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Successes, constraints, and prospects for sustainable dairy cattle breeding using artificial insemination technology in Tanzania. A brief review

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Dairy farming makes a substantial contribution to both food security and revenue generation, but because artificial insemination (AI) technology is not widely used, genetic improvement is still restricted. The present state, limitations, and potential of artificial insemination in Tanzania's dairy industry are examined in this review. The review combines national data, project reports, and existing literature to assess the AI program's success, identify important limitations, and highlight potential avenues for long-term, sustainable genetic advancement. For policymakers, researchers, and practitioners looking to tackle the intricate problems presented by AI in Tanzania's dairy production industry, this paper offers insightful information by synthesizing previous studies and identifying knowledge gaps. Good mitigation techniques are essential for offering a workable route to boost AI adoption, accelerate genetic improvement, and enhance the productivity and profitability of Tanzania's dairy sector.

KEYWORDS

artificial insemination, constraints, dairy cattle, prospects, success

Introduction

In Tanzania, dairy farming is essential to the country's economy because it creates jobs, household income, and food security (Mzingula, 2019; Twine and Omore, 2016; Mwakaje, 2012; Swai and Karimuribo, 2011). However, the prevalence of native breeds, especially the Tanzanian Shorthorn Zebu (TSZ), which produce less milk than exotic and crossbred breeds, has kept productivity low for decades (Msalya et al., 2017; Ulicky et al., 2013). The low productivity and genetic potential of the local herd are reflected in Tanzania's low milk consumption of 45 L annually, compared to an average of 200 L worldwide (Bangert et al., 2024; Twine, 2016).

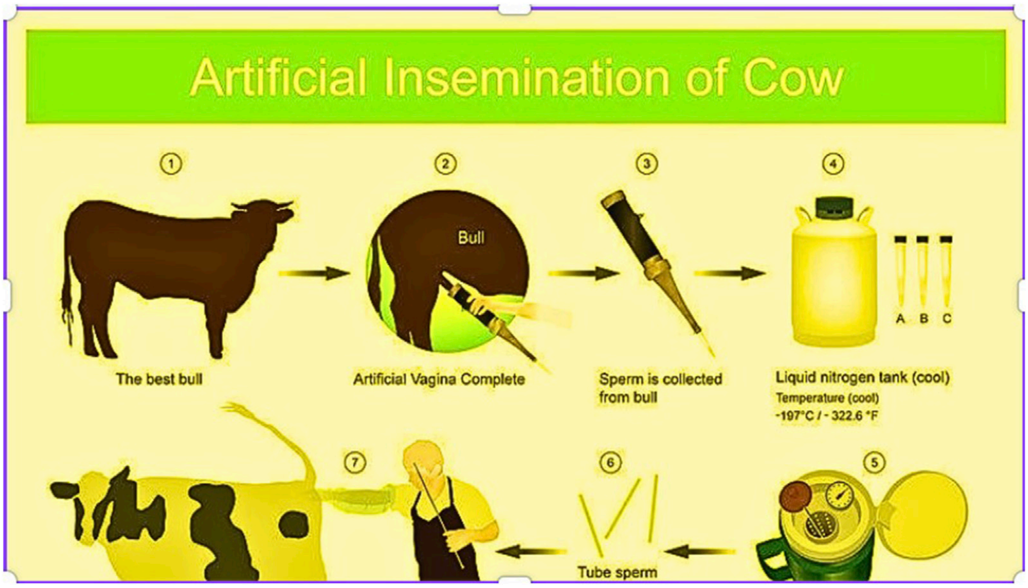

FIGURE 1
A modified schematic representation of the Artificial Insemination (AI) process in dairy cattle. The diagram illustrates the sequential steps involved in AI: selection of the best bull, semen collection using an artificial vagina, evaluation and storage of semen in liquid nitrogen at −197 °C, and insemination of the cow using thawed semen.

Artificial Insemination (AI) provides one of the most efficacious solutions to this issue. The method entails the direct insertion of processed semen into the uterus of female cattle to facilitate fertilization without natural copulation (Rauthan and Negi, 2022; Morotti et al., 2021; Kumar Patel et al., 2017). This allows farmers to obtain superior genetics from high-performing bulls without the necessity of on-farm maintenance (Zuidema et al., 2021; Mulu et al., 2018). Figure 1 demonstrates that the AI process encompasses the collection and assessment of semen from elite bulls, subsequent processing, cryopreservation, and insemination of cows, culminating in genetic enhancement at the herd level and augmented milk production over time.

