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Tracking progress toward livestock sector transformation in Tanzania using national and international datasets

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Abstract

Livestock plays a central role in Tanzania's rural economy, yet productivity remains constrained by low-input production systems, limited genetic improvement, suboptimal management practices, and weak market integration. This study assesses the extent and pace of livestock-sector transformation using a multi-source approach that integrates FAOSTAT time-series data, the National Sample Census of Agriculture (NSCA), and multi-wave household data from the National Panel Survey (NPS). Descriptive statistics and trend analysis were employed to evaluate changes in livestock productivity, adoption of improved breeds, management practices (vaccination coverage and supplementary feeding), and commercialization, as measured by household participation in purchasing and selling large and small ruminants. Results indicate measurable progress toward livestock transformation, particularly within the cattle subsector. Meat, milk, and hides productivity improved steadily over the study period, accompanied by substantial increases in improved beef and dairy cattle populations. Adoption of improved beef cattle increased more than fourteenfold, while improved dairy cattle populations more than doubled between 2002 and 2020. Management practices also improved, with vaccination coverage among large ruminants increasing from 43.6% to 64.8% and the proportion of farmers purchasing supplementary fodder rising from 11.0% to 18.5% across survey waves. Commercialization likewise strengthened, reflected by increasing proportions of households purchasing and selling cattle and small ruminants, although market participation remained relatively low overall. In contrast, transformation among small ruminants was slower, characterized by fluctuating improved goat populations, lower vaccination uptake, limited supplementary feeding, and weaker commercialization. Overall, the findings indicate that Tanzania's livestock sector is making measurable progress toward transformation, although advances remain uneven across species and production systems. Policy efforts should prioritize inclusive genetic improvement, strengthened feed and animal health systems, and improved livestock market development to accelerate sustainable transformation.

Keywords Livestock transformation, Cattle, Goats, Sheep, Improved breeds, Productivity trends, Tanzania, Livestock commercialization



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1 Introduction

Livestock production is a cornerstone of agricultural development worldwide, providing meat, milk, hides, and skins while supporting the livelihoods and incomes of millions of rural households. As demand for animal-source foods continues to rise due to population growth, urbanization, and increasing incomes, improving livestock productivity has become an important component of agricultural transformation, particularly in low- and middle-income countries [18, 39]. In sub-Saharan Africa (SSA), livestock transformation increasingly entails improving productivity and production efficiency through better genetics, feeding systems, animal health, management, and market integration rather than simply expanding herd sizes. Nevertheless, substantial productivity gaps persist across production systems. Indigenous cattle, for example, generally produce less than 500 kg of milk per cow annually, whereas improved dairy breeds can yield between 1,500 and 3,500 kg per cow per year [8].

The livestock sector in SSA has considerable potential: approximately 85% of global livestock keepers reside in the region, yet it accounts for only 2.8% of global meat and milk output [18]. This disparity reflects persistent structural constraints, including low genetic potential for conventional production traits, inadequate feeding, animal health challenges, and weak value-chain linkages [10, 25, 36]. However, most livestock production in SSA depends on indigenous breeds, including Zebu cattle, Small East African goats, and Red Maasai sheep, whose adaptation to local climatic conditions, disease pressures, and feed scarcity represents an important production advantage. Livestock transformation should therefore not be interpreted simply as replacing indigenous animals with exotic breeds or converting extensive systems into fully intensive production. Instead, context-specific intensification involving strategic crossbreeding, improved feeding within appropriate production systems, strengthened animal health services, and better management offers opportunities to increase productivity, food security, household income, and resilience while maintaining environmental sustainability [17, 23, 49]. In Tanzania, livestock remains integral to the agricultural economy, food security, employment, and rural livelihoods. Its development has been prioritized through national frameworks including the Agricultural Sector Development Programme II (ASDP-II) and the Livestock Master Plan (2017–2022), which emphasize improved genetics, feed resources, animal health services, productivity, commercialization, and livestock value-chain development [63, 67]. The sector also contributes to the broader ambition of developing a competitive, inclusive, and sustainable agricultural economy under Tanzania's national development strategies [5, 6, 11]. Despite these efforts, important production constraints remain. Studies of smallholder dairy systems have documented low productivity associated with limitations in feeding, calf health, and breed quality [13, 14, 33], while livestock mobility, degradation of feed resources, and ecological constraints continue to affect livestock performance in East African rangelands [4, 71, 72].

Despite the importance of livestock to Tanzania's economy and development agenda, empirical evidence on the extent and direction of livestock-sector transformation remains fragmented. Previous studies have commonly examined individual dimensions or specific production systems, including calf health and management in smallholder dairy systems [13], breeding and farmers' preferences for improved dairy cattle traits [15, 34], and productivity-enhancing interventions involving improved breeds, feeding, and

animal health within particular dairy production systems [49, 51]. Other studies have similarly focused on specific components of livestock production, such as the effects of improved feeding and breeds on productivity or household-level determinants of cattle milk production. Consequently, limited evidence exists that simultaneously evaluates long-term changes in productivity, genetic improvement, management practices, and commercialization across large- and small-ruminant systems using harmonized national and international datasets. This evidence gap makes it difficult to determine whether observed changes represent sustained progress toward livestock-sector transformation or largely reflect continuity in existing production systems. The gap is particularly important for understanding long-term changes in livestock productivity and populations in relation to the adoption of improved breeds, supplementary feeding, vaccination, and market participation.

This study addresses this gap by integrating three complementary data sources: FAO-STAT, the National Sample Census of Agriculture (NSCA), and the National Panel Survey (NPS). The multi-source framework combines long-term national productivity trends with information on livestock populations, breed composition, household management practices, and commercialization. This approach enables the simultaneous examination of dimensions that are usually analyzed separately and facilitates comparisons between large- and small-ruminant production systems. In this study, improved breeds are livestock genetically enhanced through selective breeding or crossbreeding to enhance economically important traits, such as growth rate, milk yield, reproductive performance, feed efficiency, and disease tolerance, compared with indigenous breeds. This distinction does not imply that indigenous breeds are universally inferior; they possess important adaptive characteristics, including resilience to local climatic conditions, endemic diseases, and feed scarcity [73, 74]. Examining both breed categories therefore provides a more balanced basis for interpreting genetic change within Tanzania's diverse livestock production systems.

The study consequently provides an integrated assessment of livestock transformation across four complementary dimensions: productivity, genetic improvement, management practices, and commercialization. Productivity is examined through trends in meat, milk, hides, and skins; genetic improvement through changes in improved and indigenous cattle, goats, and sheep; management practices through supplementary feeding and vaccination; and commercialization through household participation in livestock purchases and sales. Integrating these indicators provides a broader empirical basis for monitoring sectoral change than analyses based on a single dimension or dataset. The resulting evidence can support the implementation and future revision of livestock development policies and strategies in Tanzania while contributing to the broader literature on sustainable livestock transformation in low- and middle-income countries [17, 55].

Accordingly, the study addresses the overarching question: To what extent is Tanzania's livestock sector progressing toward higher productivity, improved management practices, genetic improvement, and increased commercialization, and how do these patterns differ between large- and small-ruminant production systems? By answering this question through integrated national and international evidence, the study seeks to provide a more comprehensive understanding of the direction, extent, and heterogeneity of livestock-sector transformation in Tanzania.

