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Research Article

Structure and Dynamics of Smallholder Beef Cattle Populations: Implications and Sustainability in The Tropical Highlands of West Sumatra, Indonesia

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ABSTRACT

Background: Livestock population structure and dynamics are key determinants of smallholder beef cattle sustainability, yet their integration has been rarely studied in tropical highland regions. **Objective:** This study aims to examine the structure and dynamics of smallholder beef cattle populations and to evaluate their implications and sustainability within small-scale smallholder livestock systems in West Sumatra, Indonesia. **Methods:** The study included 224 respondents out of a total of 511 livestock farmers. Sampling was conducted using simple random sampling, followed by interviews and direct field observations. The research parameters were: livestock breed, age distribution, sex ratio, number of livestock, and livestock input and output factors. Data analysis was performed using descriptive statistics and the chi-square test with a significance level of 5%. **Results:** The study found that the majority of the cattle were female (72.6%), while the dominant breed was Simmental crossbreeds (86.7%). This indicates that the primary purpose of livestock farming in this region is breeding. On the other hand, the cattle population growth rate remains low at 0.2%, with input factors (22.0%) nearly balanced with output factors (21.8%). The livestock replacement rate is only 5.2%, indicating that the population's regenerative capacity remains limited. Furthermore, the reproductive performance of cattle is strongly influenced by farming experience but is not affected by educational level. **Conclusion:** Beef cattle population demographics support reproduction, but low replacement rates and stagnant population growth threaten long-term sustainability. Improving reproductive efficiency and strengthening breeding programs are essential for sustainable smallholder beef cattle farming.

Keywords: Beef cattle, population dynamics, population structure, replacement rate, smallholder farming system

INTRODUCTION

Indonesia's beef cattle subsector holds strategic value for animal protein supply, food security, and rural household income. In West Sumatra, this subsector is dominated by smallholder farmers, whose limited herd size makes reproductive performance the main driver of population growth. Cattle in such systems function not only as income sources but also as savings and financial security for households (Hilmiati et al., 2024; Syaiful et al., 2019; Syaiful et al., 2023; Amam et al., 2024; Mahbubi & Uchiyama, 2020). Yet livestock numbers have grown more slowly than reproductive potential would suggest, leaving population expansion sluggish.

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Genetic improvement programs mainly artificial insemination and crossbreeding with high-performance breeds such as Simmental and Limousin have boosted production potential in West Sumatra, but may simultaneously narrow genetic diversity and weaken herd resilience to environmental and management stressors (Pineda-Quiroga et al., 2024; Martinez-Boggio et al., 2021; Cervo et al., 2023).

Population structure, encompassing genetic composition, sex ratio, and age distribution, is a well-established determinant of both reproductive capacity and long-term system sustainability (O'Brien et al., 2020; Gobena et al., 2018; Naidu et al., 2022; Engelken, 2021; Rapiya et al., 2025). Equally important is population dynamics, reflected in the balance between inflows (births, purchases) and outflows (sales, mortality, slaughter), which indicates growth performance (Li et al., 2023; Schaerer et al., 2014). A comprehensive evaluation therefore requires structure and dynamics to be assessed jointly.

Existing literature, however, has largely emphasized production outcomes, leaving the integration of structure and dynamics underexplored in smallholder contexts despite herd performance being shaped by intertwined biological, managerial, and socio-economic factors (Bombiti et al., 2025; Abdul-Rahaman & Abdulai, 2020; Rahman et al., 2020).

Livestock population structure is a key factor in determining the sustainability of livestock farming systems; however, to date, it has not been comprehensively considered in sustainability studies. Therefore, this study examines the relationship between population structure and population dynamics in smallholder beef cattle farming systems, with sustainability as the primary focus. From a livestock reproduction perspective, a low replacement rate may indicate that implementation of artificial insemination and pregnancy detection at the farmer level is not yet optimal.

Based on this, the objective of this study is to examine and analyze the population structure and dynamics of beef cattle in the tropical highlands of West Sumatra, Indonesia, and to evaluate their implications for beef cattle population growth and the sustainability of the livestock farming system.

MATERIAL AND METHODS

Research Design and Study Area

This study employed survey methods and direct field observations, using a descriptive-analytical approach, to characterize the structure and dynamics of the beef cattle population in smallholder livestock farming systems.

The study was conducted from July to October 2024 in Ampek Angkek Subdistrict, Agam Regency, West Sumatra Province, Indonesia (Figure 1). The study site was selected using purposive sampling because it is representative of beef cattle production systems in the tropical highlands of West Sumatra, characterized by small-scale, smallholder livestock operations integrated with agricultural and livestock systems.

