Original Research Article

Evaluation of artificial insemination services provided through Africa Asia Dairy Genetic Gain programme in regions of Tanzania: demographic details and herd reproductive performance

.

ABSTRACT

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| The Africa Asia Dairy Genetics Gain (AADGG) program has been supporting smallholder farmers in Tanzania's key dairy regions—Kilimanjaro, Arusha, and Tanga—by providing long-term breeding services. This evaluation comprises a two-part study; the first part focuses on herd composition and breeding practices, while the second will examine farmers' attitudes toward artificial insemination (AI). A total of 82 farms were enrolled, with 82% participating in the AADGG program. The majority of farmers (82%) were male, with a median age of 58.5 years and median farm size of 1 acre (ranging from 0.25 to 6 acres). Most farmers relied on natural breeding, with 80% of those using AI selecting Friesian sires. In total, 124 dams and their offspring were analyzed, revealing a median dam parity of 3.0; 13% of cows were at parity 1, and 48% at parity 4-8. Among the offspring, 64% were calves, and 13% were yearlings, with only 16 male offspring, 69% of which were calves. The median lactation yield was 3,900 liters over a 10-month period. The mean age at first breeding and calving were 25.1 and 34.3 months, respectively. Inter-calving intervals averaged 14.6 months for dams and 12.0 months for parous offspring. Only 34% of dams had ≤90 days open, indicating poor reproductive efficiency, particularly for dams. The study highlights an aging farmer population and suggests future research to assess farm characteristics' impact on productivity and management practices affecting reproductive efficiency and herd dynamics. |

*Keywords: Farm characteristics, Herd composition, Reproductive efficiency, Smallholder farmers, Tanzania.*

1. INTRODUCTION

Reproductive performance of domestic cattle in Africa is generally considered to be low [1]. Because reproductive performance is intrinsically linked to productivity, improving cattle reproductive performance should result in increased productivity and, hence, farmers’ livelihoods. Optimal cattle reproduction is relatively poorly defined for developing countries, but, in principle, a fertile and healthy dairy cow should be expected to first calve at approximately 24 months of age, and thereafter, to produce a calf approximately once every year (i.e. with a calving interval of 12 months), with a minimal number of inseminations per conception [1].

Most smallholder farmers in Tanzania breed their herds by natural (bull) service, with a relatively low uptake of artificial insemination (AI). The main limiters of the availability of AI across most regions of Tanzania are infrastructure, accessibility and a lack of trained AI technicians [2]. In consequence, the majority of cattle in the country lack the improvements [2; 3; 4] that which would benefit smallholder communities [5]. Further, the use of natural service breeding, which is characterised by long-term sharing of home-bred and untested bulls across farms, also limits genetic gain by significantly increasing inbreeding and reducing genetic diversity [6; 7]. All of these setbacks could be mitigated by providing adequate and effective AI services at farm level [2; 8; 9; 10].

Limited AI services are provided to smallholder dairy farmers, mainly in the Arusha region (northern zone) by the National Artificial Insemination Centre (NAIC), [11; 12], where there is greatest concentration of dairy-farming in the country [13; 14]. However, even in this region, the uptake of AI services is limited, and, outside the region, its uptake is very low indeed. In beef herds, the uptake of AI is even worse [15]. The limitations to adoption of AI, have been studied in countries such as India [16], where they include undeveloped AI facilities, inadequate numbers and training of AI technicians, inefficient oestrus detection, ineffective post-AI nutritional management plans, low conception rates to AI, unreliability of AI services and high charges for AI services. the situation seems to be very similar in Tanzania [17; 18; 19; 20; 21; 22].

On the other hand, some countries in Africa (e.g. Kenya and Ethiopia) and South America (e.g. Brazil and Argentina) have well-developed AI services, and have managed to adapt and use it in their cattle production systems; particularly within smallholder farmers’ settings [21; 23]. In Tanzania, efforts have been made to improve the uptake of AI through the Africa Asia Dairy Genetics Gain (AADGG)-NAIC joint program. This program is considered to have improved conception and pregnancy rates, with a decrease in the rate of returns to oestrus and animals that fail to conceive [24; 25] and, consequently, improved milk yields and improved longevity of productive animals.