2 Materials and methods

2.1 Study design and scope

This study employed a quantitative secondary data analysis, integrating multiple national and international datasets to assess progress toward transforming Tanzania's livestock sector. The analysis combined harmonized data from FAOSTAT, the National Sample Census of Agriculture (NSCA), and the National Panel Survey (NPS) to evaluate trends in livestock productivity, genetic improvement, management practices, and commercialization. Descriptive statistics, trend analysis, and indicator-based assessments were used to quantify changes across large-ruminant (cattle) and small-ruminant (goats and sheep) production systems. The study covered the period 2000–2022, corresponding to the availability of consistent longitudinal data across the selected data sources. The selection of variables and indicators was guided by the Livestock Sector Transformation Framework [21, 64], which emphasizes productivity enhancement, genetic improvement, feed efficiency, and animal health as key dimensions of livestock transformation. These dimensions provided the conceptual basis for integrating variables across the different datasets.

2.2 Data sources

The study relied on four major datasets to ensure analytical comprehensiveness and adequate temporal coverage. The first source was FAOSTAT, which provided annual time-series data on livestock production and productivity indicators for Tanzania from 2000 to 2022. Specifically, these data included meat output (beef, mutton, and goat meat, measured in tonnes), milk yield from cattle and goats (liters per head per year), raw hides and skins (tonnes), and livestock population estimates for cattle and goats. These indicators were instrumental in tracking long-term productivity trends and structural changes within the livestock sector.

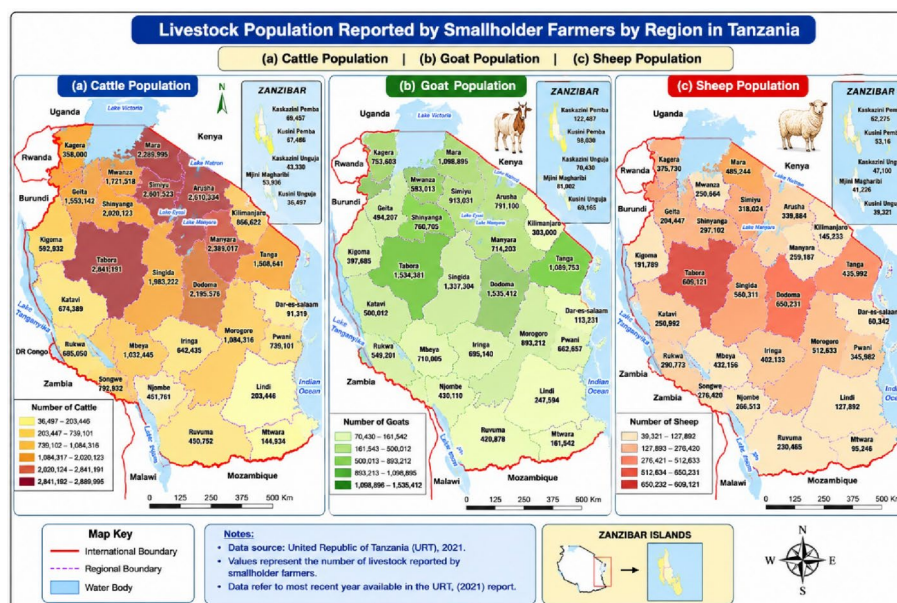


Fig. 1 Cattle population reported by smallholder farmers by region in Tanzania (Fig. 1a); Goat population (Fig. 1b), and Sheep population (Fig. 1c). Source: URT, [65, 70]

The second data source was the National Sample Census of Agriculture (NSCA), which provides nationally representative cross-sectional data on livestock ownership and management. Tanzania has conducted five agricultural censuses since 1971/72 (1971/72, 1994/95, 2002/03, 2007/08, and 2019/20). This study utilized data from the three most recent census rounds (2002/03, 2007/08, and 2019/20) to capture long-term structural changes in the livestock subsector. The NSCA collects detailed information on livestock populations, breed types (improved versus local), the regional distribution of dairy and beef cattle and dairy goats, and management characteristics such as housing systems, breeding practices, and production orientation. These data enabled estimation of adoption rates of improved breeds and assessment of spatial variability in livestock transformation indicators across regions. Figure 2 summarizes the data sources flow chart.

The third dataset was the National Panel Survey (NPS). Tanzania has collected five waves of NPS data between 2008 and 2021. The waves were conducted in the following periods: Wave 1 (2008–2009), Wave 2 (2010–2011), Wave 3 (2012–2013), Wave 4 (2014–2015), and Wave 5 (2020–2021). The NPS contributed micro-level household information collected over multiple waves (Waves 1–5). The extracted variables included household use of supplementary feed (such as fodder, crop residues, and concentrates), livestock vaccination rates for cattle and goats, and access to veterinary and extension services. These indicators captured behavioural and management dimensions of livestock transformation, particularly practices related to feeding, animal health, and service uptake. Lastly, official government and institutional reports, including the Tanzania Livestock Master Plan (2017–2022), Ministry of Livestock and Fisheries Annual Reports (2015–2023), and ASDP-II Implementation Reviews, were reviewed to provide contextual and validation references. These documents supported the interpretation of statistical trends and ensured consistency between the empirical evidence and national policy directions in the livestock sector.

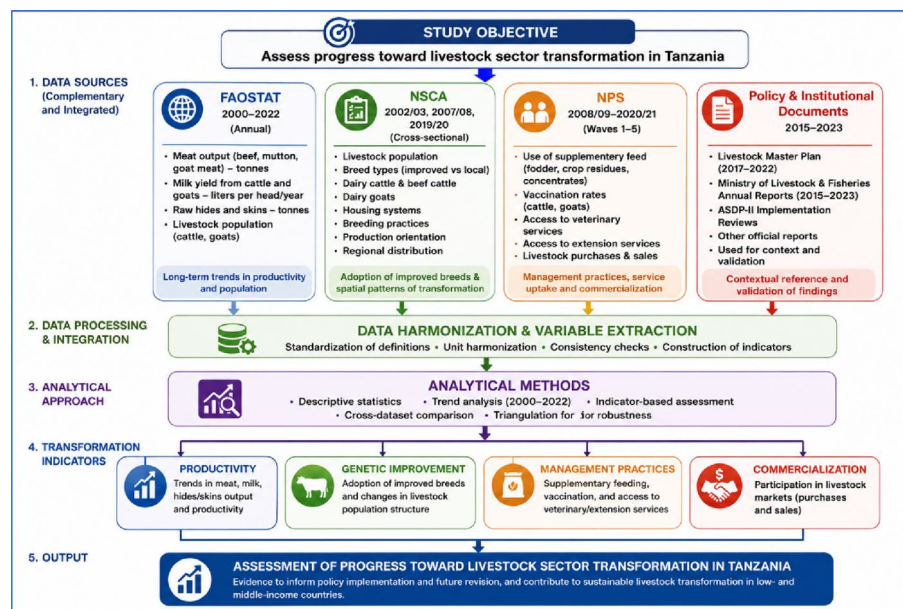


Fig. 2 Integrated analytical framework showing the four data sources, variables extracted, analytical procedures, and transformation indicators used to assess progress toward livestock sector transformation in Tanzania

2.3 Analytical framework

The analytical framework for this study employed three core techniques: descriptive statistics, trend and growth analysis (using the Compound Annual Growth Rate, CAGR), and productivity indicator estimation to assess the transformation of Tanzania's livestock sector over time and across management dimensions. Each technique provided a complementary perspective for understanding structural and behavioural changes among livestock producers.

