feeding systems, livestock feeding largely depends on seasonal availability of forage, resulting in inconsistent nutrition. The reliance on crop residues and natural grazing can lead to feed shortages, particularly during dry seasons, thereby affecting livestock growth and reproduction (Tolera & Abebe, 2007; Rojas-Downing et al., 2017).

To address these challenges, Indonesia has initiated programs aimed at integrating breeding, keeping, and feeding practices within agricultural development centers, especially in lowland areas. For instance, the establishment of Village Breeding Centers (VBC) focuses on implementing proper cultivation technologies to preserve local cattle breeds and enhance farmers' capabilities in managing cattle fattening and breeding. Additionally, community-based breeding programs have been designed to empower local cooperatives, enabling systematic livestock breeding that aligns with indigenous knowledge and livelihood support systems. These programs aim to balance livestock productivity with environmental sustainability and climate resilience. The integration of breeding, keeping, and feeding practices is essential in developing

sustainable livestock systems, particularly in agricultural development centers in tropical regions. In the lowlands of Manokwari, West Papua, agriculture plays a significant role in supporting local livelihoods and enhancing food security. However, challenges such as optimizing land use, improving livestock productivity, and minimizing environmental impacts remain persistent. Integrating livestock systems with agricultural practices offers a pathway to address these challenges while promoting sustainability and resilience in agricultural development centers. Manokwari's lowlands are characterized by their rich biodiversity, tropical climate, and extensive agricultural activities, including livestock farming. The region holds significant potential for integrating livestock production with crop farming to optimize resource use and improve economic returns. Despite this potential, traditional livestock management systems often face limitations such as inefficient breeding practices, insufficient feeding resources, and inadequate housing conditions. These challenges highlight the need for integrated approaches that combine breeding, keeping, and feeding strategies to maximize productivity and sustainability. Manokwari's lowlands cover a significant area suitable for agriculture, with average temperatures ranging from 25 – 30 °C and high annual rainfall. The region supports both crop and livestock farming due to its fertile soils and abundant natural resources. Livestock contributes to over 20% of the region's agricultural GDP, with cattle, goats, and poultry being the primary species. Integration with crop farming, such as oil palm and maize, could enhance resource efficiency and productivity. Limited access to quality breeding stock and veterinary services impacts herd health and productivity. Feeding resources, particularly during the dry season, are often insufficient or inadequately managed. Traditional keeping systems frequently lack proper housing, exposing animals to adverse weather and diseases. The Indonesian government has prioritized integrated agricultural practices under its sustainable development goals, emphasizing the need for innovative strategies in regions like Manokwari. Objectives of this research were to evaluate the current practices of breeding, keeping, and feeding in livestock systems in Manokwari's lowlands. To identify opportunities and challenges in integrating livestock management with agricultural development practices. To propose a sustainable model for

integrating breeding, keeping, and feeding strategies to enhance livestock productivity and resource use efficiency. To assess the socio-economic and environmental benefits of integrating livestock systems with crop farming in the region. To provide recommendations for policymakers, farmers, and stakeholders to promote sustainable agricultural development in Manokwari, West Papua. This comprehensive approach will contribute to building resilient agricultural systems, supporting livelihoods, and advancing the sustainable development of Manokwari's lowlands.

2. Methodology

Sample location

The Manokwari Regency is divided into 9 districts, covering a total area of 4,650.32 km². Astronomically, Manokwari Regency and its 9 districts are located below the equator, between 0°14' S and 130°31' E. The geographical boundaries of Manokwari Regency are as follows: to the west, it borders Tambrau Regency; to the north, the Pacific Ocean; to the east, the Pacific Ocean; and to the south, the Arfak Mountains Regency and South Manokwari Regency. The sample locations for this review and field research were taken from four districts within Manokwari Regency, West Papua. The nine districts in Manokwari include Warmare, Prafi, Masni, and Sidey (Manokwari, 2018). The selection of these four areas was based on their extensive use for various purposes, including plantations, transmigration areas, fertile lands, communal lands, and livestock production centers in Manokwari. The total study area is 1,022.67 km² (102,266.54 ha).

Generally, the profile of the study area consists of coastal regions, lowlands, and highlands. Precipitation in the area shows distinct patterns of wet (rainy) and dry months based on data from the Meteorology, Climatology, and Geophysics Agency (BMKG) of Manokwari Regency. The wet months occur from December to May (6 months), totalling 221 days with a rainfall of 287.4 mm². Meanwhile, the dry months occur from June to November (6 months) annually.