In order to promote the widespread uptake of AI amongst the dairy-farming smallholders of Tanzania, the present limiters to its uptake need to be understood. Further, baseline data on current dairy-herd performance are needed, particularly with respect to reproductive performance. Hence, the aim of the present survey was to assess the performance at farm level of the AI services provided by the AADGG-NAIC joint programme. The outcome of this survey would shed light on the performance of NAIC bulls at farm level, as well as it will provide an understanding of the status and preventive measures of inbreeding in the selected surveyed areas, and also identifying the significance of record keeping in breeding programmes. The present paper reports demographic and farm data for the dairy farms, together with data for lactation and reproductive outcomes. Farmers’ opinions on factors that directly limit the uptake of AI are reported elsewhere.

2. material and methods

Selection of participants

The Participants were selected from 26 villages in Kilimanjaro, Arusha and Tanga regions of Tanzania. These villages were purposively selected, inasmuch as all of the selected villages had previous involved with the AADGG programme and NAIC AI programme. Participants were recruited from the smallholder dairy farmers within the selected villages who had previously involved with the AADGG and NAIC programme. The selection was made with the assistance of local ward livestock extension officers. A total of 82 smallholder dairy farmers were selected from the 26 villages.

Development of the questionnaire

The questionnaire was designed to cover key factors such as bull, dam and offspring details, and their reproduction and production performances [25; 26] and contained both structured and unstructured questions. The questionnaire was piloted on 20 farms prior to the main study. The data obtained from the pilot study were not included in the main study, nor were the farmers resurveyed. This pilot process was designed to train the enumerators in the process and to identify the questions in the questionnaire that needed modification to improve farmers’ understanding of them.

Data collection and analysis

Data collection followed immediately after the completion of the piloting of the survey. It involved four enumerators who had received training on how to administer the questionnaire during the pilot stage. The survey was administered in a period of one week starting on 25th July, 2024. Data were collected through individual face-to-face interviews with the smallholder dairy farmers on each of the 82 farms which had a total of 248 dairy cattle. Descriptive statistics for each survey question were collated and presented as proportions of respondents, or where suitable as medians (ranges). Dams were defined as parous animals that had had at least one calf during their lifetime. Offspring were defined as animals that had been born to one of the dams.

3. results and discussion

Farms and farmers

Participating farms were located in the northern and eastern zones of Tanzania, in the Arusha (n=32: 39%;), Tanga (n=27: 34%) and Kilimanjaro (n=23: 27%) regions. Median farm size was 1 acre, with a range of 0.25 6 acres. The distribution of farm size was: <1 acre (n=21: 26%); 1-<2 acres (n=31: 38%); and 2-6 acres (n=30: 37%). Data from 124 dams were recorded across these 82 farms, and data from a further 124 animals that were the offspring of these dams were also recorded. Most (n=57: 82%) farmers were male. Their median age was 58.5 years (range 30 - 85 years). Most (n=67: 82%) farmers were registered in the AADGG project. Only one participant had no formal schooling, all of the others had completed at least primary education. Of these, 33% (n=27) had also completed secondary education, and 12% (n=10) had also undertaken tertiary education.

Cattle production and reproduction

For the dams for which parity data were available (n=103), the median parity was 3.0. Amongst these, 13% were Parity 1, 17% Parity 2, 25% Parity 3, with the remainder (48%) being Parity 4 8. Lactation yields are summarised in Table 2. Whole-of-lactation yields for the 115 dams for which data were available were 3,900 L (median), 4,316 L (average). The most common lactation lengths were 7, 10, and 11 months.