2.3.1 Descriptive statistics

Descriptive statistics were first used to summarise and characterize the key variables extracted from FAOSTAT, the National Sample Census of Agriculture (NSCA), and the National Panel Survey (NPS). These statistics included means, percentages, standard deviations, and frequency distributions that helped to depict the magnitude and variability of livestock production, breed adoption, and management practices across regions and time. For instance, descriptive analysis quantified the proportions of households that used improved breeds of cattle and goats, purchased supplementary feed, and vaccinated their animals. It also enabled comparisons between small and large ruminants and across agroecological zones. The use of descriptive tools was essential for revealing the current state of the livestock sector, identifying disparities in adoption and productivity levels, and detecting patterns of structural change consistent with sectoral transformation.

2.3.2 Trends and growth analysis

The trend and growth analysis provided a dynamic view of how productivity and output indicators have evolved over time. Specifically, the Compound Annual Growth Rate (CAGR) was computed to measure the average annual rate of change for each key production variable, namely, meat, milk, and hides and skins, over the study period from 2000 to 2022. CAGR offers a robust method for assessing long-term growth by smoothing short-term fluctuations that may result from climatic variability, market shocks, or disease outbreaks. The formula used is:

$$CAGR = \left(\frac{Y_t}{Y_0} \right)^{\frac{1}{t}} - 1 \quad (1)$$

where Y_t and Y_0 denote the terminal and initial year values of a given indicator, respectively, and t represents the number of years in the period under review.

This measure enabled the study to compare growth performance across livestock products and to assess whether Tanzania's livestock sector is progressing toward higher productivity and output levels. Complementary to CAGR, trend lines and smoothed curves were applied to visualize the evolution of livestock production, enabling identification of acceleration, stagnation, or decline phases that could indicate the effectiveness of policy interventions or structural changes within the sector. By integrating descriptive statistics, CAGR-based growth analysis, and productivity measurement, the analytical framework provided a comprehensive assessment of the scale and efficiency dimensions of Tanzania's livestock sector. Descriptive statistics provided a baseline understanding of sectoral composition and adoption behaviours; trend and growth analysis revealed long-term performance dynamics; and productivity indicators directly quantified efficiency

gains associated with management changes. Together, these approaches created a coherent, quantitative foundation for assessing progress in the livestock sector's transformation and identifying policy-relevant areas for improvement. Data processing and analysis were conducted using Microsoft Excel 2021 for preliminary cleaning, pivoting, and graphing.

The third analytical technique involved estimating productivity indicators, which provide direct measures of efficiency in livestock production. Productivity was calculated as output per animal, distinguishing between cattle and goats to capture variations between large and small ruminants. For meat, productivity was expressed as carcass weight per head slaughtered; for milk, as liters per head per year. This indicator enabled comparisons of productivity levels between improved and local breeds, as well as across different production systems and time periods. In the context of livestock transformation, higher productivity per animal reflects successful adoption of improved management practices, such as better feed utilization, enhanced genetic potential, and effective disease control. However, the selection of productivity indicators was guided by the availability of harmonized and comparable variables across the secondary datasets used in this study. Accordingly, livestock productivity was assessed using internationally standardized yield indicators available from FAOSTAT, namely carcass weight per animal for meat production and milk yield per animal for milk production. Although other indicators such as calving rate, mortality rate, reproductive efficiency, and off-take rate are also important measures of livestock productivity, these variables were not consistently available across the FAOSTAT, NSCA, and NPS datasets for the study period and were therefore beyond the scope of the present analysis. The general formula applied was:

$$P_i = \frac{Q_i}{N_i} \quad (2)$$

where P_i represents productivity for product i (meat or milk), Q_i denotes total output, and N_i refers to the number of animals being produced.

3 Results

3.1 Trends in meat productivity (kg/head/year) for cattle, goats, and sheep

3.1.1 Cattle meat productivity

Figure 3 presents trends in cattle meat productivity in Tanzania from 2013 to 2022 based on FAOSTAT yield data. Overall, cattle meat productivity increased from 97.6 kg/head in 2013 to 139.3 kg/head in 2022, representing an increase of approximately 43% over the study period. The results show that between 2013 and 2016, productivity remained relatively stable, fluctuating between approximately 100 and 103 kg/head. From 2017 onwards, productivity increased substantially, reaching 120.6 kg/head in 2017 and peaking at 145.4 kg/head in 2019. A slight decline was observed in 2020 (135.2 kg/head), followed by stabilization at 137.8 kg/head in 2021 and a further increase to 139.3 kg/head in 2022.

3.1.2 Goat and sheep meat productivity

Figure 4 illustrates trends in meat productivity for goats and sheep in Tanzania from 2013 to 2022. Goat meat productivity ranged from 17.0 to 21.5 kg/head during the study period, while sheep meat productivity ranged from 15.0 to 24.0 kg/head. Between 2013

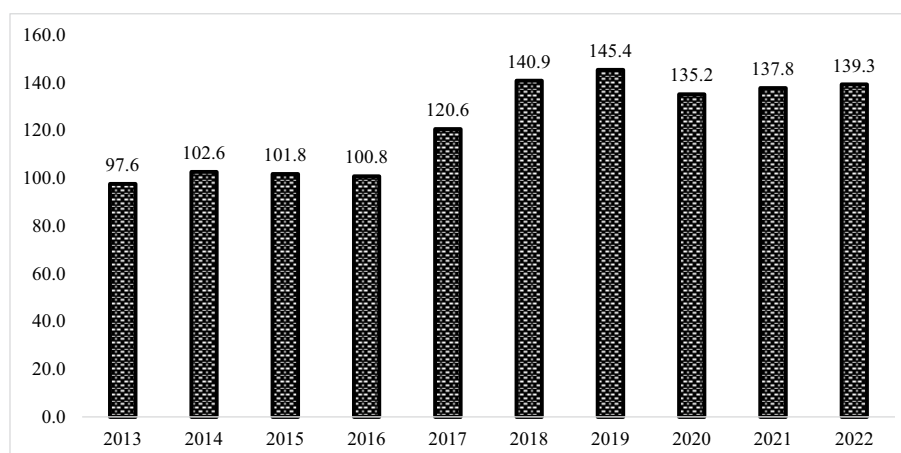


Fig. 3 Trends in cattle meat productivity (kg per head) in Tanzania, 2013–2022. Data source: FAOSTAT