Materials and procedures

The materials and data for this review include livestock population data for cattle, goats, pigs, and several other key commodities raised in the

four sample districts in Manokwari. The livestock population data are presented in Table 1. The sampling of livestock farmers was conducted using the Snowball Sampling Technique (Creswell, 2014; Snedecor & Cochran, 1989; Rao, 2018). Through this exploratory sampling method, a total of 118 household respondents were identified. The breakdown of respondents by district and village is provided in the following table. Parameters measured in the field are presented in Table 1.

In addition, the field data variables measured include the number of offspring per mother, the number of births per mother per year, the type of livestock breed used (local, crossbred, and wild), the mating system (natural and artificial insemination/AI), the management system (without shelter, with shelter, and with shelter combined with free-range), the type of feed (commercial feed, agricultural/plantation by-products, and household waste feed), the frequency of livestock feeding (times/day), and the amount of grazing area (units).

Table 1

Parameters applied in this field research

Livestock parameter	Unit of measurement	References
Number of offspring	Head/parent	(Sayori et al., 2022; Sibly et al., 2013)
Births	Head/parent	(Petrus et al., 2011)
Type of livestock		
- Local	Yes/no	(Shikuku et al., 2017)
- Crossbred	Yes/no	
- Wild	Yes/no	
Mating System		(Mekonnen et al., 2012; Gizaw et al., 2014)
- Natural	Yes/no	
- Artificial insemination	Yes/no	
Management system		(Descheemaeker et al., 2010)
- Without shelter	Yes/no	
- With shelter	Yes/no	
- Shelter and free range	Yes/no	
Feed type		(Pagala et al., 2020; Pattiselanno et al., 2021)
- Commercial feed	Yes/no	
- Agricultural/Plantation products	Yes/no	
- Household waste	Yes/no	
Feeding frequency		(Fanimu et al., 2003)
- Once a day	Yes/no	
- Twice a day	Yes/no	
- Three times a day	Yes/no	
Grazing area size		(Tohiran et al., 2019; Kamau, 2004)
- 1 hectare	Yes/no	
- 2 hectares	Yes/no	
- 3 hectares	Yes/no	

Data Analysis

Data analysis was conducted using descriptive statistics by calculating frequency, proportion, mean, standard deviation, and presenting the results in tabular form. In variance analysis for Principal Component Analysis (Iyai et al., 2011; Hosseini et al., 2016; Far & Yakhler 2015), the purpose of this analysis is to understand how much variation in the data is explained by each principal component.

3. Results and discussion

Scrutinizing livestock production parameters

Table 2 provides an overview of livestock management practices, focusing on breeding, feeding, and keeping systems in a specific agricultural context. The number of offspring per parental female livestock is relatively low (mean = 0.154), with a high variability (std. dev = 0.738), indicating inconsistent breeding success. Annual births per female parent livestock are also minimal (mean = 0.043), reflecting either low fertility rates or challenges in breeding management. The majority of livestock are of local breeds (mean = 0.350), followed by crossbred (0.077) and wild types (0.094). This suggests a dominance of indigenous stock over improved or exotic breeds. Natural mating is more common (mean = 0.684) than artificial insemination (mean = 0.376),

reflecting traditional practices and potential limitations in access to artificial breeding technologies. A significant proportion of livestock are managed without shelter (mean = 0.915), indicating traditional, extensive farming practices. Only a small fraction uses shelters (mean = 0.171) or a combination of shelter and free-range systems (mean = 0.085), suggesting limited investment in housing infrastructure.

Livestock rely mainly on agricultural or plantation products (mean = 0.479), while commercial feed (mean = 0.009) and household waste (mean = 0.009) are minimally used. Feeding frequency is primarily twice a day (mean = 0.598), with fewer farmers feeding once (0.145) or three times a day (0.154). The most common grazing area size is 1 hectare (mean = 1.350), followed by 3 hectares (mean = 0.675), with very few having 2 hectares (mean = 0.009).

Traditional practices dominate in terms of breeding, feeding, and management systems, with limited adoption of modern techniques or infrastructure. Breeding efficiency and feeding systems have room for improvement to enhance livestock productivity. There is a reliance on natural resources (e.g., agricultural by-products and grazing), suggesting the need for better resource optimization and integration of modern technologies.