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| **Table 1: Age and parity of cows and offspring** | | | |
|  | Dams  n (%) | Female Offspring  n (%) | Male Offspring n (%) |
| N | 124 | 105 | 19 |
| Parous animals | | | |
| 1 | 13 (13)a | 14 (13)b |  |
| 2 | 17 (16) | 10 (9) |  |
| 3 | 25 (24) |  |  |
| 4-8 | 48 (47) |  |  |
| Followers and males | | | |
| Yearlings (≥8 months) |  | 14 (13) | 5 (31)a |
| Calves |  | 67 (64) | 11 (69) |
| (a) proportion of animals with full data; (b) proportion of all female offspring | | | |

Milk yield over the current lactation for dams and lactating offspring were regressed against each other (r2=0.397; Figure 1). The data included lactations that were either not completed or were recently started, so limited functional significance was attributed to the correlation.

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| **Table 2 Lactation characteristics of dams and lactating offspring** | | | |
|  | Milk yield per day (L) | Lactation yield (L) | Lactation length (months) |
| Dams | | | |
| Median | 13.0 | 3,900 | 10.0 |
| Mean | 13.6 | 4,316 | 9.9 |
| Maximum | 36 | 24,000 | 24 |
| Minimum | 3 | 420 | 1 |
| Offspring | | | |
| Median | 16.0 | 5,610 | 11.0 |
| Mean | 17.1 | 5,618 | 11.0 |

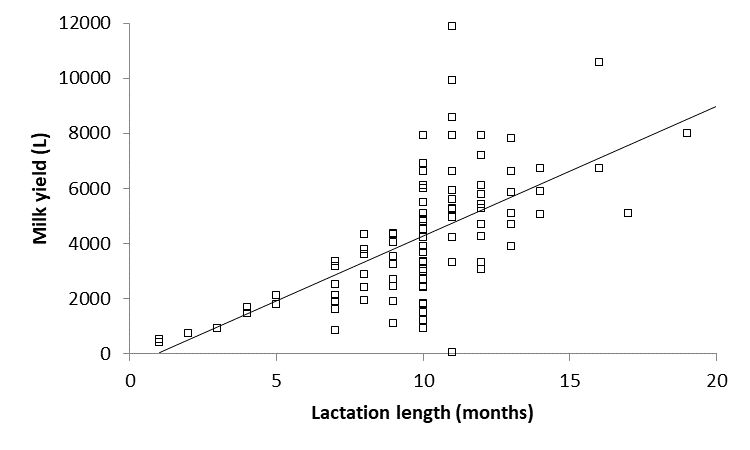


Figure 1: Relationship between lactation yield (L) and lactation length (months).

Reproductive performance is summarised in Table 3. The most common age at first service (Figure 2a) for both dams (n=75: 63%) and offspring was 24 months. Most (n=13: 11%) other cows had had their first service by 36 months; one animal was not served until 48 months. Only 12 dams (10%) and 6 offspring had been served by 20 months of age. The distribution of ages at first calving (Figure 2b) were generally parallel to age at first service: most dams had calved by 33 (n=41: 34%) or 36 (n=41, 34 %) months, although offspring showed rather better proportions (33 months: n=18, 75%, 35 months: n=4: 17%). Only 22 (18%) of dams (6 offspring: 24%) first calved at ≤32 months: the minimum age at first calving was 24 months. Inter-calving intervals were generally between 12 and 15 months: 48 dams (45%) had a calving interval of 12 months, whilst an additional 36 animals (34%) had inter-calving intervals of >12-≤15 months. One animal had an inter-calving interval of 48 months. Offspring that had had a second calving were all reported to have had inter calving intervals of 12 months.