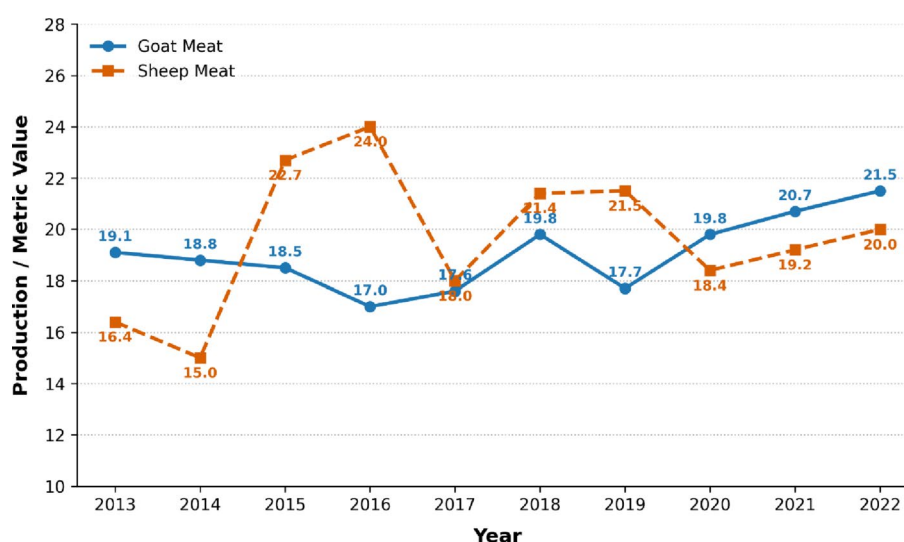


Fig. 4 Trends in meat productivity (kg per head) for goats and sheep in Tanzania; data source: FAOSTAT

and 2018, goat meat productivity increased slightly from 19.1 to 19.8 kg/head, whereas sheep meat productivity increased from 16.4 to 21.5 kg/head. After 2016, goat productivity declined moderately before stabilizing between 17 and 22 kg/head from 2017 to 2020. Sheep productivity remained relatively higher, averaging approximately 24.0 kg/head during some years. Between 2021 and 2022, both goat and sheep meat productivity increased slightly, reaching 20.7 and 21.5 kg/head, respectively.

3.2 Trends in milk productivity (kg/cow/year) for cattle and goats

Figure 5 presents trends in annual milk productivity for cattle and goats in Tanzania between 2013 and 2022. Average cattle milk productivity increased from approximately 782.9 kg/head/year in 2013 to 1,242.3 kg/head/year in 2022, representing a growth of nearly 59%. The sharpest increase occurred between 2018 and 2022, when productivity rose from 884.5 kg/head/year to over 1,240 kg/head/year. In contrast, goat milk productivity remained relatively stable throughout the study period, fluctuating between approximately 155 and 173 kg/head/year.

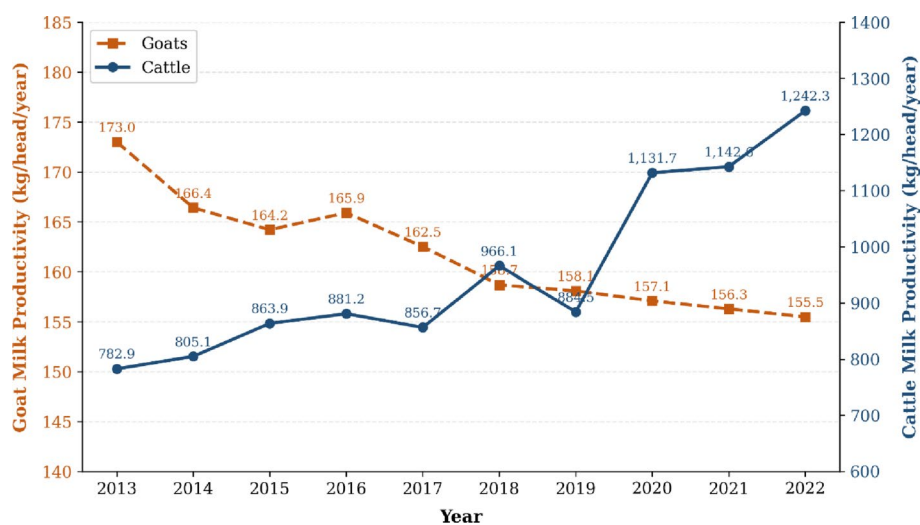


Fig. 5 Trends in annual milk productivity (kg per head) for cattle and goats: data source: FAOSTAT

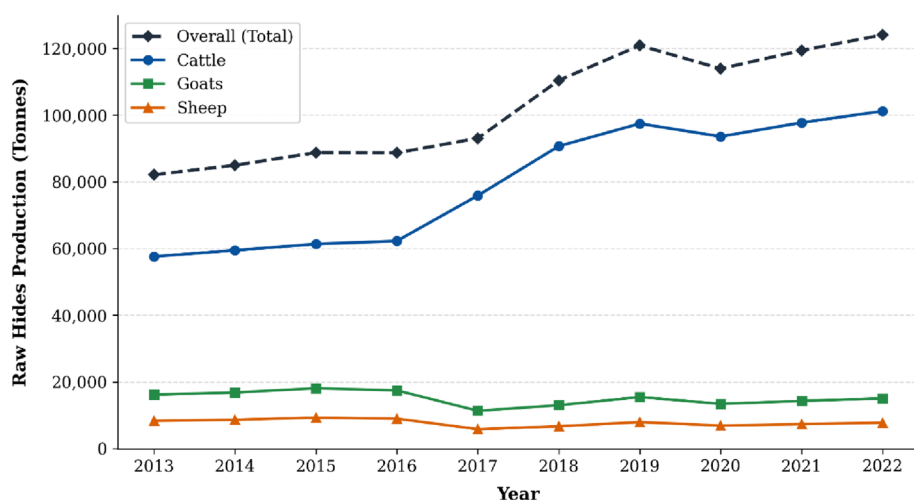


Fig. 6 Raw hides production (tonnes) from 2013 to 2022: Data source: FAOSTAT

3.3 Trends in raw hides and skins for cattle, goats, and sheep

Figure 6 presents trends in raw hides and skins production from cattle, goats, and sheep in Tanzania between 2013 and 2022. Overall production increased from 82,132 tonnes in 2013 to 124,077 tonnes in 2022. Cattle hides accounted for the largest share, increasing from 57,612 tonnes in 2013 to 101,221 tonnes in 2022. Goat skins fluctuated moderately, ranging from 16,192 tonnes in 2013 to 15,080 tonnes in 2022. Sheep skins accounted for the smallest share, ranging from 8,328 tonnes in 2013 to 7,776 tonnes in 2022. However, it is important to note that FAOSTAT raw hides and skins data are derived from animals processed through formal slaughter for meat production and do not include hides or skins originating from natural livestock mortalities. Consequently, the observed increase in hides and skins production should be interpreted primarily as reflecting increased livestock off-take associated with rising meat demand, urbanization, expanding slaughter activities, and commercialization of livestock value chains rather than changes in mortality rates.