AI technology possesses a long global history, with initial discoveries tracing back to the 14th century, significant scientific advancements occurring after the invention of the microscope in the 18th century, and Ivanoff's groundbreaking research in 1899 (Sharma et al., 2024; Lonergan, 2018; Ombelet and Van Robays, 2015). The commercial application in the 1940s transformed cattle breeding by enabling the extensive utilization of superior genetics at a lower cost (Moore and Hasler, 2017; Foote, 2010).

Justification

AI was introduced in Tanzania in the 1950s (NAIC, 2023), yet its adoption and impact are significantly lower than global standards (Twine, 2016). Ongoing challenges, including inconsistent liquid nitrogen supply, insufficient infrastructure, inadequate data management, and a lack of trained technicians, persistently hinder its efficacy (Kashoma and Ngou, 2023; Swai and Karimuribo, 2011). Moreover, detailed and current information regarding AI performance and advancements in the country is still limited (Kabuni et al., 2025; Kashoma and Ngou, 2023; Mwaipopo and Mbaga, 2022).

A narrative review was undertaken to address this gap. Key information was synthesized under three themes: (i) Success of AI, (ii) Constraints to AI, and (iii) Future prospects for sustainable dairy genetic improvement. This review utilizes these themes as an analytical framework to produce evidence-based insights that can guide policy, research, and development strategies aimed at enhancing dairy genetic improvement programs in Tanzania and analogous settings.

Materials and methods

Literature review

A comprehensive review was conducted using Google Scholar, ScienceDirect, and African Journals Online (AJOL). Search terms included combinations of keywords such as *"Artificial Insemination," "Dairy Industry," "Success," "Constraints," "Future Prospects,"* and *"Tanzania."* Boolean operators (*AND*, *OR*) were used to refine results for example, *"Artificial Insemination AND Dairy Cattle AND Tanzania"* and *"Artificial Insemination OR Reproductive Biotechnology."*

Data collection

Information regarding AI efficacy, limitations, and future potential was derived from chosen research studies. Priority was given to studies published in English from 2010 to 2025, while older yet pertinent sources were retained as needed due to insufficient national data. Studies not pertaining to cattle reproduction or lacking adequate methodological detail were excluded. Archived records from the National Artificial Insemination Centre (NAIC) on semen production, distribution, technician training, and liquid nitrogen supply between 2017/2018 and 2021/2022 were also reviewed.

Key findings from the review of the information

Successes of AI in Tanzania

Artificial Insemination (AI) has played an increasingly significant role in transforming Tanzania's dairy sector through gradual improvements in genetic quality, productivity, and institutional capacity (Varisanga, 2024; Kashoma and Ngou, 2023; Mwanga et al., 2019; Ojango et al., 2016). The technology was first introduced in the 1950s when farmers in northern Tanzania began importing semen from Kenya and Europe to improve the genetic potential of local cattle breeds (NAIC, 2023). The first national AI station was established at the Mpwapwa Livestock Research Station in 1966, marking the beginning of structured artificial breeding programs in the country (NAIC, 2023). However, the early efforts faced challenges including poor infrastructure, unfavorable climatic conditions, and limited coordination, leading to the closure of the station in 1977 (NAIC, 2023). In 1978, the Cuban Government supported the establishment of another AI center at Butiama (BAIC), but operational difficulties such as unreliable liquid nitrogen (LN_2) supply and weak field coordination constrained its effectiveness (NAIC, 2023).

With funding from the Swedish Government, the National Artificial Insemination Centre (NAIC) was established at Usa River in Arusha in 1982, marking a significant institutional milestone (NAIC, 2023). As the nation's center for semen production, processing, distribution, and storage, NAIC continues to play a key role in national AI coordination (NAIC, 2023). The provision of AI services has changed over time from being solely a government-driven endeavor to a cooperative system involving private businesses, non-governmental organizations, and community-based service providers (NAIC, 2023). In order to enhance outreach and encourage farmer education and training on reproductive management, the government facilitated this change by setting up zonal AI centers and mobile insemination units (NAIC, 2023). These developments were later reinforced under the National Livestock Policy (NLP) of 2006 (Mkama and Sulle, 2006), which emphasized sustainable livestock development and the use of modern technologies to enhance productivity and household livelihoods.

