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Socio-demographic and economic factors influencing the adoption of dairy breeding technologies in Tanzania

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Abstract

Worldwide, improved dairy breeding technologies are expanding and increasing dairy cattle production. However, socio-demographic and economic factors influencing the adoption of dairy breeding technologies are not well evidenced. This study used a cross-sectional survey design with quantitative research approach to assess the socio-demographic and economic factors influencing the adoption of dairy breeding technologies in the Eastern zone of Tanzania. Sample size was 10% of 793 being 79.3 = 79 for Kinondoni, and 10% of 711 being 71.1 = 71 for Bagamoyo. The total sample size for this study was, 150 smallholder dairy farmers selected using stratified random and systematic sampling techniques. Data was collected using a survey questionnaire in the Kobo Collect Tool. Among the investigated socio-demographic and economic characteristics, only age group and herd size were found to be significantly associated with the adoption of artificial insemination (AI) technologies. Furthermore, geographical region was a significant predictor of AI adoption, whereby farmers in Dar es Salaam region (Kinondoni district) were more likely to adopt AI compared to those from the Coast region (Bagamoyo district). The findings emphasize the need for increased accessibility to advanced breeding methods and extension services that contributing to the overall improvement of the dairy industry in Tanzania and similar contexts globally.

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Introduction

Dairy farming plays a crucial role in the livelihoods of millions of smallholder farmers in Tanzania, contributing significantly to rural economic development, poverty alleviation, and food security. As one of the main sources of income and nutrition, milk production from smallholder dairy farms is integral to the Tanzanian agricultural sector. In Tanzania, the dairy sector contributes to approximately 1.5% of its Gross Domestic Product (GDP), significantly boosting food and nutritional security and providing a source of income and employment for farmers, in rural and urban development (Kundu *et al.*, 2024). According to the United Republic of Tanzania (URT) (2017), this growth aligns with the Agricultural Sector Development Programme (ASDP), which supports increasing livestock productivity and profitability. However, the sector faces several constraints that impede its productivity, including limited market access, inadequate feed quality and availability, poor farm management practices and poor genetic potential of indigenous cattle breeds for milk production. These issues are compounded by infrastructural deficiencies such as inadequate transportation and cold storage facilities that significantly affecting milk quality and safety (Twine *et al.*, 2018). Indigenous breeds typically have lower milk yields than their exotic or crossbred counterparts (Twine *et al.*, 2018).

This genetic limitation poses a substantial challenges as the demand for dairy products continues to rise in response to population growth and increasing income levels (Banda *et al.*, 2021).

Cognizant of this, dairy breeding technologies offer a viable solution to these challenges by enhancing the genetic potential of the local cattle population.

The adoption of modern dairy breeding technologies, such as artificial insemination (AI), genomic selection, and the use of superior dairy breeds, presents an opportunity to increase milk production, enhance the genetic quality of livestock, and improve the overall efficiency of the dairy sector. Nevertheless, the uptake of these technologies among smallholder dairy farmers in Tanzania remains slow and uneven, despite the apparent benefits.

Socio-demographic and economic characteristics play a significant role in influencing the adoption of dairy breeding technologies among farmers. Key human capital factors such as age, education, sex, and household size influence the quality of labour available for adopting such practices. The relationship between age and technology adoption is contentious. While young, energetic farmers are often eager to adopt new innovations (Makori Alais and Tito Magoti, 2023).

In contrast, the literature (Wairimu *et al.*, 2022) found no significant influence of youth on dairy breeding technology adoption. On the other hand, (Zemarku *et al.*, 2022) viewed that; older farmers may have more resources and experience, increasing their likelihood of adopting new dairy breeding technologies. However, argued that older individuals may become less receptive to new ideas over time. This inconsistency suggests that the impact of age on adoption is location- and technology-specific. For example, (Feyissa *et al.*, 2023) found an inverse relationship between age and dairy technology adoption.

Education is a crucial factor in improved dairy breeding technology adoption, as it equips farmers with the skills necessary to evaluate and implement improved dairy breeding practices.