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| **Table 3 Reproductive characteristics of dams and lactating offspring** | | | |
| Dams | | | |
|  | Age at first service (months) | Age at first calving (months) | Inter-calving interval (months) |
| Median | 24.0 | 33.0 | 13.0 |
| Mean | 25.1 | 34.3 | 14.6 |
| Maximum | 48 | 48 | 48 |
| Minimum | 14 | 24 | 12 |
|  | Days open (days) | AI Services per conception (n) | Returns to oestrus (n) |
| Median | 120.0 | 1.0 | 0.0 |
| Mean | 162.3 | 1.6 | 0.6 |
| Maximum | 630 | 9 | 8 |
| Minimum | 30 | 1 | 0 |
| Offspring | | | |
|  | Age at first service (months) | Age at first calving (months) | Inter-calving interval (months) |
| Median | 24.0 | 33.0 | 12.0 |
| Mean | 23.2 | 32.4 | 12.0 |
|  | Days opena (days) | AI Services per conception (n) | Returns to oestrus (n) |
| Median | 120.0 | 1.0 | 0.0 |
| Mean | 123.2 | 1.9 | 0.9 |
| a: days open calculated for animals being bred for second calving | | | |

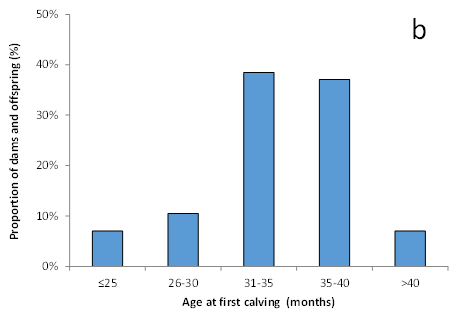
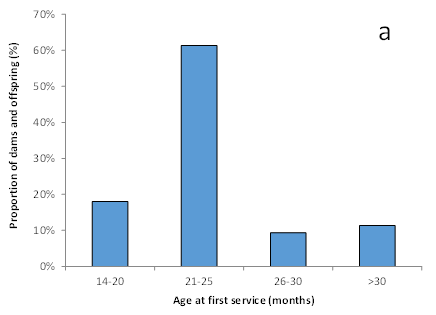


Figure 2: Dams and parous offspring breeding: (a) age at first service, (b) age at first calving

Mean days open (Figure 3) for dams was 162.3 days, considerably greater than the 85 days nominally required for a 365-day inter-calving interval. A minority (n=36, 34%) of dams had ≤90 days open. However, the mode was 120 days, and the top quartile of intervals was 180 -630 days. Data from offspring that were being bred for their second calving were slightly lower (mean: 123.2 days) but, even so, the modal interval was 120 days. In terms of the number of services/conception, the mean for dams was 1.6 services, with the mode (1) being achieved by 73 (62%) of animals. The number of returns to oestrus corresponded to the number of services/conception, although one animal returned to oestrus 8 times. Data from offspring were very similar to those from dams, with a modal value for services/conception of 1.

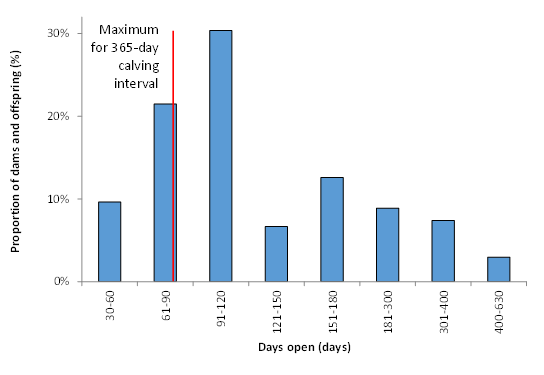


Figure 3: Days open for dams and offspring. Maximum value for 365-day calving interval is indicated.

Young stock

Most young stock <9 months of age were female (n=81; 84%) Most of these were calves (n=67; 83%); the remainder being yearlings. Of the males (n=16), 11 were calves and 5 yearlings.

AI bulls

The majority of the AI semen used on farms came from Friesian bulls (80%, n=99). Other breeds included Ayrshire (12.9%), Simmental (4.0%), Jersey (1.6%), and Fleckvieh (1.6%) bulls. Most bulls were 4 or 8 years old (n=73, 59%; n=22, 18%, respectively).