NAIC's annual performance reports between 2017/2018 and 2021/2022 (Table 1) show steady progress in semen production and distribution, number of inseminations performed, and liters of liquid nitrogen supplied to service points (NAIC, 2023). Although annual outputs fluctuated due to resource and logistical variations, the overall trend indicates increasing farmer participation and government commitment to expanding AI coverage. The ongoing training of technicians and improvement of cold chain infrastructure have enhanced technical capacity and service reliability, particularly in regions supported by zonal centers.

Strategic partnerships with both domestic and foreign partners have also contributed to Tanzania's AI achievements. Launched in 2016 with funding from the Bill and Melinda Gates Foundation, the African Dairy Genetic Gains (ADGG) project introduced digital innovations for farmer feedback systems, genetic evaluation, and data collection (Lyatuu, 2020). The project used mobile platforms to record on-farm performance, share results digitally, and give farmers customized management advice (Lyatuu, 2020). Smallholder dairy productivity and profitability rose as a result of this participatory model's enhanced herd management choices and improved ties between farmers and breeding service providers (Lyatuu, 2020).

Complementing this effort, the Public Private Partnership for Artificial Insemination Delivery (PAID) program implemented by Land O'Lakes International Development in collaboration with the Tanzania Livestock Research Institute (TALIRI), Green Dreams TECH Ltd., and other partners further strengthened the institutional and technical framework of AI delivery in the country (NAIC, 2023). The program achieved substantial results in semen production, farmer training, and the modernization of NAIC facilities (NAIC, 2023). The installation of a new liquid nitrogen plant and acquisition of high-performing breeding bulls enhanced sustainability beyond the project's lifespan (NAIC, 2023). Economically, the initiative contributed approximately TSh 119.14 billion (≈USD 51.2 million) to the national livestock asset base through improved productivity and expanded market participation (NAIC, 2023).

In terms of numbers, the PAID project produced remarkable results (Table 2): farmer training reached 101% of its target, and semen production exceeded its initial target by 48%. In addition, women made up 56% of active participants, and 77.8% of farmers continued to use AI after 2 years. According to these findings, the dairy industry can greatly improve adoption rates, service quality,

TABLE 1 AI Service Delivery at NAIC over the 5 years from 2017/2018 to 2021/2022.

Year	Number of semen straws produced	Number of semen straws distributed	Number of inseminations performed	Liquid nitrogen liters distributed	Number of AI technicians trained
2017/2018	82,801	34,139	29,297	12,588.25	152
2018/2019	53,463	49,437	48,211	14,981	140
2019/2020	125,409	65,224	76,612	13,026.75	40
2020/2021	16,019	60,827	77,375	12,632.75	102
2021/2022	62,218	63,079	65,215	13,316.44	104

TABLE 2 Summary of PAID-TZ project targets and achievements.

Section	Target	Achievement	Percentage achieved
AI delivery and support (live calves)	296,208 calves	113,648 calves	38.4%
Public sector (doses administered)	24,411 doses	9,983 doses	40.5%
Private sector (doses administered)	846,789 doses	193,751 doses	23.0%
Farmer adoption (2+ years)	Target not specified	77.8% adoption	120% (of implied target)
Farmer training (total)	85,222 farmers	85,222 trained	101%
Semen production	250,000 doses	371,235 doses	148%
Women's ownership	Target not specified	56% of target	56%
Livestock asset value	1 million tsh average	1.875 million tsh average	188%

and gender inclusivity through well-coordinated multi-stakeholder interventions.

Building on these achievements, the Government of Tanzania launched the Livestock Sector Transformation Plan (LSTP 2022/23–2026/27) to expand AI coverage and strengthen institutional capacity (Ministry of Livestock and Fisheries, 2022). The plan aims to inseminate approximately 500,000 cattle annually in strategic regions and to scale NAIC's semen production to 1.5 million doses per year (Ministry of Livestock and Fisheries, 2022). It also provides for the establishment of seven zonal AI centers equipped with modern facilities, LN_2 plants, motorcycles, and insemination kits, alongside short-term training for livestock officers in both public and private sectors (Ministry of Livestock and Fisheries, 2022).