Higher education increases allocative abilities, enabling farmers to adjust to changing conditions and adopt improved dairy breeding technologies more quickly (Mwalongo, 2018). Similarly, gender plays an important role in adoption of improved dairy breeding technology, particularly in African contexts where women are heavily involved in dairy production but often lack access to resources such as land and information; women's participation in dairy practices like milking, feeding, and record-keeping

highlights the importance of involving them in training programs to ensure broader adoption of improved dairy breeding practices (Sikira *et al.*, 2018). Household size also affects adoption decisions. Larger families can provide more labour, which is often required for implementing labour-intensive dairy technologies. The studies observed that families with more members are more likely to adopt and sustain profitable technologies (Mutungi *et al.*, 2023).

Literature shows that, socioeconomic factors such as income, land ownership, and access to off-farm income also significantly influence the adoption of improved dairy breeding practices (Kihoro *et al.*, 2021). Farmers with higher incomes are more likely to adopt improved dairy breeding technologies because they can afford the necessary inputs, such as veterinary drugs and concentrated feed. Wealthier farmers are also more willing to take risks, while low-income farmers may lack the capital needed to invest in the improved dairy breeding practices (Maleko *et al.*, 2018). Land size is another key socio-economic factor; farmers with larger plots can spread the costs of adopting improved dairy breeding technologies over a greater output, making it more feasible to experiment with innovations (Pasape, 2022). Further factors such as access to credit, extension services, and training also play a significant role in adoption. Dairy farmers with access to credit are more likely to overcome liquidity constraints and invest in capital-intensive technologies (Balana *et al.*, 2022). Extension services can increase the probability of improved dairy breeding technology adoption by providing farmers with information about modern production techniques (Seluhinga, 2023). Moreover, participation in agricultural exhibitions and field demonstrations enhances dairy farmers' perception of and willingness to adopt improved dairy breeding practices in Tanzania (Chawala *et al.*, 2019). Therefore, understanding the interaction between socio-demographic and economic factors influencing adoption of dairy breeding technology in the Eastern zone of Tanzania is crucial for enhancing the uptake of such technologies, particularly among smallholder dairy farmers.

Materials and methods

Study area

This study was conducted in Eastern Zone districts (Kinondoni and Bagamoyo). Kinondoni is located at 6.7888° S, 39.2304° E while Bagamoyo is located at 6.4428° S, 38.9085° E. The reasons were because of the substantial presence of dairy farmers to provide valuable insights into the factors affecting the adoption of these technologies. Conducting the study in the districts was also done to facilitate knowledge transfer and capacity building among local farmers, breeders, and stakeholders, enabling the sharing of best practices, innovative breeding techniques, and improved management strategies. About 52.7% of surveyed respondents came from the Kinondoni municipal council, and 47.3% were from the Bagamoyo district.

Research design

A cross-sectional research design with quantitative research approach was used to collect data from a sample of smallholder dairy farmers in the Kinondoni and Bagamoyo districts. A cross-sectional research design is suitable to collect data from many different individuals at a single point of time (Wang and Cheng, 2020). This design enabled the study to collect data instantly using quantitative research approach. Employing quantitative approach, the study systematically measured and analysed numerical data related to factors such as age, education level, livestock ownership, training participation, and access to information. This enabled a precise understanding of how each factor correlates with the adoption of breeding technologies.

Target population and sample size

The target populations were 793 individuals in Kinondoni and 711 individuals in Bagamoyo. These consisted of smallholder dairy farmers. An accurate sample size was calculated as a percentage of the population by analysing the variations between the population as described by Smith (2013) that, a sample of 10% to 30% is optimal sample size. Also, the determination of sample size was based on claims by Ramakrishnana and Arokiasamy (2019), that a

sample of 10% to 30% of the target population is representative enough for the research study. Therefore, the optimal sample size for the present study was 10% to 30% of the target population for Kinondoni and Bagamoyo respectively. 10% of 793 being 79.3 = 79 for Kinondoni, and 10% of 711 being 71.1 = 71 for Bagamoyo, the total sample size for the study was, therefore, 150.

Sampling method

Stratified random sampling was used in this study to ensure that smallholder dairy farmers from both Kinondoni and Bagamoyo were proportionally represented. The total target population was divided into two distinct groups (strata) based on their location: Kinondoni and Bagamoyo. Each location served as its own stratum, ensuring that any unique characteristics within each area were represented in the sample. After determining the number of individuals needed from each location, 79 dairy farmers from Kinondoni and 71 from Bagamoyo were randomly selected. This random selection within each stratum minimized bias, as each member of the stratum had an equal chance of being chosen, thus enhancing the representativeness and reliability of the sample. This method ensured that both locations were appropriately represented according to their population size, leading to a total sample size of 150 smallholder dairy farmers across Kinondoni and Bagamoyo.