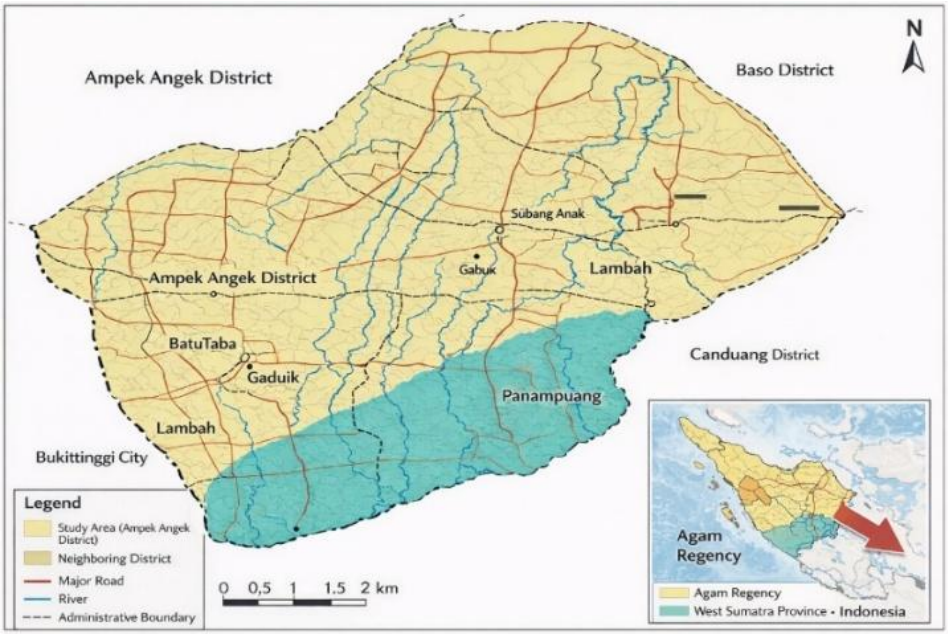

Figure 1. Map of Ampek Angkek Subdistrict, Agam Regency, West Sumatra Province, Indonesia

Population and Sampling Procedure

Out of 511 beef cattle farmers, 224 respondents made up the research sample. With a 95% confidence level and a 5% margin of error, the sample was selected by simple random sampling using the Slovin formula (Ahmed, 2024). As a result, every farmer in the population had an equal chance of getting chosen.

Data Collection

Both primary and secondary data were used in the investigation. Research using structured interviews and firsthand observations of livestock farmers yielded primary data. Meanwhile, secondary data were obtained from the Agam Regency Livestock Service in West Sumatra and from farmers' official documents.

The following variables were noted: 1. farmer characteristics (gender, age, education level, experience raising livestock, and primary occupation); 2. breed composition of cattle; 3. size of the livestock population; 4. sex ratio; 5. age; and 6. population input factors (births and purchases) and population output factors (sales, deaths, and slaughter).

Age Structure Determination

The dentition, specifically the eruption and wear patterns of livestock incisors, was used to determine the animals' ages (Mushonga et al., 2020). Two assessors who had undergone calibration performed the entire cattle age estimation procedure in this study to ensure data accuracy and consistency in age measurement outcomes.

Population Structure Analysis

Based on the quantity of cattle held, age distribution, sex ratio, and breed composition, the livestock population structure was examined. In the meantime, the percentage of young female cattle between the ages of one and two determines the replacement rate, which is then compared to a reference range of twenty to thirty percent, which is thought to be sufficient to support the population's reproductive sustainability (Amole & Ayantunde, 2016; Engelken, 2021).

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Population Dynamics Analysis

Population dynamics are evaluated based on livestock population input factors (births and purchases) and output factors (sales, deaths, and culling), expressed in terms of the number of livestock (heads) and as a percentage of the total observed livestock population. Population growth is calculated as the difference between the total input factors (%) and the total output factors (%). A positive value indicates an increase in the livestock population, while a negative value indicates a decrease in the livestock population.

Statistical Analysis

The data obtained were analyzed descriptively to characterize the farmers and the livestock population. Meanwhile, the relationship between farmer characteristics and livestock demographic indicators was analyzed using the chi-square (χ^2) test at a significance level of $P < 0.05$. The categories used included farming experience, educational level, number of livestock owned, and birth and death rates.

RESULTS AND DISCUSSION

Farmers' Characteristics and Their Association with Livestock Performance

Figure 2 shows that 86.2% of livestock producers in this study region are men, and 92.0% are of productive age. The majority of farmers (79.9%) have raised cattle for more than ten years, indicating adequate practical experience. Furthermore, most farmers have only completed high school, suggesting that their primary jobs involve agriculture and livestock raising. The performance of the cattle farming systems at this study location is not immediately reflected in these traits, but they do characterize the human resource profile there.