Table 2

Descriptive statistic status of livestock production parameters

Livestock Parameter	Mean	Std. Deviation	Minimum	Maximum
Number of Offspring/prnt	0.154	0.738	0.000	4.000
Births/prnt/Year	0.043	0.203	0.000	1.000
Type of Livestock				
- Local	0.350	0.479	0.000	1.000
- Crossbred	0.077	0.268	0.000	1.000
- Wild	0.094	0.293	0.000	1.000
Mating System				
- Natural	0.684	0.467	0.000	1.000
- Artificial Insemination (AI)	0.376	0.486	0.000	1.000
Management System				
- Without Shelter	0.915	0.281	0.000	1.000
- With Shelter	0.171	0.959	0.000	10.000
- Shelter and Free Range	0.085	0.281	0.000	1.000
Feed Type				
- Commercial Feed	0.009	0.092	0.000	1.000
- Agricultural/Plantation Products	0.479	0.502	0.000	1.000
- Household Waste	0.009	0.092	0.000	1.000
Feeding Frequency				
- Once a Day	0.145	0.354	0.000	1.000
- Twice a Day	0.598	0.492	0.000	1.000
- Three Times a Day	0.154	0.362	0.000	1.000
Grazing Area Size				
- 1 Hectare	1.350	0.479	1.000	2.000
- 2 Hectares	0.009	0.092	0.000	1.000
- 3 Hectares	0.675	0.470	0.000	1.000

The model explains a significant proportion of variation in the number of offspring per parent, as indicated by a high F-value (1460.860) and $Pr > F < 0.0001$. The mean squares for the model (15.514) are much higher than for the error (0.011), indicating that the factors included in the model strongly influence this parameter. Overall, the type of livestock significantly impacts the outcomes ($F = 7.705$, $Pr > F < 0.0001$). Local and Crossbreds have no significant effects ($Pr > F = 0.816$ and 0.575), respectively. Wild breed has highly significant effect ($F = 94.911$, $Pr > F < 0.0001$), suggesting that wild livestock exhibit distinct differences in performance or outcomes compared to other types. Mating systems significantly affect outcomes ($F = 8.385$, $Pr > F < 0.0001$). Natural Mating shown highly significant effect ($F = 256.165$, $Pr > F < 0.0001$). Artificial Insemination (AI) also is significant at $F = 12.650$, $Pr > F < 0.0001$.

Management systems significantly influence outcomes ($F = 256.165$, $Pr > F < 0.0001$). Both, Without Shelter and With Shelter, have moderate significance ($Pr > F = 0.042$ and 0.043), respectively. Shelter and Free Range have no significant effect ($Pr > F = 0.777$). Feed type has a significant overall effect ($F = 7.433$, $Pr > F < 0.0001$). Commercial Feed has highly significant ($F = 42.499$, $Pr > F < 0.0001$). Agricultural/Plantation Products shown significant ($F = 6.936$, $Pr > F < 0.0001$). Household Waste as well shown very highly significant ($F = 192.232$, $Pr > F < 0.0001$). Overall, feeding frequency is not significant ($F = 0.444$, $Pr > F = 0.777$). Once a Day of feeding on offer shown significant effect ($F = 144.589$, $Pr > F < 0.0001$), indicating that feeding once a day may significantly influence livestock performance compared to other frequencies. The number of offspring / parent, births/parent/year, mating system, management system, feed type, and feeding frequency (specifically once a day) are significant factors influencing livestock outcomes. Wild livestock, natural mating, and artificial insemination significantly impact livestock performance.

Certain subcategories such as "Shelter and Free Range" under management systems and

"Feeding Frequency" (overall) show no statistically significant effects. Management practices such as using natural mating, improving feed quality (e.g., commercial or agricultural by-products), and optimizing shelter systems can significantly enhance livestock productivity. Wild livestock requires tailored management strategies due to their distinctive performance characteristics.

The table provides the eigenvalues, the percentage of variability explained by each principal component (PC), and the cumulative percentage of explained variance. PCA is used to reduce dimensionality by identifying the most influential components. Eigenvalues represent the amount of variance captured by each principal component. Components with eigenvalues greater than 1 typically have significant contributions to explaining variance (Kaiser Criterion). This shows the proportion of total variability explained by each component. Higher variability percentages indicate more influence of that component in summarizing the data. The cumulative variance shows the total variance explained as components are added sequentially. This helps determine how many components are necessary to capture a substantial amount of information. Eigenvalue is 3.330 (highest among all components). Explains 17.525% of the total variance. F2 to F6 explains between 8.672% and 12.759% of the variance. Together, F1 to F6 explain 71.643% of the total variability, which is a substantial amount. Based on the Kaiser Criterion, components with eigenvalues >1 are significant. F1 through F9 meets this criterion, explaining 90.888% of the variability cumulatively. The first 6 components explain over 70% of the total variability, suggesting they capture most of the information in the dataset. Depending on the context, retaining F1 through F6 could be a reasonable trade-off between simplification and data retention.