Data collection method

Data was collected using a quantitative semi-structured questionnaire, administered via the Kobo Collect Tool to capture dairy farming socio-demographic and economic factors influencing the adoption of improved dairy breeding technology. The questionnaire included 232 items, ensuring an adequate ratio of questions to respondents to allow comprehensive analysis. Research assistants trained in survey protocols and the Kobo Collect tool administered the surveys, and responses were electronically recorded to minimize data entry errors. To maintain data quality and reduce bias, separate team members were assigned to code responses and review the data; items were validated by research experts and by piloting with a sample from the target population. After data collection, responses were exported to Excel and then to SPSS (Version 27) and SAS for in-depth analysis, where variables were identified and coded, and statistical tests such as chi-square tests and p-value were applied. Skipped questions were systematically coded as missing values, and the sample of respondents was selected through stratified random sampling ensuring representativeness across the socio-economic spectrum of smallholder farmers in the study area.

Data analysis

Descriptive statistics were used through SPSS to analyse the characteristics of the study population, such as age, marital status, education level, number of dairy cattle kept, access to and control of resources available for dairy production against the breeding methods used as well as their adoption patterns. Logistic regression analysis was used to analyse the socio-economic factors affecting adoption of artificial insemination among dairy Farmers in the eastern districts of Tanzania. Moreover, statistical test such as Chi-square was used to determine the significant correlation between the socio-demographic and economic factors and the adoption of dairy breeding technologies among smallholder dairy farmers.

The questionnaire was administered to the different participants at different points in time to check for consistency of results and 15 items were tested in Statistical Package for Social Sciences (SPSS-Version-27 then the Cronbach's alpha coefficient was used to measure its consistency. The results showed the consistency of 0.733 per Cronbach’s alpha and 0.634 per Cronbach’s alpha based on standardised items which was greater than 0.5 per the measurement of Cronbach's alpha coefficient, hence the instrument was reliable.

Results and discussion

Socio-demographic information of the respondents

Table 1 shows the demographic information of the respondents. In Kinondoni district, the gender

distribution among respondents revealed a relatively balanced representation, with 27.3%; (41/79) male and 25.3%; (38/79) female. The age distribution showed a significant presence in the 41-60 age group, comprising 26.7%; (40/79) of the respondents. Regarding education levels, 21.3%; (32/79) attended primary education. Regarding cattle ownership, the results indicated this was shared among spouses. Regarding the average number of cows owned, 38%; (57/79) indicated that they kept 4 to 6 cows.

In Bagamoyo district, the gender distribution showed a relative balance, with 26.7%; (40/71) male and 20.7%; (31/71) female respondents. A majority of the respondents 24% (36/71) fell within the 41-60 age group, reflecting a mature demographic interested in adoption interventions.

Table 1. Socio-demographic characteristics of respondents participated in study

Demographic information		Surveyed districts	
		Kinondoni	Bagamoyo
		f (%)	f (%)
Gender	Male	41(27.3)	40 (26.7)
	Female	38 (25.3)	31 (20.7)
Age	21-40 years	4 (2.7)	6 (4.0)
	41-60 years	40 (26.7)	36 (24.0)
	61-80 years	35 (23.3)	28 (18.7)
	over 80 years	0 (0.0)	1 (0.7)
Education level	No formal education	5 (3.3)	2 (1.3)
	Primary education	32 (21.3)	33 (22.0)
	Secondary education	27 (18.0)	14 (9.3)
	College	11 (7.3)	12 (8.0)
	University	4 (2.7)	10 (6.7)
Marital Status	Single	4 (2.7)	3 (2.0)
	Married	62 (41.3)	51 (34.0)
	Divorced	4 (2.7)	5 (3.3)
	Widow	9 (6.0)	1 (28.0)
People household	1-3	5 (3.3)	24 (16.0)
	4-6	31 (20.7)	43 (28.7)
	7-8	39 (26.0)	3 (2.0)
	9-10	4 (2.7)	1 (0.7)
Cattle ownership	Husband	9 (6.0)	27 (18.0)
	Wife	26 (17.3)	27 (18.0)
	Both Husband and Wife	44(29.3)	17 (11.3)
Number of cows	1- 3 cows	21(14.0)	35 (23.3)
	4-6 cows	57(38.0)	27 (18.0)
	7-9 cows	1 (0.7)	8 (5.3)
	10- 11 cows	0 (0.0)	1(0.7)