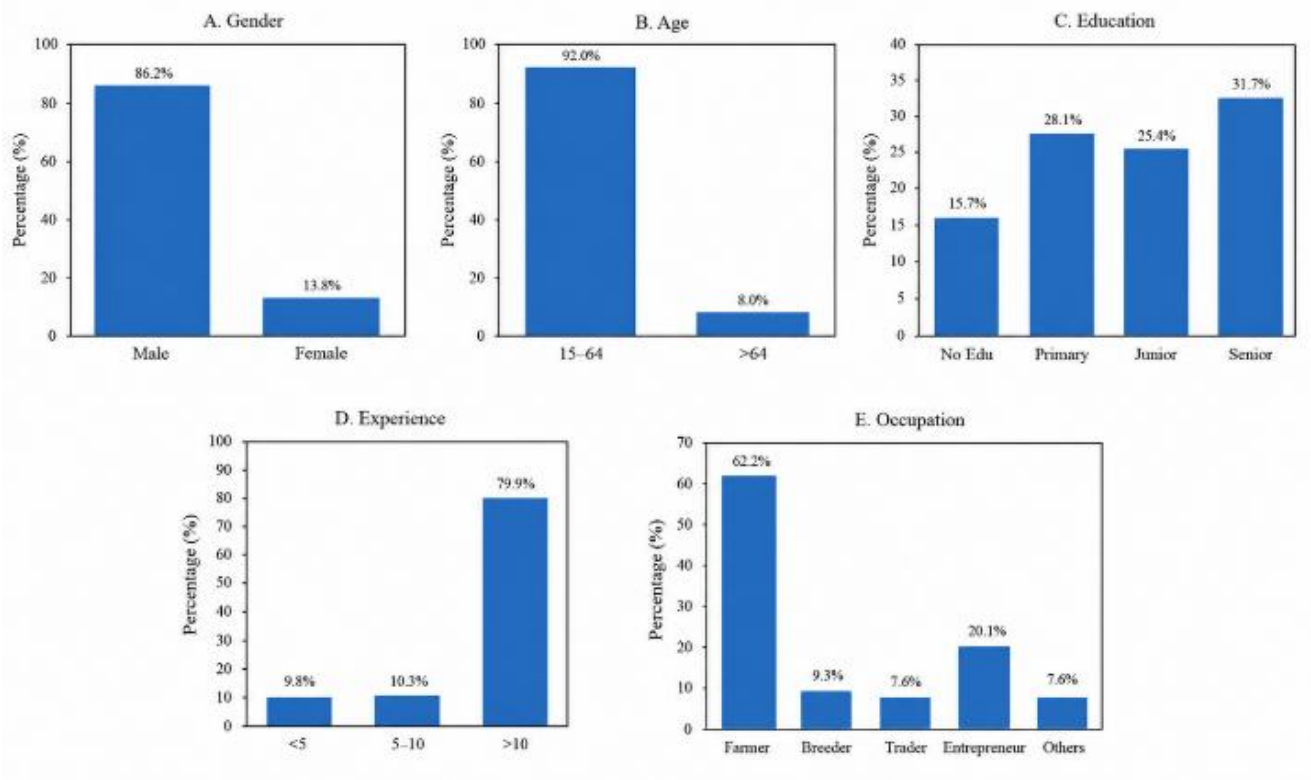

Figure 2. Sociodemographic Profile of Respondents

Table 1. The association between farmer characteristics and livestock performance indicators

Variable	Category	Indicator	χ^2	p-value
Livestock Experience	≤10 years vs >10 years	Birth Rate	6.21	0.013*
Primary Occupation	Farmer vs Livestock Farmer	Livestock Scale	5.47	0.019*
Education Level	Low vs High	Mortality Rate	2.11	0.146

Note: * Significantly different at $p < 0.05$

Table 1 demonstrates that primary occupation is substantially correlated with herd size (χ^2 = 5.47; p = 0.019) and livestock-raising experience is significantly correlated with birth rates (χ^2 = 6.21; p = 0.013). Conversely, educational level was not significantly associated with livestock mortality rates (p = 0.146). The results of this study suggest that farmers with longer experience are likely to have better reproductive management skills.

Herd Ownership Structure

Table 2 shows that 96.4% of respondents own only one to five cows, while ownership of six to ten cows (2.7%) and more than ten cows (0.9%) is relatively rare. The results of this study indicate that small-scale operations still dominate livestock farming in the study area. This limited scale of livestock ownership could restrict the number of productive breeding cows and farmers' ability to maintain replacement livestock, hindering the growth of the livestock population and the long-term sustainability of the business.

Table 2. Distribution of Livestock Ownership by Scale

Herd Size (Number of Cattle)	Number of Farmers (n)	Percentage (%)	Expected (E)	$(O-E)^2/E$
1–5	216	96.4	74.7	266.7
6–10	6	2.7	74.7	69.3
>10	2	0.9	74.7	68.6
Total	224	100		404.6

Note: $\chi^2 = 404.6$; df = 2; $p < 0.001$

Breed Composition

Figure 3 shows Simmental crossbreds dominating the population (86.7%), followed by Limousin crossbreds (12.5%), with Ongole (0.6%) and Brahman (0.2%) present only marginally reflecting widespread artificial insemination use and farmer preference for high-yielding crossbreeds. While this suggests narrowing breed representation, the absence of pedigree or molecular data means genetic diversity, disease resistance, or adaptability cannot be inferred; these results describe breed representation only. Preserving locally adapted breeds alongside crossbreeding could support long-term population resilience in tropical settings.

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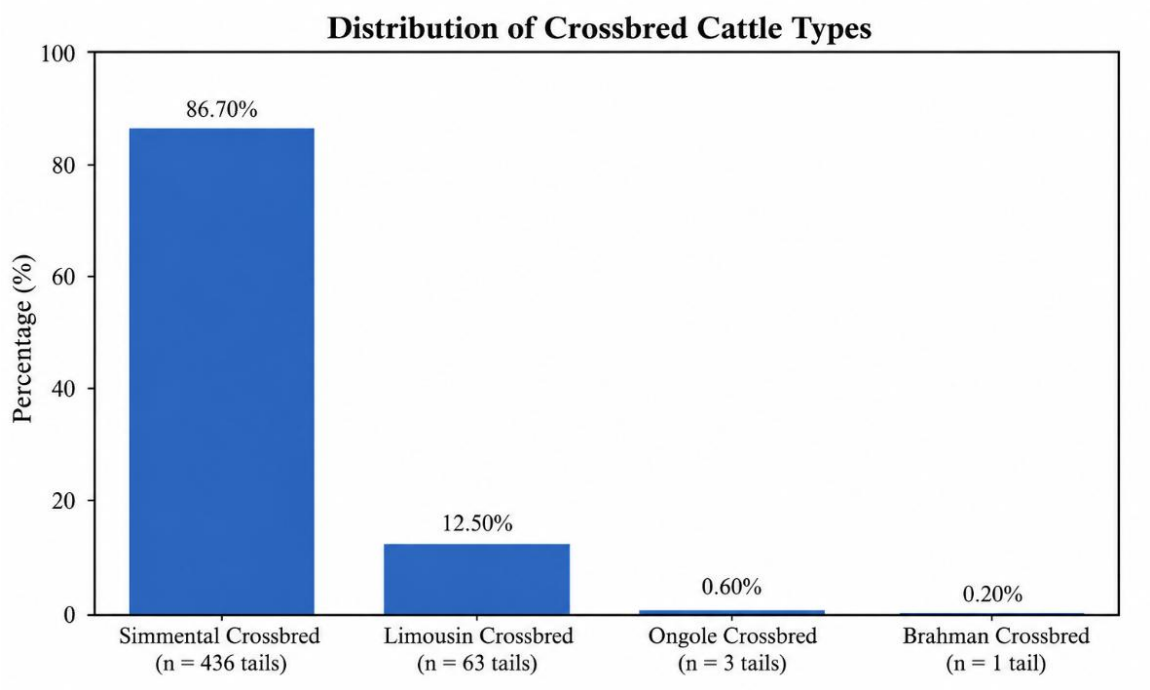