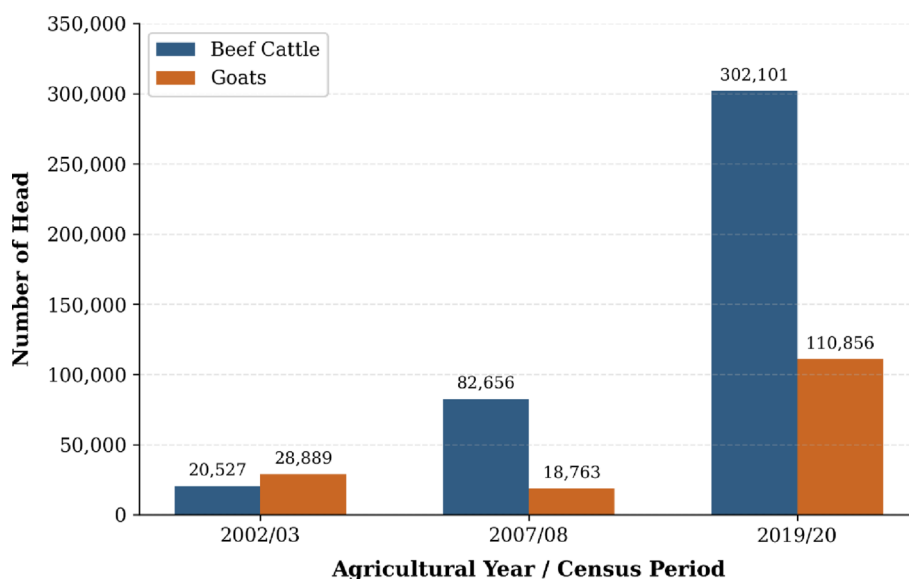


Fig. 7 Population of improved beef cattle and goats from 2002 to 2020. Data Source (NSCA)

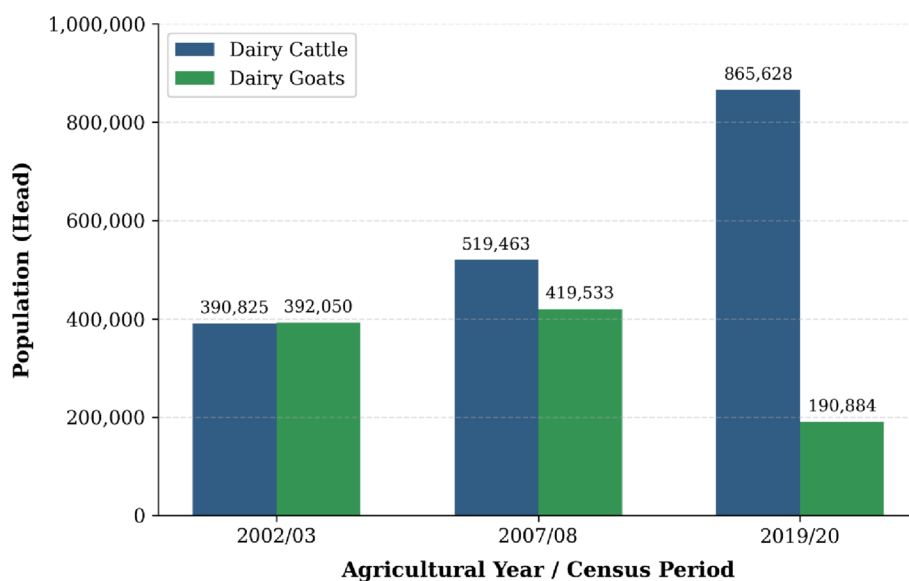


Fig. 8 Population of improved dairy cattle and goats from 2002 to 2020. Data Source (NSCA)

3.4 Trends in the adoption of improved breeds

3.4.1 Trends in improved breeds of beef cattle and goat meat

Figure 7 presents trends in the population of improved beef cattle and goats in Tanzania from 2002/03 to 2019/20. The population of improved beef cattle increased from 20,527 animals in 2002/03 to 82,656 in 2007/08, and then to 302,101 in 2019/20. Improved goat populations declined from 28,889 animals in 2002/03 to 18,763 in 2007/08, then increased substantially to 110,856 in 2019/20.

3.4.2 Trends in the population of improved dairy cattle and goats

Figure 8 illustrates changes in the population of improved dairy cattle and dairy goats in Tanzania between 2002/03 and 2019/20. Improved dairy cattle increased from 390,825

animals in 2002/03 to 519,463 in 2007/08 and further to 865,628 in 2019/20. In contrast, improved dairy goats increased slightly from 392,050 animals in 2002/03 to 419,533 in 2007/08, then declined to 190,884 in 2019/20.

3.5 Trends in livestock vaccination

Figure 9 presents trends in livestock vaccination coverage for large and small ruminants in Tanzania from Wave 1 (2008/09) to Wave 5 (2020/21), based on NPS data. Vaccination coverage among large ruminants increased steadily from 43.6% in Wave 1 to 64.8% in Wave 5. For small ruminants, vaccination coverage increased from 19.3% in Wave 1 to 47.5% in Wave 2, followed by fluctuations across subsequent waves, reaching 30.0% in Wave 5.

3.6 Trends in purchases of supplementary feeds (fodders)

Figure 10 presents trends in the proportion of livestock keepers purchasing supplementary fodders or crop residues between 2008/09 and 2020/21. Among large-ruminant keepers, the proportion purchasing fodder declined slightly from 11.0% in Wave 1 to 9.3% in Wave 2 before increasing to 18.1% in Wave 3 and reaching 18.5% in Wave 5. For small-ruminant keepers, fodder purchases increased from 2.9% in Wave 1 to 7.6% in Wave 3 before fluctuating and declining slightly to 4.7% in Wave 5.

3.7 Trends in commercialization of large and small ruminants

Figures 11 and 12 present trends in the commercialization of large and small ruminants in Tanzania from Wave 2 (2010/11) to Wave 5 (2020/21). Commercialization was measured using the proportion of households that bought and sold livestock in the previous 12 months. For large ruminants, the proportion of households purchasing cattle increased from 3.4% in Wave 2 to 6.0% in Wave 5. The proportion of households selling cattle remained relatively low, fluctuating between 0.4 and 0.9%. For small ruminants, the proportion of households purchasing goats or sheep fluctuated between 3.8 and 5.2%, while sales remained relatively stable between 0.8 and 1.4% across waves.

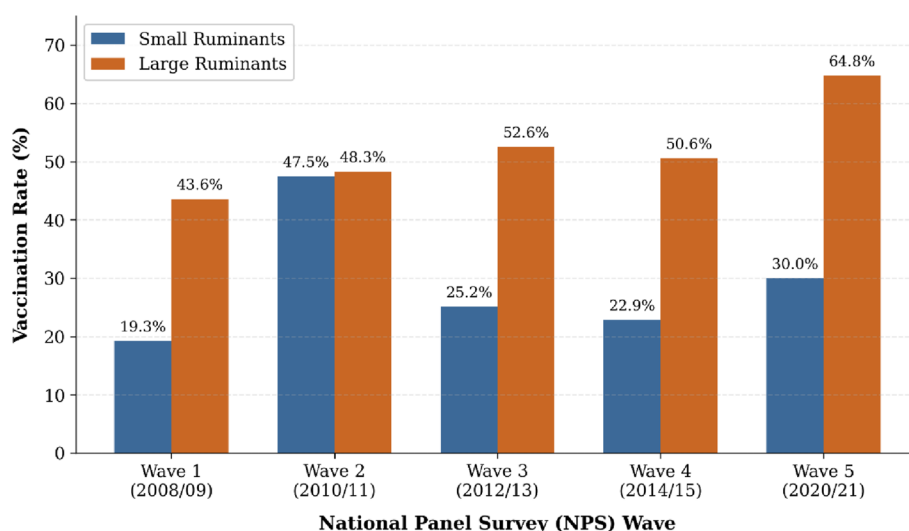


Fig. 9 Proportion of large and small ruminants vaccinated in the previous 12 months across NPS waves (1 to 5). Data Source NPS