Education levels varied, with significant portions having attained primary 22%; (33/71) and secondary education 9.3%; (14/71), and some had attended college 14.7%; (22/71). About 34% (51/71) of the respondents were married. Household sizes typically ranged between 4-6 members 28.7%; (43/71), and cattle ownership was primarily by husbands 18%; (27/71) or jointly 11.3%; (17/71), owning about 1-3 dairy cattle.

Socio-demographic and economic factors influencing the adoption of dairy breeding technologies in Tanzania

The study investigated the socio-demographic and economic factors influencing the adoption of dairy breeding technologies in Tanzania. In this study, the inferential statistics, specifically the Chi-Square tests, were used to examine whether socio-economic factors such as gender, age group, education level, household size, experience in dairying, and herd size significantly influence the adoption behavior of farmers. The Chi-Square test assesses whether there is a significant association between categorical variables. The results of this analysis can be interpreted to determine whether the differences observed between adopters and non-adopters are due to chance or reflect a true underlying relationship in the population as shown in Table 2.

Table 2. Socio-demographic factors affecting the adoption of artificial insemination in the eastern districts of Tanzania

Socio-demographic characteristics		Adopters (n=83)	Non-adopters (n=67)	Chi-Square test χ^2 (P-value)
Gender	Female	51.8	38.8	2.52 (0.07)
	Male	48.2	61.2	
Age group (years)	61-80	49.4	32.8	6.75 (0.04)
	41-60	47.0	55.2	
	21-40	3.6	10.4	
Education level	College	25.3	23.9	1.04 (0.746)
	Secondary	25.3	29.9	
	Primary	43.4	43.3	
	Informal	6	3	
Household size	9-10	4.8	1.5	4.0951 (0.251)
	7-8	32.5	22.4	
	4-6	47.0	52.24	
	1-3	15.7	23.9	
Experience in Dairying (years)	31-40	1.3	0	7.8 (0.06)
	21-30	6	3.3	
	11-20	24	12	
	n < 10	12.7	5.3	
Herd size (Cows)	10- 11	0.7	0	6.36 (0.0451)
	7-9	1.3	1.3	
	4-6	22	15.3	
	1- 3	20	4	

Regarding gender, the Chi-Square test results (χ^2 = 2.52, P-value = 0.07) suggest that gender is not significantly associated with adoption behavior. While the proportion of females was higher among adopters (51.8%) compared to non-adopters (38.8%), the P-value indicates that this difference is not statistically significant at the 0.05 level. This implies that, based on the sample, gender does not appear to be a major factor in determining whether a farmer adopts a certain practice or technology. Thus, gender differences between the groups may be due to random variation rather than a systematic influence.

For the age group, the results (χ^2 = 6.75, P-value = 0.04) indicate a statistically significant difference between adopters and non-adopters, with the older age group (61-80 years) being more likely to adopt the practice (49.4% adopters with 32.8% non-adopters). This suggests that older farmers may have more experience or stability in their farming operations, making them more inclined to adopt new practices. In contrast, younger farmers (21-40 years) were less represented among adopters, which might reflect their lower experience levels or different priorities in farming, leading them to be less likely to adopt new technologies.

The education level did not show a significant relationship with adoption (χ^2 = 1.04, P-value = 0.75), indicating that the education level of the farmers, whether primary, secondary, or college-educated, does not significantly affect adoption behavior. Both adopters and non-adopters had a similar distribution of educational backgrounds, suggesting that the level of formal education may not be a determining factor in the decision to adopt the practice in question. This could imply that factors other than education, such as access to information, financial resources, or social networks, play a more critical role in adoption decisions.