Figure 3. Proportional Composition of Crossbred Cattle Breeds

Sex Ratio and Age Structure

Figures 4. show females made up 72.6% of the herd, giving a male to female ratio of roughly 1:3.9. Figure 5. show females adult animals over two years old accounted for 76.7% of the population, calves under one year made up 18.1%, and young cattle between one and two years represented only 5.2%. This population structure's preponderance of adult and female cattle suggests comparatively high reproductive capacity. With a replacement rate of just 5.2%, the proportion of young animals is low and well below the recommended level. This implies that the number of replacement livestock entering the breeding population is limited. These circumstances suggest that the population's capacity for regeneration is insufficient to ensure its long-term survival, even though the existing demographic structure appears favorable.

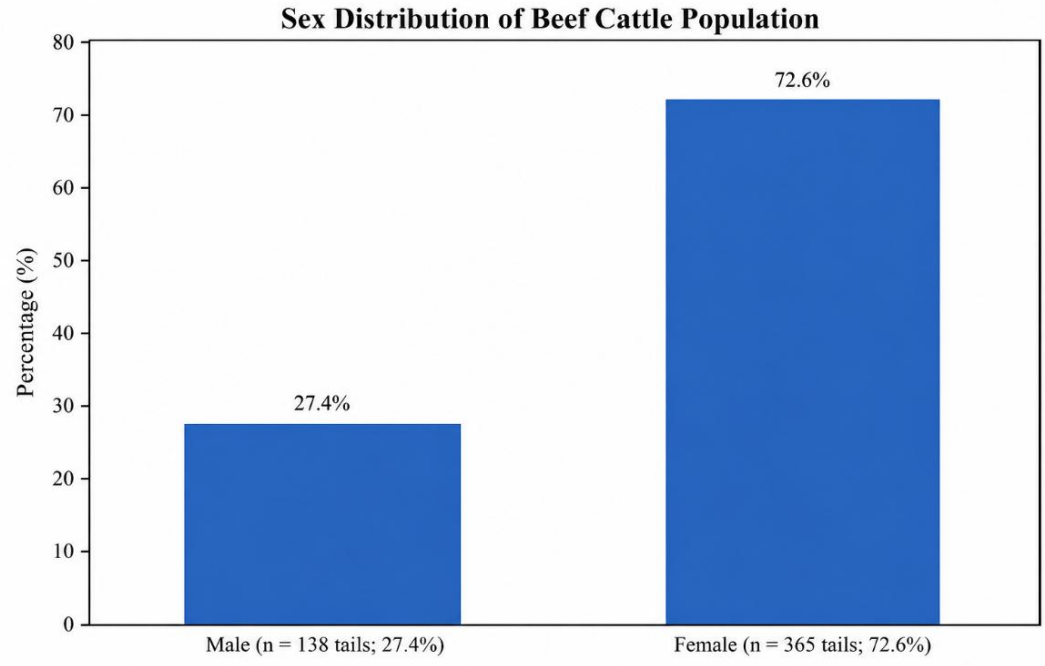