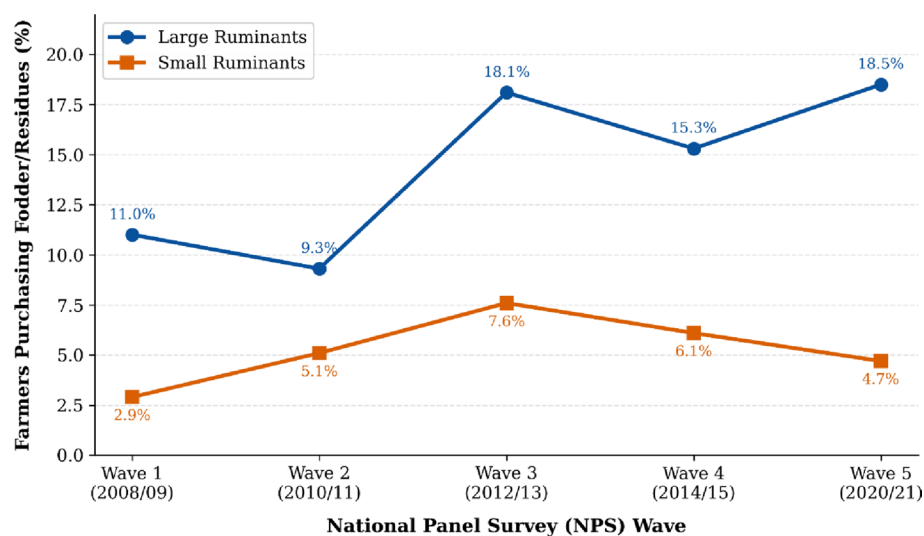


Fig. 10 Proportion of farmers purchasing fodder or crop residues for their cattle and small ruminants across NPS waves (1 to 5). Data Source NPS

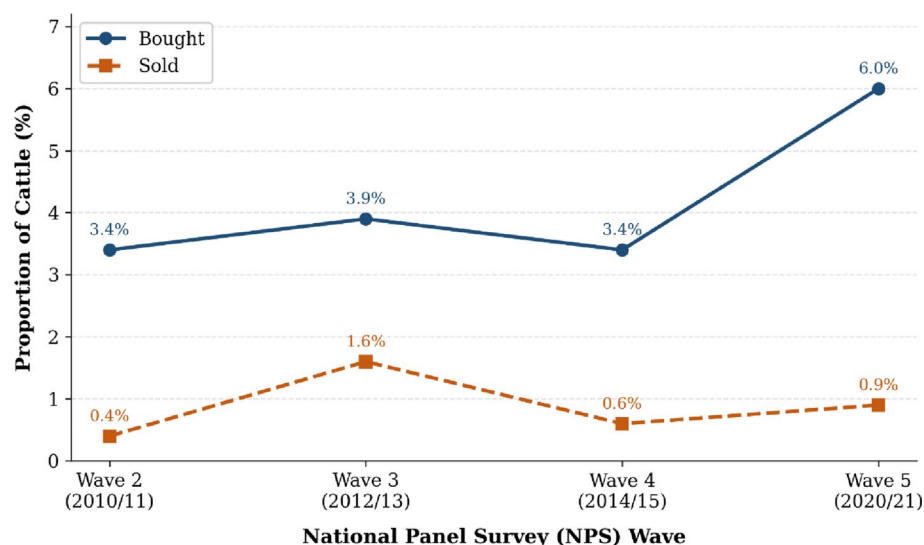


Fig. 11 Proportion of cattle bought versus sold across NPS waves. Data Source: NPS

4 Discussion

The findings from this study provide strong evidence that Tanzania's livestock sector is making measurable progress toward transformation, although the pace of change varies across species and livestock value chains. Trends in meat and milk productivity, adoption of improved breeds, vaccination coverage, supplementary feeding, and commercialization collectively indicate gradual modernization and intensification, particularly within cattle production systems. However, the observed differences between cattle and small-ruminant subsectors should not be interpreted solely as the result of policy interventions. Rather, they are likely to reflect a combination of species-specific biological characteristics, differences in production objectives, management systems, market demand, and the varying adoption of improved technologies. These interacting factors suggest that livestock transformation is inherently heterogeneous across production

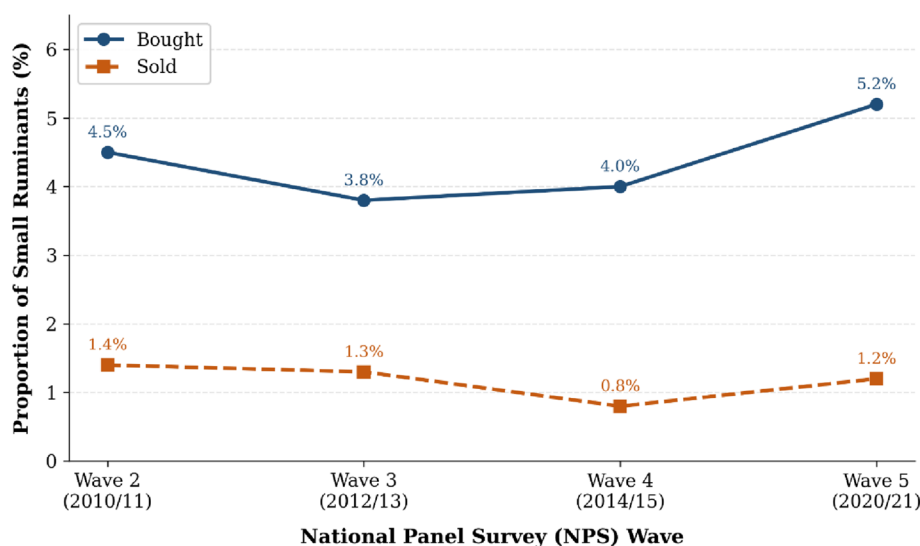


Fig. 12 Proportion of small ruminants bought versus sold across NPS waves. Data Source: NPS

systems, underscoring the need for species-specific approaches when interpreting transformation pathways and designing future interventions.

The substantial increase in cattle meat productivity from 97.6 kg/head in 2013 to 139.3 kg/head in 2022 suggests meaningful improvements in carcass performance and herd management within Tanzania's beef sector. The relatively stable productivity observed between 2013 and 2016 indicates that the subsector remained largely dominated by extensive, low-input production systems during this period. However, the sharp increase observed from 2017 onward coincides with heightened policy attention and investment under frameworks such as the Livestock Master Plan (2017–2022) and ASDP-II, which prioritized breed improvement, feed development, and animal health services. The expansion of improved breeds, including beef–dairy crosses, alongside increased access to veterinary and feeding interventions, likely contributed to these productivity gains.

These findings are consistent with broader regional evidence showing that gradual improvements in cattle productivity in sub-Saharan Africa are associated with enhanced genetics, feeding efficiency, disease management, and commercialization [8, 18–20]. The temporary decline observed in 2020 may reflect the effects of external shocks such as the COVID-19 pandemic, which disrupted feed supply chains, market access, and veterinary services. Drought conditions reported in several regions during the same period may also have reduced feed availability and animal body condition. Nevertheless, the rapid recovery after 2020 demonstrates resilience within Tanzania's cattle subsector and suggests adaptive improvements in herd management.