In contrast, herd size and experience in dairying were found to have a significant relationship with adoption behavior. For herd size, the Chi-Square test (χ^2 = 6.36, P-value = 0.05) revealed that farmers with larger herds (10-11 cows) were more likely to be adopters, suggesting that those with larger operations might have more resources or a greater need to improve productivity through adopting new practices. Similarly, experience in dairying (χ^2 = 7.8, P-value = 0.06) approached significance, indicating that farmers with more years of experience were more likely to adopt the practice. This could be because

experienced farmers may have a deeper understanding of the benefits and risks of adopting new practices and may feel more confident in their ability to implement changes effectively. These findings suggest that both herd size and dairying experience are key socio-economic characteristics influencing adoption behavior.

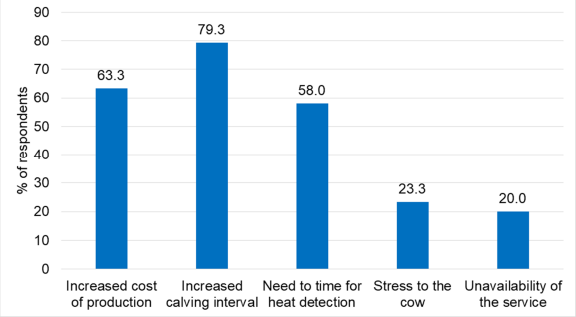

Fig. 1. Challenges of adopting artificial insemination as perceived by the farmers

Factors hinder the adoption of artificial insemination

Fig. 1 presents the factors hinder the dairy farmers on the adoption AI in their dairy farming practices. The bar chart highlights the challenges faced by dairy farmers in reproductive management, particularly in artificial insemination. The most significant concern, reported by 79.3% of respondents, is an increased calving interval. A longer calving interval means cows take more time between successive births, leading to lower milk production efficiency and financial losses. This issue can arise due to poor heat detection, failed insemination attempts, or reproductive health problems.

Another major concern is the increased cost of production, cited by 63.3% of respondents. The high expenses associated with artificial insemination include semen procurement, veterinary services, labour for heat detection, and hormonal treatments required for cows that struggle to conceive naturally. Additionally, 58% of respondents highlighted the challenge of timing heat detection. Identifying when a cow is in oestrus is crucial for successful insemination, but it requires close monitoring and expertise. Failure to detect heat accurately can lead to unsuccessful breeding and prolonged calving intervals.

Stress to the cow is another concern, though reported by a smaller proportion of respondents (23.3%). Frequent handling, reproductive procedures, and artificial insemination can cause discomfort, which may impact the cow's productivity and well-being. Lastly, 20% of respondents indicated that the unavailability of artificial insemination services poses a challenge, especially in remote areas where trained technicians and quality semen are not easily accessible.

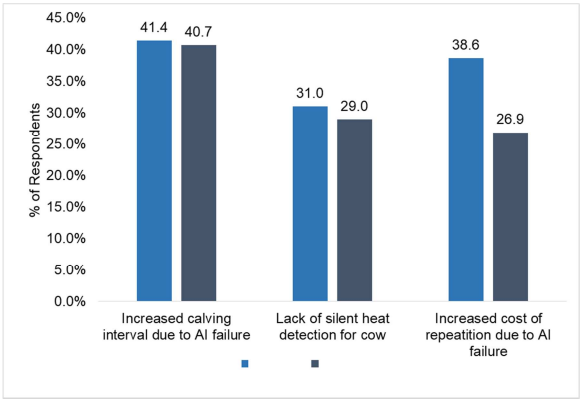

Fig. 2. Constraints for artificial insemination service in Tanzania

Constraints to artificial insemination in Tanzania

The findings on the constraints experienced by farmers for AI service in the eastern zone of Tanzania are shown in Fig. 2. The bar chart presents key constraints to artificial insemination (AI) in the eastern zone of Tanzania, comparing responses from two districts: Kinondoni and Bagamoyo. The major challenge reported is an increased calving interval due to AI failure, with 41.4% of respondents in Kinondoni and 40.7% in Bagamoyo identifying this as a problem. A prolonged calving interval results in lower milk production efficiency and economic losses for farmers, often caused by failed insemination attempts or reproductive health issues in cows.

Another significant constraint is the lack of silent heat detection in cows, affecting 31.0% of respondents in Kinondoni and 29.0% in Bagamoyo. Silent heat

occurs when cows do not display obvious signs of estrus, making it difficult for farmers to identify the right time for insemination. This challenge can lead to missed breeding opportunities and contribute to increase calving intervals.