Figure 4. Male To Female Composition of The Surveyed Cattle Population

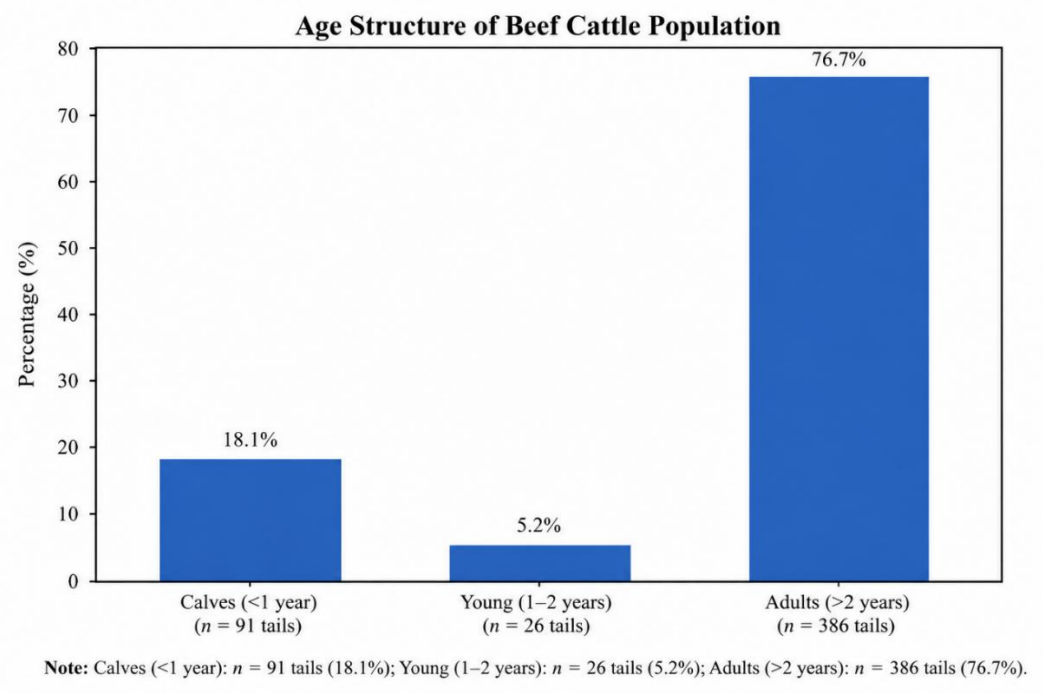

Figure 5. Age Class Composition of The Studied Beef Cattle Herd

Population Dynamics

Sales are the highest output element (19.5%), whereas births are the largest input factor (16.2%), as seen in Figure 6 and 7. The annual population growth rate is only 0.2% because total inputs (22.0%) and total outputs (21.8%) are about equal. This near-balance illustrates how high livestock sales rates counteract the population growth caused by ongoing reproduction.

The study's findings show that cattle are a household financial asset in addition to a source of productivity, which ultimately leads to a comparatively slow pace of livestock population growth.

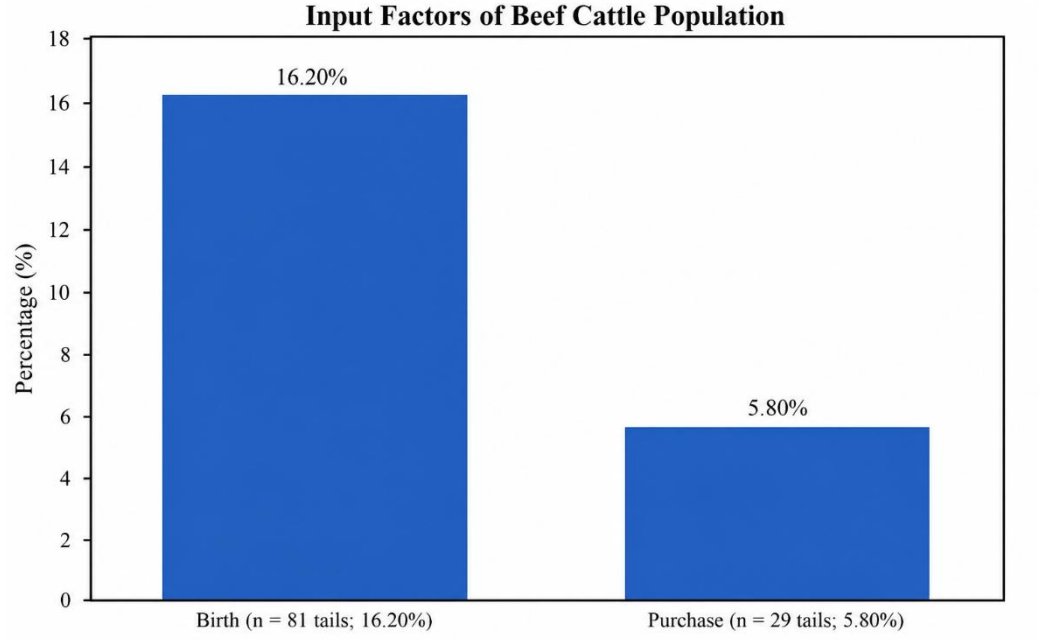

Figure 6. Population Input Factors (Births and Purchases)

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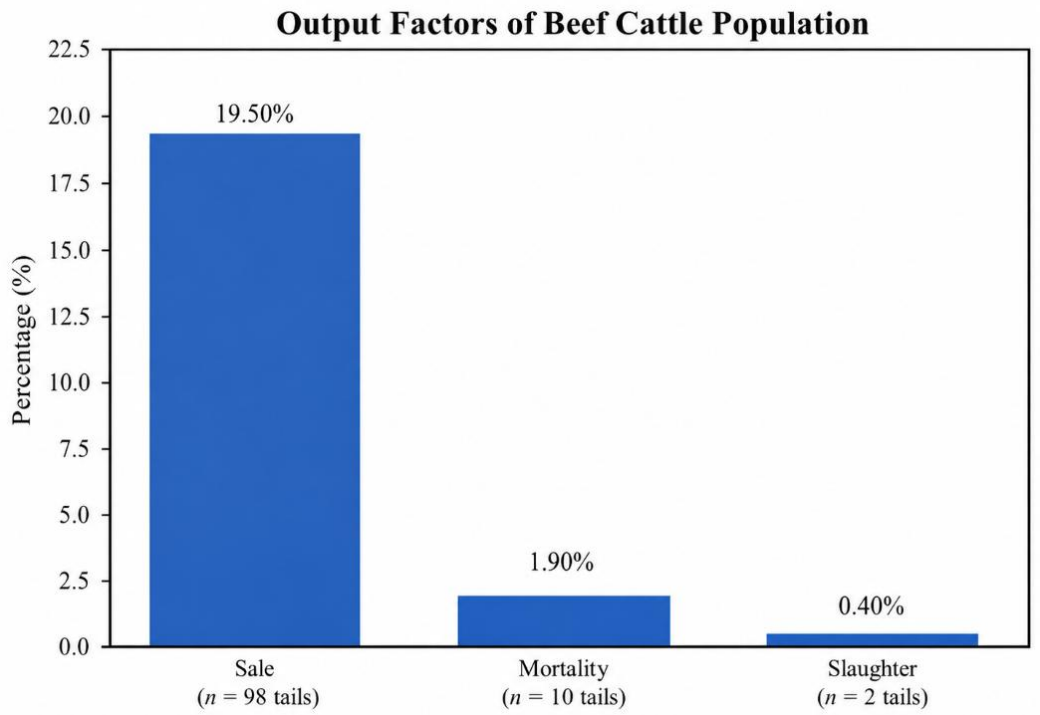