F10 to F15 have eigenvalues <1 , and their individual contributions to variability are minimal ($<5\%$ each). They collectively account for only about 9.112% of the variance and may be excluded in further analysis for simplification.

Table 3
Principal Component Analysis

Parameters	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
Eigenvalue	3.33	2.42	2.29	2.09	1.81	1.64	1.35	1.27	1.03	0.84	0.55	0.19	0.09	0.04	0.009
Variability (%)	17.52	12.75	12.06	11.04	9.57	8.67	7.13	6.68	5.42	4.42	2.90	1.02	0.48	0.21	0.047
Cumulative %	17.52	30.28	42.34	53.39	62.97	71.64	78.77	85.46	90.88	95.31	98.22	99.24	99.73	99.95	100.00

The first 6 to 9 components (F1–F9) can be used to reduce dimensionality without significant loss of information, simplifying further analysis. Retaining components with eigenvalues >1 ensures that only meaningful variations are captured, focusing on the most influential factors in the dataset. The threshold for retained variability can depend on specific needs, such as retaining 70% – 90% of the total variance. The PCA reveals that the first 6 components (F1–F6) explain over 71.643% of the total variance, making them sufficient for capturing most of the information in the dataset. Components with eigenvalues <1 (F10–F15) contribute minimally and can likely be excluded for efficiency in analysis.

This graph is a Scree Plot (Figure 1), a common visualization in Principal Component Analysis (PCA). It shows: The height of each bar represents the eigenvalue of the corresponding principal component (F1, F2, F3, etc.). Principal components with higher eigenvalues contribute more to explaining the variance in the dataset. Typically, components with eigenvalues greater than 1 are considered significant (Kaiser Criterion). The red line shows the cumulative percentage of the total variance explained by the components. The curve levels off as more components are added, indicating diminishing returns in the amount of variance explained.

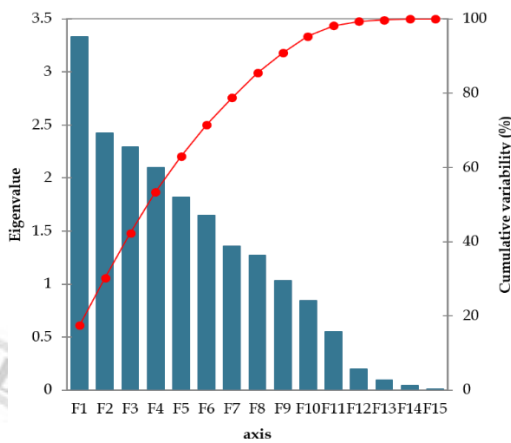


Figure 1. Scree plot of parameters.

Adding more components (F7–F15) contributes little to the cumulative variability (flattened curve). Based on the screen plot, retaining the first 6 components (F1–F6) is a reasonable choice, as they capture most of the variance while reducing the dimensionality of the dataset. Components beyond F6 (with eigenvalues <1) have a negligible contribution to the variance and can be excluded for simpler and more efficient analysis. This plot highlights how PCA can simplify complex datasets

while preserving the most critical information. This figure is a biplot with bootstrap ellipses for the first two principal components (F1 and F2) in a Principal Component Analysis (PCA) (Figure 2). It provides insights into the variability and clustering of observations within the dataset. The horizontal axis (F1) explains 17.53% of the total variance. The first few components (F1 to F6) have the highest eigenvalues and explain most of the variance. After F6, eigenvalues drop below 1, suggesting those components contribute minimally to the total variance. The curve begins to flatten after F6, meaning additional components (e.g., F7–F15) contribute less to explaining the variance. This is often referred to as the elbow point, where the number of components to retain can be decided. F1 through F6 explain approximately 70% – 75% of the total variance, making them sufficient for summarizing the data.

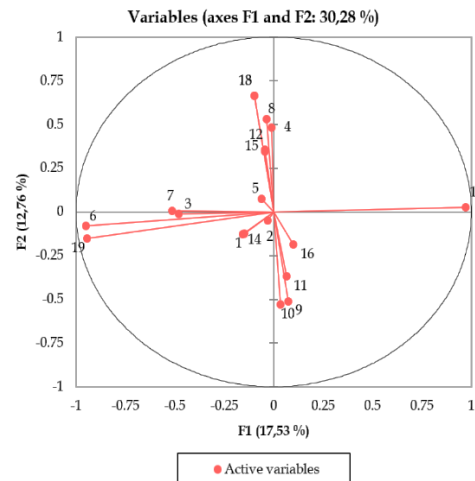


Figure 2. Variables on axes F1 and F2.