The study revealed a diverse sample of farms and farmers in the Arusha, Tanga, and Kilimanjaro regions of northern and eastern Tanzania. Farm sizes varied from 0.25 to 6 acres, with a median of 1 acre, indicating a prevalence of smallholder farms which is likely to affect resource management and economic viability. The predominantly male farming population (82%) and median age of 58.5 years raise concerns about an aging workforce and farm succession. A high participation rate (82%) in the AADGG project shows strong engagement with dairy cattle farming development. Educational attainment is relatively high, suggesting openness to new technologies, though further research is needed on the link between education and the adoption of AI breeding services [27; 28].

The reproductive performance and milk production of the dams in the study provided useful insights into the productivity of these dairy herds. The median parity of 3.0 (dams) indicated a relatively mature breeding population, as confirmed by the distribution across parity groups which showed a considerable proportion of dams in their later lactations: 48% were Parity 4 or higher, compared to 13% in Parity 1, 17% in Parity 2, and 25% in Parity 3. This distribution suggests a relatively stable herd with a history of successful breeding and calving. Further, the presence of 24 offspring as parous animals shows that there is viable herd succession. Data for culling rate and for non-lactating cows in the herd, which are characteristically inversely related to calving interval [29; 30], would confirm the stability of herd structure. On the other hand, the presence of many older cows in the herd, especially in the face of long inter-calving intervals, could indicate that farmers are unable to cull these cows without jeopardizing the herd’s milk production [30]. Further analysis could explore the potential impact of parity on milk production and reproductive performance, considering factors such as age and management practices [31; 32].

Lactation yields, as summarized in Table 2, showed a median whole-of-lactation yield of 3,900 L and an average of 4,316 L (n=115). This provides a benchmark for milk production within this specific population, but further contextualization is needed by comparing these figures to regional or national averages for similar breeds and management systems. The variation in yields warrants investigation, exploring potential contributing factors such as nutrition, genetics, and health status [32]. The most common lactation lengths were 7, 10, and 11 months. This variability in lactation length could influence the overall milk yield. Further investigation should explore the factors contributing to these variations, such as management practices, nutritional strategies, and potential health issues affecting lactation duration. Understanding the interplay between lactation length and milk yield is crucial for optimizing milk production strategies [33]. Analysing the data to determine if there's a correlation between lactation length and yield within parity groups would be valuable.

A moderate positive correlation (r² = 0.397) was observed between the milk yield of dams and their lactating offspring during the current lactation. However, the inclusion of incomplete or recently started lactations (Figure 1) in the dataset limits the strength of this correlation and its functional significance. The observed correlation may be influenced by several factors, including genetic inheritance, shared environmental conditions (e.g., nutrition, management practices), and the stage of lactation [34]. Because the data includes lactations at various stages of completion, the correlation may not accurately reflect the full extent of the relationship between dam and offspring milk yield. Incomplete lactations may introduce bias, as yields are not fully realized. Similarly, recently started lactations may not yet fully reflect the animal's inherent milk production potential. To better understand the relationship between dam and offspring milk yield, future analyses should focus on complete lactations only. This would provide a more robust assessment of the genetic and environmental influences on milk production across generations [35]. Further investigation could also explore other factors that may contribute to the correlation, such as the age of the dam, the offspring's breed, and the overall health and management practices employed. Controlling for these variables could strengthen the interpretation of the correlation and provide more meaningful insights into the heritability of milk yield. Table 3 summarizes the reproductive performance of the dams and their offspring, revealing several key aspects of their breeding history. The age at first service (Figure 2a) showed a strong clustering around 24 months for both dams (63%, n=75) and offspring, indicating a common breeding management practice. A smaller proportion (11%, n=13) had their first service by 36 months, while a single animal was served at 48 months. Only a small percentage (10%, n=12 dams; 24%, n=6 offspring) were served at or before 20 months of age. This indicates that a breeding strategy targeting first service around 24 months is generally applied. Further investigation into the reasons for early or delayed first service in the outliers could provide valuable insights into reproductive management practices. First service at 24 months is recognised to limit cows’ lifetime performance in dairying systems of developed countries, in which 24 months is recommended as the age for first calving [1]. However, where nutritional resources are inadequate to obtain sufficient growth rates to achieve appropriate live weights at 15 months of age for successful breeding (as well as successful calving at 24 months), first breeding at a later age becomes necessary. Even so, even in semi-intensive cow-calf breeding units, decreasing age at first breeding is associated with improved lifetime performance.