Additionally, the increased cost of repeat insemination due to AI failure is a major concern, particularly in Kinondoni, where 38.6% of respondents reported this issue compared to 26.9% in Bagamoyo. When AI fails, farmers must repeat the process multiple times, increasing costs related to semen, veterinary services, and labor. This added financial burden can make AI less accessible and sustainable for small-scale farmers.

Overall, the findings indicate that AI inefficiencies, particularly calving interval prolongation, silent heat detection challenges, and the high cost of repeat inseminations, are significant barriers to reproductive success in dairy farming. Improving AI success rates through better heat detection methods, farmer education, and access to quality reproductive services could help address these constraints and enhance dairy productivity in the region.

Cost of artificial insemination per service

Table 3, shows that the cost of artificial insemination (AI) per service varies between Kinondoni and Bagamoyo, with most farmers incurring expenses above 30,000 Tanzanian Shillings (Tsh) per service. The data reveals that a small proportion of farmers in both districts pay the lowest AI costs. Only 3.3% of respondents in Kinondoni and 1.3% in Bagamoyo reported paying between 0-10,000 Tsh per AI service. Similarly, 2.0% of respondents in both districts reported paying between 11,000-20,000 Tsh, while 2.0% in Kinondoni and 3.3% in Bagamoyo paid between 21,000-30,000 Tsh per service.

The majority of farmers, however, face higher AI costs. A notable percentage—12.7% in Kinondoni and 12.0% in Bagamoyo—incur costs ranging between 31,000-40,000 Tsh. The percentage increases for the 41,000-50,000 Tsh range, where 12.0% of respondents in Kinondoni and 5.3% in Bagamoyo fall into this category. The highest AI cost category, exceeding 50,000 Tsh per service, has the most respondents, with 20.7% in Kinondoni and 23.3% in Bagamoyo reporting such expenses.

The findings suggest that artificial insemination is relatively costly, especially in Bagamoyo, where a higher percentage of farmers pay more than 50,000 Tsh per service. The high cost of AI can be a barrier to its adoption, particularly for small-scale dairy farmers. Addressing these cost challenges through subsidies, improved AI efficiency, and access to affordable veterinary services could help increase AI adoption and enhance dairy productivity in both districts.

Table 3. Cost of artificial insemination per services

Cost of artificial insemination per service	Kinondoni f (%)	Bagamoyo f (%)
0 -10,000	5 (3.3)	2 (1.3)
11,000- 20000	3 (2.0)	3 (2.0)
21,000- 30,000	3 (2.0)	5 (3.3)
31,000-4,0000	19 (12.7)	18 (12.0)
41,000-50,000	18 (12.0)	8 (5.3)
n>50,000	31 (20.7)	35 (23.3)

To enhance the adoption of dairy breeding technologies in Tanzania, improving access to artificial insemination (AI) services is essential. This can be achieved by increasing the number of trained AI technicians, particularly in rural areas where access is limited. Additionally, farmers should receive training on heat detection and proper breeding management to improve AI success rates. To make AI services more affordable, the government and relevant stakeholders should consider providing subsidies or financial support, enabling more farmers to benefit from modern breeding techniques.

Farmer education and awareness programs should be strengthened to ensure widespread adoption of dairy breeding technologies. Extension programs and workshops can help farmers understand the benefits of improved breeding practices, such as AI and crossbreeding, leading to better herd productivity. Encouraging farmers to keep proper records of their

cows' reproductive performance will also enhance decision-making and breeding efficiency. Moreover, creating knowledge-sharing platforms, such as farmer cooperatives or digital networks, can facilitate the exchange of best practices and experiences.

Recommendations

Strengthening veterinary and extension services is another critical step in promoting dairy breeding technologies. Expanding veterinary support will ensure timely reproductive healthcare for cows, reducing cases of failed insemination and prolonged calving intervals. Mobile veterinary services can be introduced to reach remote farming communities, providing them with essential breeding and healthcare services. Additionally, improving access to financial support, such as low-interest loans and grants, will enable farmers to invest in AI services, quality semen, and improved breeding management practices. These combined efforts will enhance dairy productivity and sustainability in Tanzania.

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