The vertical axis (F2) explains 12.76% of the total variance. Together, these two dimensions explain 30.28% of the variability in the data (Figure 3). Each ellipse represents the variability or confidence region of an observation after resampling (bootstrap) (Figure 4). The size of an ellipse indicates the variability in the principal component space. Larger ellipses represent greater uncertainty or variability. Smaller ellipses indicate more stable or consistent observations. Observations such as Obs13 and Obs54 have relatively large ellipses, suggesting higher variability or distinct characteristics in their data. Most observations are clustered near the origin (0, 0), indicating minimal variation along F1 and F2 for these points. Outliers, such as Obs13 and Obs54, are farther from the center, suggesting they are significantly different from the main cluster (Figure

3). The variance explained by F1 and F2 is relatively low (30.28%), meaning additional principal components (e.g., F3, F4) may contribute to capturing more variability in the dataset. Obs13 and Obs54 are distinct observations based on their location and the size of their ellipses. These may warrant further investigation to understand their unique properties or potential data issues.

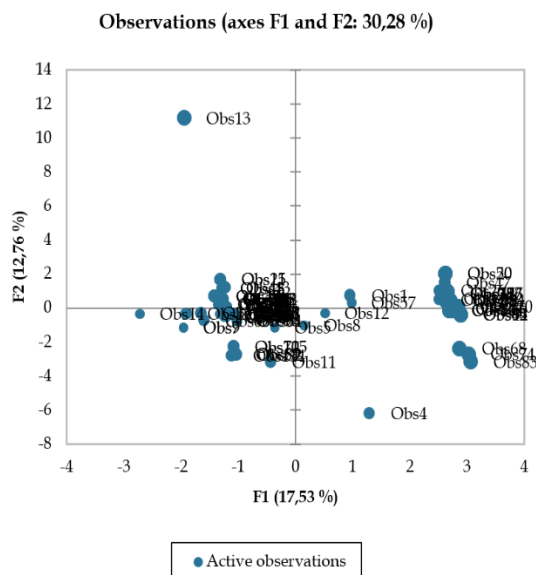


Figure 3. Observations on F1 and F2.

The figure provides insights into data structure and helps identify clusters and outliers. Obs13 and Obs54 may represent distinct groups or anomalies and should be further analyzed. The moderate variance explained (30.28%) suggests that while F1 and F2 capture some key patterns, additional components may be necessary for a comprehensive understanding of the data. This plot is useful for visualizing the relationships among observations and identifying variability or grouping patterns in the data.

The horizontal axis (F1) explains 17.53% of the variance. The vertical axis (F2) explains 12.76% of the variance. Together, these two components account for 30.28% of the total variability in the dataset. While this captures some variability, additional components (e.g., F3, F4) likely hold significant information.

The blue points represent individual observations in the dataset. Most observations are clustered near the origin (0, 0), suggesting they exhibit average characteristics along F1 and F2. Outliers such as Obs13 and Obs54 are located farther from the center, indicating that these observations have distinct patterns or characteristics relative to the majority. The red arrows represent the variables included in the PCA. The direction and length of

each arrow indicate direction, i.e. variables pointing in similar directions are positively correlated. The Length, i.e. longer arrows indicate stronger contributions to the variance explained by F1 and F2. Variables pointing in opposite directions have negative correlations.

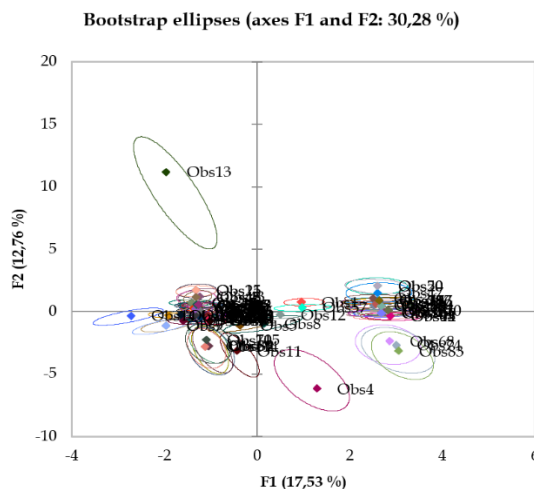


Figure 4. Bootstrap ellipses on axes F1 and F2.