Goat and sheep meat productivity also showed gradual improvements, though at lower levels and with greater fluctuations than in cattle. Sheep productivity generally remained higher than goat productivity throughout the study period. The increase in sheep productivity between 2013 and 2018 may reflect improvements in flock management and selective breeding initiatives promoted under livestock development projects in central and northern Tanzania. Chagunda et al. [12] and Mujibi et al. [44] similarly report that small-stock improvement programs under initiatives such as SAGCOT contributed to the dissemination of dual-purpose breeds suited for meat and milk production.

The moderate fluctuations observed in goat and sheep productivity may suggest differences in species-specific responses to environmental and management conditions. Although this study did not directly assess grazing behaviour or feed resource utilization, the observed patterns could reflect differences in how these species respond to seasonal variations in forage availability and production environments. The relatively stable productivity levels between 2017 and 2020 may also indicate that small-ruminant production systems possess a degree of resilience under predominantly extensive production systems. These findings highlight the importance of considering species-specific management strategies when designing interventions to improve small-ruminant productivity. Similar observations have been discussed by Bonilla-Cedrez et al. [9] and Afshar [2], who note that the adaptive characteristics of small ruminants may contribute to their ability to cope with climatic variability and feed-related challenges.

The upward trend in cattle milk productivity provides further evidence of structural transformation within Tanzania's dairy subsector. The increase from approximately 783 kg/head/year in 2013 to over 1,240 kg/head/year in 2022 reflects the gradual adoption of improved dairy breeds, better feeding practices, enhanced veterinary care, and expanded milk-collection infrastructure. The rapid increase after 2018 coincides with the intensified implementation of dairy development interventions under the Livestock Master Plan and the expansion of semi-commercial dairy systems in regions such as Mbeya, Iringa, Njombe, Kilimanjaro, Tanga, and Arusha. The strengthening of dairy processing, marketing, and value-chain linkages across East Africa has similarly been identified as an important component of dairy-sector development [32].

These findings align with Ndambi et al. [46], Opoola et al. [52], and Ruvuga and Maleko [58], who observed that improved dairy genetics and better feeding systems substantially enhance milk productivity among smallholder farmers in East Africa. The coexistence of low-yielding indigenous cattle with higher-yielding improved dairy breeds helps explain why national average productivity remains moderate despite significant improvements in some production systems. Mpira et al. [42] similarly note that improved dairy breeds under semi-intensive management can produce substantially higher yields than indigenous zebu cattle under extensive management.

Conversely, goat milk productivity remained largely stagnant throughout the study period, suggesting limited transformation within the dairy goat subsector. This stagnation likely reflects low genetic potential, weak market orientation, limited feed availability, and inadequate extension support. Kosgey and Okeyo, [30] and Simões et al. [61] attribute similar stagnation in small-ruminant dairy systems across Africa to underinvestment in breeding programs and limited incentives for commercialization. The underdeveloped goat milk market in Tanzania, where most production is consumed at the household level, further reduces incentives to intensify production.

Trends in hide and skin production provide additional evidence of commercialization and market integration within Tanzania's livestock sector. The substantial increase in cattle hide production reflects rising off-take rates, increased slaughter activity, and the expansion of beef value chains, particularly in urban centers. Similar trends have been linked to rising urbanization, population growth, and increasing demand for animal-source foods in sub-Saharan Africa [26, 45]. In contrast, goat and sheep skins showed limited growth, highlighting slower transformation within small-ruminant value chains.

The slower growth in goat and sheep skins is likely linked to poor flaying practices, high disease prevalence, weak value chain integration, and limited investment in quality improvement. Kosgey et al. [30], Muigai et al. [43], and Monau et al. [41] similarly report that quality constraints and inadequate processing infrastructure limit competitiveness within East African leather sectors. Nonetheless, the overall increase in hide and skin production indicates growing opportunities for industrialization in the leather sector and export diversification.

The analysis of improved breed adoption clearly demonstrates that genetic transformation is advancing more rapidly among cattle than among goats. The dramatic increase in improved beef cattle populations between 2002/03 and 2019/20 reflects a strong policy commitment to herd upgrading through artificial insemination, breeding programs, and the dissemination of high-performing breeds such as Boran, Sahiwal, and dairy–beef crosses. These trends align with findings by Ouédraogo et al. [53] and Chawala et al. [15], who emphasize the role of improved genetics in enhancing growth performance, feed efficiency, and carcass quality.

Although improved goat populations also increased substantially after 2007/08, their overall growth trajectory remained slower and more volatile. This disparity reflects weaker breeding infrastructure, lower investment, and historically limited policy focus on small-ruminant systems. Similar patterns have been documented by Kosgey et al. [30], Mapiye et al. [35], and Anim-Jnr et al. [3], who note that goat improvement programs across East Africa often lag behind those for cattle. Nevertheless, the recent increase in improved goat populations suggests growing recognition of goats' economic and climate-resilience potential.

The divergence between improved dairy cattle and dairy goats further reinforces the uneven nature of livestock transformation in Tanzania. The rapid increase in improved dairy cattle reflects the successful expansion of dairy intensification programs, AI services, and the dissemination of high-yielding dairy breeds. In contrast, the decline in improved dairy goats suggests persistent structural constraints, including limited breeding programs, inadequate veterinary support, and weak dairy-goat value chains. Similar concerns have been raised by Negassa et al. [48], Molotsi et al. [40], and Legese and Fadiga [31].

Despite these challenges, goats remain critically important for women, youth, and resource-constrained households because of their affordability, short reproductive cycles, and adaptability to harsh environments. The declining trend in improved dairy goats, therefore, raises concerns about inclusiveness in Tanzania's livestock transformation agenda. Erdaw, [18] and Simpkin et al. [62] similarly argue that sustainable livestock transformation must incorporate species and production systems that support vulnerable households.

The increasing vaccination coverage observed in both large and small ruminants highlights the gradual strengthening of animal health systems in Tanzania. Higher vaccination rates among cattle suggest stronger institutional and policy support for large-ruminant systems. Improved vaccination coverage is particularly important because effective disease control enhances productivity, reduces mortality, and strengthens resilience against production shocks. These findings align with Enahoro et al. [17], Mapiya et al. [37], Erdaw [18], and Herrero et al. [24], who identify animal health management as a critical pillar of livestock transformation.

Nevertheless, lower and more fluctuating vaccination rates among small ruminants indicate weaker health service delivery systems for goats and sheep. Small-ruminant vaccination programs often face disruptions due to seasonal herd mobility, inadequate veterinary infrastructure, and limited availability of vaccines for diseases such as PPR and sheep/goat pox [22]. Similar constraints have been reported by Anim-Jnr et al. [3], Armson et al. [7], and Sargison [60]. Expanding community-based vaccination systems and mobile veterinary services could improve inclusiveness in livestock health interventions. Evidence from sub-Saharan Africa further demonstrates that preventive veterinary interventions can reduce disease-related production losses and generate substantial economic benefits for livestock keepers [50]. The increasing purchase of supplementary fodders among livestock keepers reflects the gradual intensification of feeding systems in Tanzania. Stronger uptake among large-ruminant keepers is consistent with the increasing adoption of improved breeds that require higher-quality nutrition. (Paul et al. [55, 56] and Bonilla-Cedrez et al. [9]) similarly note that feed intensification is central to productivity growth within modernizing livestock systems.