Figure 7. Components of The Beef Cattle Population Output (Sales, Deaths, And Slaughter)

Relationship Between Population Structure and Population Dynamics

By combining the input and output components of the population, Figure 8 illustrates the general population dynamics of beef cattle. These results show a glaring disparity when compared to the population structure analysis results. The number of cattle is still quite small, despite the fact that adults and females predominate, which demographically should favor increase. Low replacement rates and a near-balance between the number of cattle joining the herd (input factor) and departing it (output factor) have an impact on this condition.

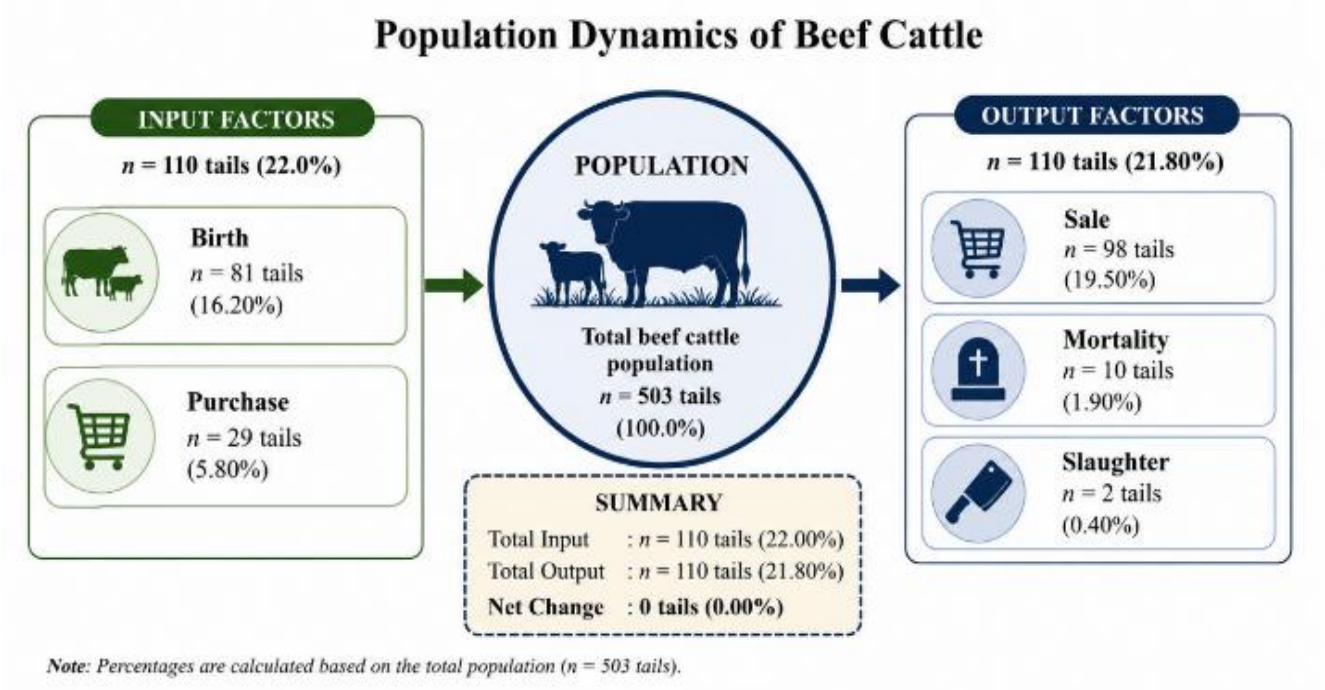

Figure 8. Integrated Flowchart of Input and Output Factors in Beef Cattle Population Dynamics

The study's findings show that livestock population expansion cannot be fueled solely by a favorable population structure. Improving reproductive efficiency, keeping more female animals

as possible replacement breeding stock, and putting more planned husbandry management into practice are all necessary to maximize available reproductive potential.

CONCLUSION

The study's findings show that the population of beef cattle on smallholder farms exhibits demographic traits conducive to livestock reproduction, as evidenced by the prevalence of adult animals and females of reproductive age. However, due to low replacement rates and a balance between livestock inputs and outputs, the population growth rate remains very low, maintaining the demographic stability of the beef cow population. These circumstances point to demographic limitations that may affect the long-term viability of the beef cow population, notably poor livestock regeneration and small-scale livestock ownership. To provide a more thorough understanding of the dynamics of beef cow populations and the long-term viability of smallholder livestock systems, further research that incorporates demographic, economic, environmental, and social indices is required.