Observations located in the direction of a variable (red arrow) are strongly influenced by that variable. For example, Obs13 aligns more with certain variables, making it distinct from the central cluster. Obs13 and Obs54 are far from the main group and may represent unique patterns or potential anomalies. These could warrant further investigation to understand their significance. Observations closer to the arrows are more influenced by the corresponding variables. Variables pointing toward different quadrants suggest distinct influences on observations. The figure highlights variability among observations and their relationships to variables. Outliers such as Obs13 and Obs54 may represent unique cases worth exploring further. The low variance explained (30.28%) by F1 and F2 suggests that higher components (e.g., F3, F4) should also be examined for a fuller understanding of the dataset. This biplot is a powerful visualization for identifying relationships between observations and variables while highlighting patterns and outliers in the data (Figure 5). Figure 6 is a dendrogram, which is a hierarchical clustering diagram. It visualizes the grouping (clustering) of variables or observations based on their similarity or dissimilarity. The vertical axis represents the dissimilarity or distance between clusters. Higher values indicate greater dissimilarity between groups. The observations or variables are grouped together at different levels of dissimilarity. Clusters are joined at different heights depending on their similarity,

with smaller distances (closer to the bottom) indicating more similar observations. This line indicates the threshold or cutoff for grouping.

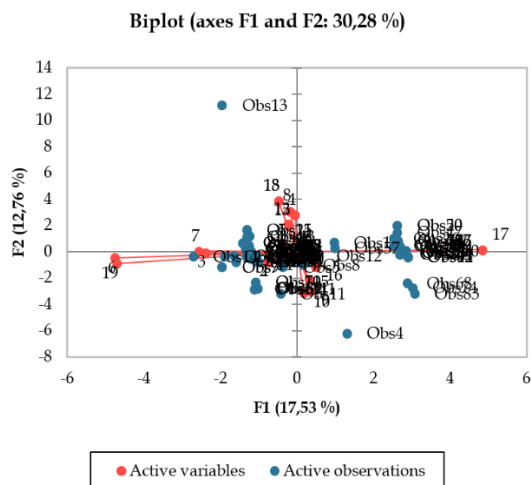


Figure 5. Biplot on Axes F1 and F2.

Observations joined above this line are grouped into distinct clusters. In this case, two main clusters are identified based on the cutoff: C1 (red) and C2 (blue). Contains a large group of closely related observations, as indicated by the shorter branch lengths (lower dissimilarity). This cluster represents observations that are more similar to each other. Contains a smaller group of observations that are distinct from those in C1. The longer branch length leading to C2 suggests that these observations are more dissimilar from those in C1.

The dendrogram helps identify groups of observations with shared characteristics. C1 (Red)

likely represents a more homogeneous set of observations, while C2 (Blue) includes outliers or distinct patterns.

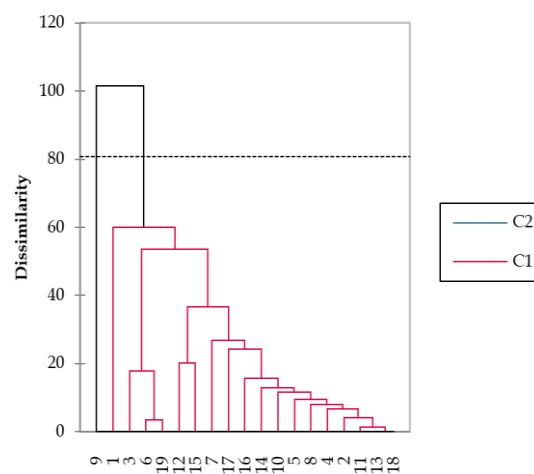


Figure 6. Dendrogram.

The cutoff line determines the number of clusters formed. Adjusting this line can result in more or fewer clusters, depending on the level of granularity needed for the analysis. Further analysis of the clusters (e.g., examining their characteristics or performing statistical tests) can provide deeper insights into what differentiates these groups. This dendrogram shows two main clusters (C1 and C2) based on the dissimilarity threshold. C1 contains a larger, more homogeneous group, while C2 includes more distinct or outlier observations. The dendrogram provides a useful way to visualize relationships and structure within the data.