The age at first calving (Figure 2b) shows a similar pattern to age at first service, with most dams calving by 33 months (34%, n=41) or 36 months (34%, n=41). The offspring exhibit a slightly improved distribution, with a greater proportion calving at 33 months (75%, n=18) compared to the dams. Only a minority of dams (18%, n=22) and offspring (24%, n=6) first calved at 32 months or younger, suggesting a potential for improvement in breeding management to accelerate reproductive performance. The minimum age at first calving was 24 months, aligning with the age at first service [36]. Again, the age at first calving is influenced by the nutritional status of growing stock and pregnant heifers. Further evaluations (e.g. regular weighing of young stock) could elucidate such relationships. However, attaining adequate body size at first calving is crucial, inasmuch as it determines both the heifer lactation yield and at least two subsequent lactation yields, calving to conception interval after the first calving, and dystocia rate at first calving [37].

The inter-calving intervals (CI) largely fall within the 12-15-month range, with 45% (n=48) of dams having a 12-month CI and an additional 34% (n=36) having an CI between 12 and 15 months. The presence of one dam with a 48-month CI suggests a significant reproductive event or management issue [38]. In contrast, all offspring with a second calving had a 12-month CI. This difference warrants further investigation to understand the factors contributing to variations in CI between dams and offspring. Analysis should explore potential correlations between CI and factors such as age, parity, nutrition, and health status. The relatively short CI for most animals might indicate a generally efficient reproductive cycle, although the effects of the long calving to first service interval may compound this. Further, the presence of a long calving to first service interval with an adequate CI may mean that the effect of culling has not been fully accounted [39; 40]. Optimization could potentially be achieved by addressing the outliers and investigating the causes of extended CIs and fully determining the relationship between culling rate and CI.

Analysis of days open (Figure 3) revealed a mean of 162.3 days for the dams, significantly exceeding the 85 days theoretically required for a 365-day inter-calving interval. Whether this indicates a considerable period of suboptimal reproductive efficiency within the herd [41], or whether it represents management decisions (e.g. increasing the WVP to allow BCS to recover), is not clear from the present data. Nonetheless, a minority of dams (34%, n=36) had ≤90 days open, suggesting that early breeding is feasible in at least some herds; but the modal interval was 120 days, and the top quartile spanned a wide range (180–630 days). This significant variation highlights the presence of both highly efficient and inefficient reproductive cycles within the population [42]. Further investigation is needed to identify the factors contributing to this variability, including nutritional status, health management, breeding practices, culling policies and potential underlying health conditions affecting fertility.

The offspring that were, being bred for their second calving, showed slightly improved reproductive performance than the dams, with a lower mean days open (123.2 days). However, even in this group, the modal interval remained at 120 days, suggesting that a substantial proportion of animals still experience extended days open. This consistency across generations warrants a comprehensive review of breeding and management practices to improve overall reproductive efficiency.