The relatively lower uptake among small-ruminant keepers suggests that goats and sheep remain largely dependent on low-input grazing systems. Nonetheless, the gradual increase in supplementary feeding indicates growing recognition of feed scarcity as a productivity constraint. Kilima and Kurwijola [29], Katiku et al. [27], and Matovu and Alçiçek [38] similarly report that small-ruminant producers often face limited access to feed technologies and extension support. Although vaccination and supplementary feeding are widely recognized as management practices that improve animal health, reproductive performance, survival, and productivity, the datasets used in this study were designed primarily to monitor management practices rather than quantify their biological outcomes. Consequently, the observed increases in vaccination coverage and supplementary feeding should be interpreted as evidence of changes in livestock management practices rather than as direct evidence of improvements in mortality, calving rates, or other productivity outcomes. Establishing these causal relationships will require longitudinal farm-level studies that simultaneously collect information on management practices, animal performance, and health indicators.

The commercialization trends observed in this study further demonstrate that Tanzania's livestock sector is gradually transitioning from subsistence-oriented systems toward more market-oriented production. Increased livestock purchases, particularly among cattle producers, reflect growing integration into livestock markets, expansion of livestock trade, and rising urban demand for animal-source foods. Similar commercialization dynamics have been documented by Dizyee et al. [16], Paul et al. [54], and Abebe et al. [1]).

However, livestock sales remained relatively low overall, suggesting that market participation remains constrained by weak infrastructure, limited price information, poor access to reliable buyers, and cultural preferences for herd accumulation. Similar findings have been reported by Solomon [59], Ransom and Stagner [57], Ndoro et al. [47], and Kibara and Gyula [28]. The higher rates of livestock purchasing relative to sales also suggest herd-building behavior among livestock keepers.

Overall, this study's findings demonstrate that Tanzania's livestock sector is steadily progressing toward transformation through improvements in productivity, genetic upgrading, animal health management, feeding systems, and commercialization.

Nevertheless, transformation remains highly uneven across species and value chains. Cattle systems consistently demonstrate stronger modernization trajectories than goat and sheep systems, reflecting differences in policy support, market development, institutional investment, and technological adoption.

These findings have important policy implications. Accelerating inclusive livestock transformation in Tanzania will require balanced investments across both large- and small-ruminant subsectors. Key priorities include strengthening breeding programs for goats and sheep, improving access to feed resources, expanding veterinary and extension services, enhancing the value chains for leather and milk, and supporting commercialization through improved market infrastructure and livestock finance. Furthermore, climate-resilient interventions targeting pastoral and agro-pastoral systems will be critical for ensuring sustainable and equitable transformation across all livestock systems. These results suggest that Tanzania's livestock sector is undergoing meaningful structural change, characterized by gradual modernization, commercialization, and productivity enhancement. However, the pace of transformation remains uneven across species and production systems, underscoring the need for more inclusive and integrated livestock development strategies that support both productivity growth and rural livelihoods.

4.1 Policy implications

The findings of this study have important implications for livestock development policy and investment in Tanzania. Although the observed trends indicate measurable progress toward livestock sector transformation, uneven performance across livestock species suggests that future interventions should adopt a more balanced, species-specific approach. While substantial gains have been achieved in cattle productivity, genetic improvement, and management practices, comparable progress among goats and sheep remains limited.

Strengthening genetic improvement programmes beyond cattle should therefore remain a priority. Expanding community-based breeding programmes, improving access to quality breeding stock, and promoting locally adapted improved breeds would enhance productivity while preserving the adaptive advantages of indigenous livestock. At the same time, investment in sustainable feed and forage systems, including fodder production, forage seed multiplication, feed-processing enterprises, and rangeland management, will be essential for improving livestock productivity and resilience under increasing climate variability.

The findings also emphasize the importance of strengthening animal health systems through improved vaccination programmes, disease surveillance, veterinary outreach services, and extension support, particularly in pastoral and remote production areas. Furthermore, increasing commercialization will require continued investment in livestock markets, transport infrastructure, cold-chain facilities, market information systems, and value-chain development to enable producers to benefit from improved livestock productivity.

Finally, because small ruminants contribute substantially to the livelihoods of resource-poor households, women, and youth, future livestock development strategies should place greater emphasis on goat and sheep improvement programmes. Promoting species-specific interventions alongside broader investments in productivity, animal

health, and market access will contribute to a more inclusive, resilient, and sustainable livestock sector in Tanzania.

4.2 Ethical considerations and limitations

All data used were secondary and publicly available; no human or animal subjects were directly involved. Data usage complied with the terms of FAO and the National Bureau of Statistics (NBS) licensing agreements. Proper attribution was given to all datasets, consistent with open-data ethical guidelines. Although multi-source integration enhances comprehensiveness, variations in sampling design, periodicity, and indicator definitions across datasets may limit comparability. Furthermore, some management practices (e.g., breed improvement intensity, feed quality) are not directly measurable and rely on proxy indicators. These limitations are mitigated through triangulation and sensitivity testing, but residual uncertainty remains inherent in analyses of secondary data.

In addition, minor discrepancies may exist between figures reported in international databases, such as FAOSTAT, and those in administrative statistics published by the Ministry of Livestock and Fisheries. These differences arise primarily from variations in data compilation methods, reporting timelines, estimation procedures, and indicator definitions. FAOSTAT harmonizes national submissions using standardized statistical protocols to ensure cross-country comparability, while Ministry figures often rely on administrative records from field campaigns, routine reporting systems, and budget statements. Similarly, vaccination indicators derived from the National Panel Survey reflect household-reported uptake within the previous 12 months rather than disease-specific administrative coverage. Consequently, differences between yield-based productivity indicators, aggregate national output figures, and administrative vaccination records should be interpreted as methodological variations rather than inconsistencies. While triangulation across multiple sources enhances robustness, complete harmonization of independently generated datasets remains inherently challenging in secondary data analyses.

5 Conclusion

This study integrated FAOSTAT, the National Sample Census of Agriculture (NSCA), and the National Panel Survey (NPS) to assess progress toward the transformation of Tanzania's livestock sector. The findings demonstrate measurable improvements in livestock productivity, genetic improvement, management practices, and commercialization, indicating that the livestock sector is making gradual progress toward transformation. However, this progress remains uneven across livestock species and production systems, with cattle generally showing greater advancement than small-ruminant systems.

Overall, the study demonstrates the value of integrating multiple national and international datasets to provide a comprehensive assessment of livestock transformation. The evidence generated contributes to understanding the multidimensional nature of livestock development and provides a robust empirical basis for monitoring structural changes in livestock systems over time.

This study is subject to several limitations associated with the use of secondary datasets. Some important indicators of livestock performance, including calving rates, mortality rates, reproductive efficiency, off-take rates, and spatially disaggregated productivity

measures, were not consistently available across the integrated data sources and therefore could not be incorporated into the analysis. Future research should integrate longitudinal farm-level data with geospatial and qualitative information to provide a more comprehensive understanding of livestock transformation and its underlying drivers.

Author contributions

I.L. Ki; Conceptualization, data collection, data analysis, first draft write-up, review, and editing.

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Data availability

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Declarations

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