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REFERENCES

Abdul-Rahaman, A., & Abdulai, A. (2020). Farmer groups, collective marketing and smallholder farm performance in rural Ghana. *Journal of Agribusiness in Developing and Emerging Economies, 10*(5), 511–527. https://doi.org/10.1108/JADEE-07-2019-0095

Ahmed, S. K. (2024). How to choose a sampling technique and determine sample size for research: A simplified guide for researchers. *Oral Oncology Reports, 12*, 100662. https://doi.org/10.1016/j.oor.2024.100662

Amam, A., Jadmiko, M. W., Harsita, P. A., & Rusdiana, S. (2024). Formulating a strategy for development of smallholder beef cattle farming in Indonesia with the force field analysis (FFA) method. *BIO Web of Conferences, 88*, 00030. https://doi.org/10.1051/bioconf/20248800030

Amole, T. A., & Ayantunde, A. A. (2016). Assessment of existing and potential feed resources for improving livestock productivity in Niger. *International Journal of Agricultural Research, 11*(2), 40–55. https://doi.org/10.3923/ijar.2016.40.55

Assefa, S., Duguma, B., & Worku, Z. (2024). Assessment of livestock husbandry practices and production constraints among smallholder mixed crop-livestock production systems in the Majang zone, southwest Ethiopia. *Heliyon, 10*(19), e37400. https://doi.org/10.1016/j.heliyon.2024.e37400

Bombiti, J. R. N., Taurayi, S., Mugari, E., Tatsvarei, S., Zvinavashe, A. P., & Musakwa, W. (2025). Household and farm-level drivers of the use and intensity of soil fertility amendments in smallholder farming systems: A case of Masvingo District, Zimbabwe, and Mopani District, South Africa. *Frontiers in Agronomy, 7*, 1471052. https://doi.org/10.3389/fagro.2025.1471052

 DOI: 10.25077/alive.v3.n2.p157-168.2026

Cao, J., Baumung, R., Boettcher, P., Scherf, B., Besbes, B., & Leroy, G. (2021). Monitoring and progress in the implementation of the global plan of action on animal genetic resources. *Sustainability, 13*(2), 775. https://doi.org/10.3390/su13020775

Cervo, H. J., Jardim-Barcellos, J. O., Peripolli, V., & McManus, C. (2023). Use of artificial insemination in dairy herds in Northwestern Rio-grandense, Brazil. *Revista Colombiana de Ciencias Pecuarias, 36*(3), 141–151. https://doi.org/10.17533/udea.rccp.v36n3a3

Depardieu, C., Girardin, M. P., Nadeau, S., Lenz, P., Bousquet, J., & Isabel, N. (2020). Adaptive genetic variation to drought in a widely distributed conifer suggests a potential for increasing forest resilience in a drying climate. *New Phytologist, 227*(2), 427–439. https://doi.org/10.1111/nph.16551

Engelken, T. J. (2021). Breeding season evaluation of beef herds. In R. S. Youngquist & W. R. Threlfall (Eds.), *Bovine reproduction* (2nd ed., pp. 532–537). Wiley-Blackwell. https://doi.org/10.1002/9781119602484.ch44

Gobena, M., Elzo, M. A., & Mateescu, R. G. (2018). Population structure and genomic breed composition in an Angus–Brahman crossbred cattle population. *Frontiers in Genetics, 9*, 90. https://doi.org/10.3389/fgene.2018.00090

Hilmiati, N., Ilham, N., Nulik, J., Rohaeni, E. S., DeRosari, B., Basuki, T., Hau, D. K., Ngongo, Y., Lase, J. A., Fitriawaty, F., Surya, S., Qomariyah, N., Hadiatry, M. C., Ahmad, S. N., Qomariah, R., Suyatno, S., Munir, I. M., Hayanti, S. Y., Panjaitan, T., & Yusriani, Y. (2024). Smallholder cattle development in Indonesia: Learning from the past for an outcome-oriented development model. *International Journal of Design & Nature and Ecodynamics, 19*(1), 169–184. https://doi.org/10.18280/ijdne.190119

Li, Y., Mayberry, D., Jemberu, W., Schrobback, P., Herrero, M., Chaters, G., Knight-Jones, T., & Rushton, J. (2023). Characterizing Ethiopian cattle production systems for disease burden analysis. *Frontiers in Veterinary Science, 10*, 1233474. https://doi.org/10.3389/fvets.2023.1233474

Lubungu, M. (2017). Factors affecting the livestock herd size among smallholder households in Zambia. *Tropical Animal Health and Production, 49*(8), 1607–1612. https://doi.org/10.1007/s11250-017-1366-9

Mahbubi, A., & Uchiyama, T. (2020). Assessing the sustainability of the Indonesian halal beef supply chain. *International Journal on Food System Dynamics, 11*(5), 468–481. https://doi.org/10.18461/ijfsd.v11i5.68

Marques, M. O., Morotti, F., Lorenzetti, E., Bizarro-Silva, C., & Seneda, M. M. (2018). Intensified use of TAI and sexed semen on commercial farms. *Animal Reproduction, 15*(3), 197–203. https://doi.org/10.21451/1984-3143-AR2018-0070

Martinez-Boggio, G., Lema, M., Aguilar, I., Gimeno, D., & Ravagnolo, O. (2021). Reproductive performance of Angus, Hereford, Salers and Nellore crossbred females: Additive and non-additive effects. *Journal of Animal Breeding and Genetics, 138*(6), 688–697. https://doi.org/10.1111/jbg.12553

Misra, A. K., Rama Rao, C. A., Subrahmanyam, K. V., Vijay Sankar Babu, M., Shivarudrappa, B., & Ramakrishna, Y. S. (2007). Strategies for livestock development in the rainfed agro-ecosystem of India. *Livestock Research for Rural Development, 19*(6).