These combined interventions have started to produce quantifiable increases in productivity, according to evidence from ADGG and other regional programs. While targeted training and better service infrastructure in areas like the Southern Highlands and Tanga have led to a 20 percent increase in AI service delivery, with over 20 calves born monthly in some areas, participating dairy farmers have reported a 60 percent increase in daily milk yield (Lyatuu, 2020). The resilience and sustainability of AI operations across the country are further reinforced by NAIC's modernization and continued government investment.

All things considered, Tanzania's AI development follows a path of steady but slow advancement. From its humble origins in the middle of the 20th century to the organized, multi-partner programs of today, the program has grown in institutional capacity, technology, and scope. Increased production of LN_2 and semen, a larger number of trained inseminators, greater farmer awareness, and the use of digital technologies for data management and decision-making are all important success factors. Tanzania's experience shows that long-term investment, partnership-driven approaches, and policy commitment can turn AI from a government-supported service into a sustainable driver of genetic improvement and the growth of the dairy sector, even though adoption levels are still below their full potential.

Constraints of AI in Tanzania

Despite the significant progress achieved in Artificial Insemination (AI) development and delivery across Tanzania, several challenges continue to constrain its full adoption and effectiveness. The most critical among these is the irregular and unreliable supply of liquid nitrogen (LN_2), which is essential for the preservation and transportation of semen (Varisanga, 2024; Kashoma and Ngou, 2023; Kusumawati and Karyasa, 2022; Rugwiro et al., 2021). Production facilities for LN_2 remain limited to a few centralized locations, primarily under the NAIC (NAIC, 2023). As a result, frequent breakdowns, high operational costs, and logistical bottlenecks disrupt the cold-chain system, particularly in remote and rural areas. The uneven distribution of LN_2 leads to the deterioration of semen quality before use, consequently lowering conception rates and reducing farmer confidence in AI technology (Ngoda P. P. et al., 2023; Kashoma and Ngou, 2023).

This is closely related to the transportation and distribution network's shortcomings, which make it logistically difficult to efficiently reach farmers' semen (Varisanga, 2024; Kashoma and Ngou, 2023). Poor road infrastructure further hinders timely insemination, particularly during rainy seasons when access to villages becomes challenging, and many technicians lack dependable modes of transportation. The viability of semen during transit and storage is also jeopardized by inadequate cold storage facilities at the zonal and district levels, which leads to inefficiencies in the provision of AI services (Ngoda P. et al., 2023; Kashoma and Ngou, 2023).

Another major constraint lies in insufficient technical capacity (Luyombya et al., 2025). Although NAIC and several training institutions conduct short courses for AI technicians, the number of trained inseminators remains below national demand. Moreover, many existing technicians operate with outdated skills, limited access to refresher training, and inadequate field supervision. This shortage of well-trained personnel has contributed to inconsistencies in service quality, resulting in low conception rates and poor record-keeping. In some areas, AI services are provided by unlicensed or inadequately trained individuals, further undermining the credibility of the program (Luyombya et al., 2025; Kabuni et al., 2025).

Another limitation is the presence of data management and performance recording systems. The majority of AI initiatives are carried out without digital monitoring frameworks or standardized data collection. Because of this, it is challenging to determine the long-term effects of AI interventions, track genetic lineage, and gauge conception rates. There is less accountability in the field, fragmented reporting, and duplication of effort when there is no centralized national AI database. Through digital data collection and farmer feedback systems, projects like the ADGG have started to close this gap; however, these are still regional in scope and have not yet been institutionalized nationally (Mrode et al., 2024; Ojango et al., 2022).

The majority of Tanzania's dairy producers are smallholder farmers, and their adoption of AI is further hampered by financial and economic limitations. AI is frequently out of reach for low-income households due to the combined expenses of semen, technician services, and transportation. Many farmers turn to natural breeding because they believe it to be less risky and more economical when they are unable to obtain financing or subsidies. Furthermore, farmers looking to genetically improve their herds have fewer options due to the irregular availability of semen from proven bulls (Mwaipopo and Mbaga, 2022; Temba, 2011).