Table 4
Eigen vectors of parameters

Parameters	F1	F2	F3	F4	F5
Number of Offspring/prnt	-0.081	-0.080	0.422	0.414	-0.229
Births/ prnt /Year	-0.086	-0.083	0.424	0.416	-0.229
Local breed	-0.263	-0.008	-0.169	-0.085	0.186
Cross bred	-0.006	0.310	-0.118	0.145	-0.003
Wild breed	-0.034	0.049	0.045	-0.123	0.126
Natural mating	-0.521	-0.052	-0.078	0.001	0.067
Artificial Insemination (AI)	-0.282	0.004	0.057	0.240	-0.014
Without Shelter	-0.019	0.341	0.353	-0.030	0.464
With Shelter	0.040	-0.328	-0.316	0.351	0.312
Shelter and Free Range	0.019	-0.341	-0.353	0.030	-0.464
Commercial Feed	0.036	-0.236	-0.220	0.355	0.464
Agricultural/Plantation Products	-0.025	0.230	-0.118	-0.103	-0.088
Household Waste	-0.054	0.426	-0.270	0.342	-0.087
Feed freq Once a Day	-0.017	-0.032	0.057	-0.025	0.206
Feed freq Twice a Day	-0.024	0.221	-0.163	-0.179	-0.175
Feed freq Three Times a Day	0.055	-0.120	0.011	-0.024	0.030
No. graze area 1 Hectare	0.532	0.016	0.027	0.077	0.028
No. graze area 2 Hectares	-0.054	0.426	-0.270	0.342	-0.087
No. graze area 3 Hectares	-0.518	-0.099	0.025	-0.143	-0.011

This table represents the loadings of different variables (parameters) on the first five principal components (F1, F2, F3, F4, F5) in a Principal Component Analysis (PCA). Each value indicates how strongly a variable contributes to the respective principal component. The higher the absolute value, the stronger the influence of that variable on the component. Number of grazing area with one hectare has the highest positive loading (0.532), indicating it strongly influences F1. Natural mating (-0.521) and number of grazing areas with 3 hectares (-0.518) have strong negative contributions to F1. Grazing practices and natural mating are the dominant factors captured by this component. F1 likely represents land use and mating strategies (Altaye et al., 2014; Parsons et al., 2013; Musa et al., 2006; Serey et al., 2014). Household waste (0.426) and number of grazing areas with two hectares (0.426) are the strongest contributors to F2. Parameters of without shelter (0.341) and crossbred (0.310) also have notable positive contributions. With shelter (-0.328) and shelter and free range (-0.341) contribute negatively. Component of F2 contrasts feeding practices (e.g., household waste) with sheltering systems and breed types. This component may represent feeding and housing strategies. Number of offspring/parents (0.422) and births/ Mother/Year (0.424) are the strongest contributors. Without Shelter (0.353) and shelter and free range (-0.353) also influence F3. Component of F3 emphasize reproductive performance and housing systems. This component likely reflects breeding productivity (Frison et al., 2011; Mekonnen et al., 2012).

Commercial Feed (0.355) and Household Waste (0.342) positively contribute to F4. With Shelter (0.351) also contributes significantly. F4 highlights the impact of feeding frequency and housing systems on livestock performance. This component likely represents feeding and housing efficiency. Without Shelter (0.464) and Commercial Feed (0.464) have the strongest contributions. With Shelter (0.312) and Feed frequency Once a Day (0.206) also contribute. Shelter and Free Range (-0.464) negatively influences F5. F5 contrasts the use of shelter and feeding systems, suggesting it represents shelter and feed management practices (Das, 2018; Goddard et al., 2013; Steffens, 2016).

Number of Offspring per Mother and Births per Mother/Year strongly influence F3, linking them to breeding efficiency. Natural mating heavily influences F1, contrasting with Artificial Insemination (AI) (weakly positive). Without Shelter and With Shelter have contrasting contributions across components, particularly F2 and F5. Shelter and Free Range consistently contribute negatively where sheltering practices are prominent. Commercial Feed and Household Waste are key influencers for F4 and F5, showing their role in livestock systems. Grazing on 1 Hectare and 3 Hectares dominate F1, while 2 Hectares align with F2. F1 to F5 collectively capture different dimensions of livestock management. These components emphasize the interplay of grazing area, breeding practices, feeding systems, and housing, highlighting their importance in optimizing livestock performance.