Mushonga, B., Shinexuugi, I., Mbiri, P., Samkange, A., Madzingira, O., & Kandiwa, E. (2020). Applicability of teeth examination as a tool for age estimation in a semi-arid cattle production environment in Namibia. *Tropical Animal Health and Production, 52*(4), 1649–1654. https://doi.org/10.1007/s11250-019-02172-x

Mustafa, A. (2025). Strategies to balance productivity and genetic diversity for the sustainable use of indigenous livestock breeds: A case study of Ethiopia. *Genetic Resources, 6*(11), 82–98. https://doi.org/10.46265/genresj.NNFE5064

Mwanga, G., Mujibi, F. D. N., Yonah, Z. O., & Chagunda, M. G. G. (2019). Multi-country investigation of factors influencing breeding decisions by smallholder dairy farmers in sub-Saharan Africa. *Tropical Animal Health and Production, 51*(2), 395–409. https://doi.org/10.1007/s11250-018-1703-7

Naidu, S. J., Arangasamy, A., Selvaraju, S., Binsila, B. K., Reddy, I. J., Ravindra, J. P., & Bhatta, R. (2022). Maternal influence on the skewing of offspring sex ratio: A review. *Animal Production Science, 62*(6), 501–510. https://doi.org/10.1071/AN21086

Nassambaev, E., Akhmetalieva, A. B., Nugmanova, A. E., & Kulbaev, R. M. (2019). Reproductive indicators of stud bulls and bull calves of the Kazakh white breed of various genotypes. *Advances in Animal and Veterinary Sciences, 7*(Suppl. 1), 85–87. https://doi.org/10.17582/journal.aavs/2019/7.s1.85.87

O'Brien, A. C., Purfield, D. C., Judge, M. M., Long, C., Fair, S., & Berry, D. P. (2020). Population structure and breed composition prediction in a multi-breed sheep population using genome-wide single-nucleotide polymorphism genotypes. *Animal, 14*(3), 464–474. https://doi.org/10.1017/S1751731119002398

Pineda-Quiroga, C., Granado-Tajada, I., Basterra-García, A., & Ugarte, E. (2024). Environmental and additive genetic factors that affect artificial insemination success in Latxa dairy sheep breed. *Livestock Science, 289*, 105580. https://doi.org/10.1016/j.livsci.2024.105580

Rahman, M. T., Nielsen, R., Khan, M. A., & Ankamah-Yeboah, I. (2020). Impact of management practices and managerial ability on the financial performance of aquaculture farms in Bangladesh. *Aquaculture Economics & Management, 24*(1), 79–101. https://doi.org/10.1080/13657305.2019.1647578

Rapiya, M., Mndela, M., Truter, W., & Ramoelo, A. (2025). Assessing the economic viability of sustainable pasture and rangeland management practices: A review. *Agriculture, 15*(7), 690. https://doi.org/10.3390/agriculture15070690

Rusinamhodzi, L., Corbeels, M., & Giller, K. E. (2016). Diversity in crop residue management across an intensification gradient in southern Africa: System dynamics and crop productivity. *Field Crops Research, 185*, 79–88. https://doi.org/10.1016/j.fcr.2015.10.007

Schärrer, S., Presi, P., Hattendorf, J., Chitnis, N., Reist, M., & Zinsstag, J. (2014). Demographic model of the Swiss cattle population for the years 2009–2011 stratified by gender, age, and production type. *PLoS ONE, 9*(10), e109329. https://doi.org/10.1371/journal.pone.0109329

Schultz, B., Serão, N., & Ross, J. W. (2019). Genetic improvement of livestock, from conventional breeding to biotechnological approaches. In *Animal agriculture: Sustainability, challenges and innovations* (pp. 393–405). Academic Press. https://doi.org/10.1016/B978-0-12-817052-6.00023-9

Syaiful, F. L., Afriani, T., & Purwati, E. (2019). Effect of FSH dosage on the number and quality of Pesisir cattle embryos. *IOP Conference Series: Earth and Environmental Science, 287*(1), 012003. https://doi.org/10.1088/1755-1315/287/1/012003

Syaiful, F. L., Jaswandi, J., Mundana, M., Ilham, I., Jamarun, N., & Efrizal, E. (2023). Comparison of pregnant diagnosis in local buffalo with a seed germination inhibition test and rectal palpation. *Advances in Animal and Veterinary Sciences, 11*(11), 1869–1874. https://doi.org/10.17582/journal.aavs/2023/11.11.1869.1874

Syaiful, F. L., Jaswandi, J., Mundana, M., & Udin, Z. (2024). The effect of using HEPES in culture medium on oocyte maturation rates and in vitro fertilization in Pesisir cattle. *Journal of Animal Health and Production, 12*(3), 450–457. https://doi.org/10.17582/journal.jahp/2024/12.3.450.457

Tahir, M. B., Wossen, A. M., & Mersso, B. T. (2018). Evaluation of livestock feed balance under mixed crop-livestock production system in the central highlands of Ethiopia. *Agriculture & Food Security, 7*(1), 19. https://doi.org/10.1186/s40066-018-0170-8

Taruvinga, A., Kambanje, A., Mushunje, A., & Mukarumbwa, P. (2022). Determinants of livestock species ownership at the household level: Evidence from the rural OR Tambo District Municipality, South Africa. *Pastoralism, 12*(1), 8. https://doi.org/10.1186/s13570-021-00220-6

Tuffa, S. (2017). Modeling Boran cattle populations under climate change and varying carrying capacity. *Ecological Modelling, 352*, 113–127. https://doi.org/10.1016/j.ecolmodel.2017.03.009

Wernberg, T., Coleman, M. A., Bennett, S., Thomsen, M. S., Tuya, F., & Kelaher, B. P. (2018). Genetic diversity and kelp forest vulnerability to climatic stress. *Scientific Reports, 8*(1), 1851. https://doi.org/10.1038/s41598-018-20009-9

Zuidema, D., Kerns, K., & Sutovsky, P. (2021). An exploration of current and prospective semen analysis and sperm selection for livestock artificial insemination. *Animals, 11*(12), 3563. https://doi.org/10.3390/ani11123563