Socio cultural factors further complicate AI adoption. In many rural communities, farmers continue to prefer natural breeding due to long-standing traditions and misconceptions about AI. Some believe that AI results in unnatural offspring or reduced fertility, while others are discouraged by failed conception experiences linked to poor service quality. Low awareness of estrus detection and reproductive management practices also contributes to poor conception outcomes. Where AI has failed once or twice, farmers often lose confidence and revert to traditional breeding systems (Kabuni et al., 2025; Varisanga, 2024; Temba, 2011; Kanuya et al., 2000).

Coordination between public and private stakeholders is still disjointed institutionally. Although government agencies like NAIC have a major regulatory role, there is still little cooperation with cooperatives, non-governmental organizations, and private insemination providers. Particularly outside of zonal centers, weak links lead to coverage gaps, uneven service pricing, and overlapping roles. There are still issues with policy implementation, such as insufficient financing for extension services, few incentives for private investment, and ineffective oversight procedures (Rutatora and Rwenyagira, 2005).

Another emerging concern is the limited local production of high quality semen and breeding bulls suited to Tanzania's tropical conditions. Heavy reliance on imported semen increases costs and sometimes leads to mismatched genetics that perform poorly under local climatic and feeding conditions. While ongoing initiatives aim to strengthen local bull selection and breeding programs, investment in research and genomic evaluation remains insufficient to sustain long-term progress (Kabuni et al., 2025; Ngoda P. P. et al., 2023; Chawala et al., 2021).

AI results are also influenced by equity and gender factors. Even though recent initiatives like the PAID project have specifically sought to increase women's involvement, socioeconomic barriers still prevent women farmers who frequently lack financial resources and decision-making authority over herd management from accessing AI services. This restricts AI technology's accessibility and inclusivity in rural areas (Kashoma and Ngou, 2023; Achandi et al., 2023).

Together, these limitations represent a complex interaction of institutional, technical, socioeconomic, and infrastructure factors. Despite growing awareness and investments, the pace of genetic improvement has been slowed by the persistence of irregular LN_2 supply, limited data systems, low technical capacity, and weak policy coordination. Stronger public-private partnerships, infrastructure and technician training investments, the creation of digital data systems, and focused farmer education to improve reproductive management practices and alter perceptions are all necessary components of a comprehensive strategy to address these problems. Tanzania's dairy industry will continue to struggle to realize AI's full potential as a tool for long-term genetic improvement and productivity growth unless these obstacles are methodically removed.

Future prospects of AI in Tanzania

Looking ahead, the future of Artificial Insemination (AI) in Tanzania's dairy sector depends on the country's ability to translate current lessons and challenges into sustainable strategies for genetic improvement and productivity growth. The growing recognition of AI as a critical tool for livestock transformation has led to increased government attention and investment, creating a favorable environment for reform and innovation. However, realizing AI's full potential will require deliberate integration of policy, technology, and institutional capacity-building efforts that address weaknesses identified in current service delivery models (Kashoma and Ngou, 2023; Mwanga et al., 2019).

To increase access to AI services, boost productivity, and guarantee sustainability, one of the most promising opportunities is to fortify public-private partnerships (PPPs). The African Dairy Genetic Gains (ADGG) initiative (Lyatuu, 2020; Ojango et al., 2022) and the Project for Agricultural Innovation and Development (PAID) (NAIC, 2023) are two examples of projects that have shown that cooperation between public and private entities can greatly enhance service coverage and quality. Future efforts should build on these models by creating inclusive frameworks that explicitly outline the roles of public and private actors in the production, distribution, and extension support of semen. Encouraging private investment in cold chain logistics, AI kits, and technician networks could reduce government dependency and increase responsiveness to market demand (Rutatora and Rwenyagira, 2005; Mangeni, 2019; Kumar et al., 2025).

Equally important is the empowerment of the National Artificial Insemination Centre (NAIC) as both a regulatory and research hub. NAIC's current mandate should be expanded beyond semen production and distribution to include data driven genetic evaluation, national AI performance monitoring, and coordination of breeding programs across regions (Ngoda P. et al., 2023). Establishing a centralized national AI database would help track conception rates, genetic progress, and service performance, thereby improving decision-making and accountability. In addition, NAIC could work closely with universities and research institutions to promote applied research in reproductive biotechnology, semen cryopreservation, and the genetic adaptability of local breeds (Chawala et al., 2021).