Table 5
Factor loadings of parameters

Parameters		F1	F2	F3	F4	F5
Number of Offspring/prnt	P1	-0.148	-0.125	0.639	0.600	-0.309
Births/prnt/Year	P2	-0.157	-0.129	0.642	0.602	-0.309
Local breed	P3	-0.481	-0.012	-0.256	-0.124	0.251
Cross bred	P4	-0.010	0.483	-0.178	0.210	-0.004
Wild breed	P5	-0.062	0.076	0.067	-0.178	0.169
Natural mating	P6	-0.951	-0.081	-0.117	0.001	0.090
Artificial Insemination (AI)	P7	-0.514	0.007	0.086	0.348	-0.019
Without Shelter	P8	-0.035	0.531	0.535	-0.043	0.625
With Shelter	P9	0.074	-0.510	-0.478	0.509	0.420
Shelter and Free Range	P10	0.035	-0.531	-0.535	0.043	-0.625
Commercial Feed	P11	0.066	-0.368	-0.333	0.514	0.626
Agricultural/Plantation Products	P12	-0.045	0.357	-0.179	-0.150	-0.119
Household Waste	P13	-0.099	0.663	-0.409	0.495	-0.117
Feed freq Once a Day	P14	-0.030	-0.050	0.086	-0.036	0.278
Feed freq Twice a Day	P15	-0.044	0.345	-0.246	-0.259	-0.236
Feed freq Three Times a Day	P16	0.100	-0.187	0.017	-0.035	0.041
No. graze area 1 Hectare	P17	0.970	0.025	0.041	0.111	0.037
No. graze area 2 Hectares	P18	-0.099	0.663	-0.409	0.495	-0.117
No. graze area 3 Hectares	P19	-0.945	-0.153	0.039	-0.207	-0.014

This table represents factor loadings from a Principal Component Analysis (PCA). Factor loadings measure the correlation between the original variables (parameters) and the extracted components (F1–F5). Each parameter's loading shows its contribution to a specific component, with higher absolute values indicating stronger influence. Number of grazing area 1 hectare (P17) is 0.970. The most significant positive contributor, indicating that grazing area (1 hectare) strongly aligns with F1. Number of grazing area 3 hectares (P19) is -0.945. It means that a strong negative contributor, contrasting with 1-hectare grazing. Natural mating (P6) (-0.951) has a strong negative influence on this component. F1 is likely associated with grazing area usage and mating strategies, with contrasting patterns between smaller grazing areas and traditional mating systems. Household Waste (P13) (0.663) and Number of grazing area 2 hectares (P18) is 0.663 showing strong positive contributions. Without Shelter (P8) (0.531) is also a significant positive influence. With Shelter (P9) (-0.510) and Shelter and Free Range (P10) is -0.531 means a negative contribution, contrasting with "Without Shelter. F2 likely reflects feeding systems and sheltering practices, highlighting the influence of feeding types (e.g., household waste) and housing strategies. Number of Offspring per Mother (P1) (0.639) and Births per Mother/Year (P2) (0.642): Strong positive contributors, emphasizing reproductive performance. Without Shelter (P8) (0.535) and Shelter and Free Range (P10) (-0.535): Shelter practices also influence F3. F3 represents reproductive productivity and sheltering systems, indicating a link between sheltering conditions and breeding success. Commercial Feed (P11) (0.514) and With Shelter (P9) (0.509): Strong positive contributors. Household Waste (P13) (0.495): Another significant positive influence. F4 likely reflects feeding and shelter efficiency, particularly the impact of commercial feed and household waste on livestock performance. Without Shelter (P8) (0.625), Commercial Feed (P11) (0.626), and With Shelter (P9) (0.420): Strong positive contributors. Shelter and Free Range (P10) (-0.625): A strong negative influence, contrasting with structured shelter systems. F5 captures contrasting housing and feeding strategies, differentiating structured shelter and feed systems from mixed or free-range systems. Number of offspring per parent (P1) and Births per parent/Year (P2) strongly influence F3, empha-

sizing their role in breeding efficiency. One hectare grazing (P17) dominates F1, contrasting with 3 hectares grazing (P19). The F1 highlights the effect of grazing area size on livestock systems. Shelter variables (P8, P9, P10) contribute significantly across F2, F3, and F5, indicating their central role in livestock management. Commercial Feed (P11) and Household Waste (P13) influence F4 and F5, suggesting their impact on efficiency and livestock performance. This analysis highlights the distinct roles of grazing areas, feeding types, breeding productivity, and shelter systems in shaping livestock management outcomes.

4. Conclusions

Conclusions of this study constitute traditional practices dominate in terms of breeding, feeding, and management systems, with limited adoption of modern techniques or infrastructure. The number of offspring or parent, births/parent/year, mating system, management system, feed type, and feeding frequency (specifically once a day) are significant factors influencing livestock outcomes. Wild livestock, natural mating, and artificial insemination significantly impact livestock performance.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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