The mean number of services per conception for dams was 1.6, with a mode of 1 achieved by 62% (n=73) of the animals. This might suggest that a significant proportion of animals conceived after a single service, indicating relatively good fertility in a subset of the herd [43]. On the other hand, as much of the breeding was by natural service, it could simply reflect inadequate recording of repeat services: - which is a common phenomenon across many dairy industries [39; 40]. As evidence that this may be so, a considerable number of animals required multiple services to achieve conception, although this may merely highlight the need for improved reproductive management to reduce the number of services required [44]. The number of returns to oestrus generally mirrored the number of services per conception, but the presence of one animal with eight returns to oestrus underscores the need for individual animal assessment and targeted interventions to address persistent reproductive challenges. The data from the offspring were very similar to the dams, with a modal value of 1 service per conception [44]. Thus, while a proportion of animals exhibit efficient reproductive cycles, a significant portion experience extended days open and require multiple services for conception. A multi-faceted approach involving improved breeding management, nutrition, and health monitoring is crucial to enhance overall reproductive performance and reduce the economic losses associated with prolonged calving intervals [45]. Further investigation into the factors influencing days open and services per conception is needed to develop targeted interventions.

Most of the young stock were female (84%). This disproportionate representation of females presumably reflects intentional management practices, such as selective culling of male calves or preferential rearing of females for future breeding purposes. Further information on the management practices employed would be necessary to confirm this conjectures. The age distribution within the female young stock showed a predominance of calves (83%, n=67), with the remaining animals being yearlings. The male young stock also consisted primarily of calves (11 out of 16), with a smaller number of yearlings (5 out of 16). This age distribution suggests a relatively consistent pattern of births and animal management practices over time. However, additional data on mortality rates and culling practices would provide a more complete understanding of the dynamics influencing the observed age and sex distribution. The age distribution and proportions of male vs female young stock probably warrant further investigation to fully understand the underlying management strategies and their implications for herd structure and future productivity. Qualitative data gathering, such as interviews with farmers, could provide valuable insights into the decision-making processes behind the observed pattern. This information would enhance the interpretation of the quantitative data and provide a more comprehensive understanding of the herd dynamics [46].

The choice of AI semen used on the farms demonstrates a strong preference for the Friesian breed, which accounted for the majority (80%) of the semen used. This dominance of Friesian genetics reflects the perceived economic value of the breed. The relatively high proportion of Friesian semen suggests a focus on traits associated with this breed, such as milk production and body conformation [47]. Other breeds represented include Ayrshire (12.9%), Simmental (4.0%), Jersey (1.6%), and Fleckvieh (1.6%). Whether the Friesian breed is appropriate for the climatic/farming conditions of Tanzania is worthy of further investigation: Holstein-Friesian cattle often struggle with semi-tropical conditions, with reproduction often being other breeds indicates some diversification in breeding strategies, potentially reflecting attempts to introduce desirable traits from different genetic backgrounds, such as improved disease resistance or adaptability to specific environmental conditions.

4. Conclusion

In conclusion, this study provides a comprehensive overview of the dairy farming landscape in the Arusha, Tanga, and Kilimanjaro regions of northern and eastern Tanzania. The findings highlight a diverse range of smallholder farms that are characterized by generally small acreages and a predominantly male farming population. Concerns regarding an aging workforce and the sustainability of farm succession are likely to be important issues to be addressed. The high participation rate in the AADGG project indicates a strong commitment to dairy cattle development, coupled with a relatively high level of educational attainment among farmers, which may facilitate the adoption of new technologies. The reproductive performance metrics, including parity, age at first service and calving, inter-calving intervals, and days open, reveal areas for improvement. While a significant proportion of dams exhibit stable reproductive cycles, extended days open and the need for multiple services per conception highlight the necessity for enhanced reproductive management practices. Additionally, the preference for Friesian bulls in artificial insemination practices underscores the importance of breed selection in optimizing production traits. Future analyses should examine the relationships between farm characteristics (size, location, farmer demographics), productivity, and the impact of farmer education on animal management practices. Key areas for investigation should include the influence of farm size on animal numbers, regional differences in animal health/productivity, and the relationship between education and management practices. Overall, this study lays the groundwork for further exploration of the dynamics within the farms of the AADGG smallholder dairy farmers and the factors influencing their productivity and sustainability.

Ethical approval AND CONSENT

Research Ethical Clearance was obtained from the Tanzania Livestock Research Institute (TALIRI) (August 2024).

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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