Another significant new opportunity for sustainable dairy improvement is funding genomic research and local bull selection. Exotic genetics and Tanzania's tropical climate are frequently at odds due to an over-reliance on imported semen (Ngoda P. et al., 2023). Long-term sustainability, decreased reliance on outside sources, and increased genetic resilience can all be achieved by creating a systematic national breeding program that finds and supports locally adapted bulls with high milk yield potential. Using genomic selection methods could increase breeding precision even more and hasten the spread of superior genetics that are appropriate for regional production systems (Ojango et al., 2022).

The use of digital and artificial intelligence tools also offers transformative potential for the future of AI service delivery. Mobile applications and digital platforms can facilitate estrus detection, AI scheduling, farmer technician coordination, and data recording. Digital record keeping systems such as those pioneered under ADGG can provide real-time feedback to farmers and extension officers, ensuring timely insemination and improved conception outcomes (Lyatuu, 2020). Expanding such tools nationally would modernize the AI value chain and make it more transparent, efficient, and data driven.

Improving access to AI services and reproductive technologies at the local level can be greatly aided by fortifying farmer organizations and livestock cooperatives. Cooperatives can invest in shared infrastructure like transport facilities, AI equipment, and LN_2 storage tanks by pooling their resources (Achandi et al., 2023). They also offer forums for knowledge sharing, credit availability, and farmer training. Such cooperatives can develop into business-oriented organizations that meet the demand for AI while generating jobs in rural areas and enhancing market integration when connected to processors, feed suppliers, and input distributors (Chawala et al., 2021).

Capacity building will remain central to these efforts. Expanding training programs for AI technicians, extension officers, and farmers is crucial to maintaining service quality and promoting the proper use of AI (Kanuya et al., 2000). Introducing refresher courses and certification systems will ensure that inseminators remain competent and accountable. Simultaneously, farmer training programs focusing on heat detection, reproductive health, and dairy herd management will help improve conception rates and encourage long-term adoption of AI services (Achandi et al., 2023).

Mechanisms like voucher systems, cooperative-based savings plans, and microfinance could be implemented to make AI more accessible to smallholder farmers in order to guarantee financial sustainability (Rutatora and Rwenyagira, 2005). Adoption rates dramatically rise when financial barriers are removed through targeted subsidies or revolving credit programs, according to experiences from other developing nations. Therefore, scaling AI among low-income rural households would require incorporating financial inclusion strategies into national livestock plans.

The recently launched Livestock Sector Transformation Plan (LSTP 2022/23–2026/27) provides a strong policy foundation for achieving these goals (Ministry of Livestock and Fisheries, 2022). By setting clear targets such as inseminating 500,000 cattle per year, producing 1.5 million semen straws annually, and strengthening seven zonal AI centers the plan represents a concrete step toward institutionalizing AI as a pillar of dairy sector modernization. If effectively implemented, it will not only expand genetic improvement but also enhance Tanzania's competitiveness in regional dairy markets.

In the long term, the sustainability of AI in Tanzania will depend on creating a resilient, inclusive, and innovation-driven ecosystem that brings together government agencies, private investors, researchers, and farmers. This ecosystem should prioritize transparency, accountability, and continuous learning. By embedding digital technologies, strengthening institutional linkages, promoting gender inclusion, and aligning national policies with global best practices, Tanzania can transform its AI subsector into a model for sustainable dairy development in Sub Saharan Africa (Achandi et al., 2023; Ojango et al., 2022).

In the end, Tanzania's AI future holds promise and opportunity. Through decades of investment, policy development, and cooperative efforts, the nation has already established the foundation. Consolidating these advancements through concerted action that incorporates science, technology, and community empowerment is what's left to do. AI has the potential to be a breeding technology as well as a driver of food security, economic expansion, and rural change in Tanzania with sustained support and innovative application.

Discussion

The evolution of artificial insemination (AI) in Tanzania reflects a steady trajectory of institutional growth, technological improvement, and increasing awareness among farmers. From its modest beginnings in the mid-20th century, the program has matured into a coordinated system involving multiple public and private partners. The establishment of the National Artificial Insemination Centre (NAIC), expansion of semen and liquid nitrogen (LN_2) production, and the training of inseminators have laid a strong foundation for genetic improvement and dairy sector transformation. These achievements mirror experiences in other Sub-Saharan countries, where long-term policy commitment and partnership-driven approaches have strengthened national breeding programs (Chawala et al., 2021; Ojango et al., 2022).

Adoption rates, however, are still below potential despite these advancements, which is a result of a complex interaction between institutional, technical, socioeconomic, and infrastructure factors. Performance and impact are still limited by irregular LN_2 supply, inadequate technician coverage, ineffective data management systems, and uneven policy coordination. Similar systemic issues have been documented in low-income dairy systems, where service delivery is hampered by cold-chain disruptions, inadequate funding, and subpar logistics (Kanuya et al., 2000; Rutatora and Rwenyagira, 2005). Monitoring conception rates, tracking semen quality, and assessing field performance all crucial components of genetic advancement are also hampered by the inadequate integration of trustworthy digital data platforms.

Socio economic and behavioral factors further limit AI adoption at the farm level. High service costs, limited access to credit, and persistent gender norms reduce the frequency of AI use, particularly among smallholder farmers and women (Achandi et al., 2023). Moreover, traditional beliefs that natural mating is more effective than AI remain widespread, underscoring the need for sustained farmer sensitization, community-based demonstrations, and behavioral change communication. The persistence of these barriers suggests that technological improvement alone cannot guarantee widespread adoption unless accompanied by structural and attitudinal transformation.

When considered collectively, the Tanzanian experience demonstrates the potential and vulnerability of artificial insemination as a tool for improving the genetic makeup of livestock. The advancements made thus far show that a robust AI system can be created through steady investment, cross-sectoral cooperation, and policy continuity. However, the limitations highlight that the advantages of these investments will continue to be unequally distributed if logistical inefficiencies, institutional fragmentation, and limited farmer capacity are not addressed. Therefore, a comprehensive approach that incorporates digital data management, infrastructure development, technician training, and gender-sensitive farmer education is crucial. While genomic and locally adapted breeding programs may improve long-term sustainability, strengthened public-private partnerships may aid in supply chain stabilization and service accessibility.

Generally, the Tanzanian case shows that success and constraint are interrelated aspects of a system that is still undergoing change rather than diametrically opposed realities. In order to achieve inclusivity, efficiency, and innovation, the same institutional and policy frameworks that made early gains possible must now change. AI has the potential to completely revolutionize Tanzania's dairy industry and genetic advancement by building on past successes and methodically removing any remaining obstacles.

Conclusion

Artificial insemination (AI) has emerged as a transformative technology for improving dairy productivity and genetic quality in Tanzania. Over seven decades, the program has evolved from small-scale efforts using imported semen to a nationally coordinated system under the National Artificial Insemination Centre (NAIC). Progress has been driven by government commitment, partnerships, and institutional reforms that enhanced semen production, technical capacity, and farmer awareness.

Despite these gains, adoption among smallholder farmers remains limited due to infrastructural, technical, financial, and socio-cultural barriers. Irregular liquid nitrogen supply, weak data systems, inadequate technician coverage, and affordability challenges continue to hinder performance. Addressing these issues requires a holistic strategy that integrates technology, policy, finance, and farmer empowerment.

Enhancing capacity building through ongoing training and farmer education, creating locally adapted breeding bulls, growing digital and genomic tools, and fortifying institutional coordination and public-private partnerships will all be necessary for future advancement. Accessibility can be further enhanced by financial inclusion tools like voucher systems and microfinance.

All things considered, Tanzania's AI journey represents a slow but significant shift. AI can become a key component of sustainable dairy productivity, rural income growth, and national food security by building on past achievements, addressing systemic barriers, and institutionalizing innovations within frameworks such as the Livestock Sector Transformation Plan (LSTP 2022/23–2026/27).

Author contributions

JM was responsible for the conceptualization, methodology, literature review, data analysis, validation, and drafting of the manuscript, as well as finalizing the original draft. GM and IK provided supervision and contributed to the critical review of the manuscript.

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Conflict of interest

The authors(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

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