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Assessment of challenges associated with artificial insemination service delivery in dairy cattle in Rwanda

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Abstract
Most Rwandan farmers need artificial insemination (AI) services to improve their dairy breeds. This is because AI as a breeding service is the most available assisted reproductive technology to improve these breeds. However, this breeding service is associated with several technical, socio-economic, managerial, and logistical constraints. Therefore, AI service is likely to remain poor and even declining due to inconsistent service delivery to dairy farmers. In other words, the decline in AI use among dairy farmers in Rwanda could be reversed by improving AI service delivery. However, empirical evidence is lacking for the challenges experienced by artificial insemination technicians (AITs) in delivering AI services. Thus, the objective of this study was to assess the challenges associated with bovine AI service delivery in Rwanda. A pre-tested structured questionnaire survey was prepared and used, and 89 respondents (AITs) were asked accordingly in a retrospective cross-sectional sampling design. The results of the study showed that the top four major challenges frequently experienced by AITs regarding AI service delivery were irregular and interruptions supply of liquid nitrogen and other AI consumables (95.5%), followed by the presence of uterine infections (metritis/endometritis) (95.5%), conception failure (91.0%), and poor herd management practices by farmers (76.4%). It mostly emerged from this study that there is a need to provide AI inputs regularly and without interruption, establish a performance-based incentive system for AITs, and improve general herd management, feeding, and breeding practices by farmers. These strategies should be considered for prioritisation in extension services and research to overcome the challenges that have so far impeded efficient dissemination and accessibility of AI technology among dairy farmers. This could improve AI service delivery, increase productivity, profitability, and sustainability of the dairy herds.

Keywords: AI inputs, Artificial insemination technicians, breeding service, challenges, strategies

1. Introduction
The dairy sub-sector is an integral part of the agricultural sector in Rwanda. It offers a pathway out of poverty for over 80.0% of households involved directly or indirectly in the dairy value chain. The dairy subsector contributes 28.0% to the agricultural Gross Domestic Product (GDP) and 4.0% to the national GDP [1]. Increasing productivity in the dairy sub-sector is necessary for enhancing farm incomes, reducing poverty, improving nutrition as well as meeting the growing demand for dairy products by the growing urban population [2]. Therefore, the provision of efficient and affordable breeding services is crucial in ensuring access to improved dairy breeds that are necessary for increased productivity, profitability, and sustainability of the dairy sub-sector. Artificial insemination (AI) is one of the earliest great biotechnology innovations related to animal reproduction and breeding, dating back to the 1780s [3], and has brought enormous socio-economic benefits to the livestock farming industry [4]. It is the use of semen collected from a genetically superior male to inseminate a female detected in heat, resulting in a genetically superior offspring [5]. The use of AI can also be seen as a chain of events - from the collection of semen from a bull to the birth of a calf. And to be successful in AI work, no failures can be tolerated anywhere since each link in this chain of events is of equal importance because the concept of the fertility chain is that it is only as strong as the weakest link [6]. This indicates that dairy producers must desire to make AI work and instil this commitment into each link in the fertility chain.

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Therefore, the weakest link sets the level of success of the AI service. This means that all the links in the chain should be strong enough to strengthen the whole chain, as one weak link results in no conception, most likely to the extent it will cancel many of the benefits the AI technology offers [7].

The AI technology has been in operation in Rwanda for over 70 years. However, some concerns like the long term sustainability of the dairy sub-sector are undermined by a number of constraints, but not limited to low conception rate, absence of heifer replacement which needs to be introduced to maintain a stable herd size, and disharmony in the organization of assisted reproductive technologies [2]. These constraints can result in reproduction and production losses [8]. In Rwanda, dairy production is a prioritised development intervention for rural farming households, but the reproductive and productive performance of dairy cows is suboptimal [9]. This is because a large number of dairy cows are served several times but remain unproductive, which results in production and economic losses to the farmers as such cows have reduced potential to produce their heifer replacements [10]. Yet, the dairy farming system supplies the bulk of the milk for the domestic market [11]. However, the supply has not satisfied the local demand. The average per capita milk consumption for both urban and rural areas estimates by the Rwanda Livestock Master Plan [12] is 63.0 litres per person per annum against the expected 220 litres/year [13]. This demonstrates that a fundamental problem with dairy development is the limited stock of high producing dairy cows. The national bovine herd is estimated at 1,340,792, of which 45.0% are indigenous cattle, 33.0% are dairy crossbreds, and 22.0% are pure dairy breeds [11]. This is an indication that the AI service in the country has not been successful in improving the productivity and reproductive performance of the dairy industry [11, 14]. Recognizing the above limitations on milk production, the Government of Rwanda (GoR) has adopted policies aimed at increasing yields through genetic improvement through the importation of exotic cattle; and crossbreeding using AI technique that has great potential to improve the productivity and profitability of dairy cattle.

To make bovine AI successful, the GoR through the Rwanda Agriculture and Animal Resources Development Board, and different stakeholders, trained AITs to provide proximity services at the farm level. Despite all the efforts made to use AI technology, the conception rate after the first AI service is still low, ranging from 20.8% to 42.2% as reported by previous studies [10, 14]. This indicates that technical, socioeconomic, and logistic constraints still exist along the cattle genetic improvement value chain [15] demonstrating that the efficiency of AI services in the country, however, has remained at a very low level.

Despite the significant increase in the availability of AITs over the last 10 years, recent studies have shown that a great proportion of dairy farmers are reverting to natural mating, probably due to inconsistent AI service in the livestock production systems of the country in general [15]. According to Mushonga *et al*. (2015), approximately 63.1% of farmers use bull service, 16.9% use AI service, and 20.0% use both AI and bull services. Correspondingly, Nyabinwa *et al*. (2020) reported that more cows were mated with breeding bulls (65.4%) compared to AI (34.6%). This demonstrates the low adoption rate of AI service by dairy farmers, probably due to a number of reasons, but not limited to low farmers' awareness of the use of AI, dairy farmers may have kept breeding bulls due to the inaccessibility of AI service within the herd's environment, and bull service is convenient when the farmer does not have the money to pay for AI service [2, 17, 18]. This may result in a reduction of the number of AI services offered to farmers by AITs, which in turn results in reduced income from services. However, there would be a need to launch an educational campaign to show farmers the advantages of AI technology as opposed to bull service [19].

The reported low adoption of AI and low conception rate indicate a problem in the AI service delivery system. Unfortunately, empirical evidence on challenges experienced by AITs in delivering AI services in Rwanda is lacking. Such evidence would be valuable in informing management interventions to target those challenges. Consequently, the general objective of this study is to contribute to improving herd fertility, productivity, and profitability through better-targeted management actions to prevent challenges faced by AITs in Rwanda. Specifically, this study targeted AITs from different districts to assess challenges associated with the bovine AI service delivery system.

2. Materials and Methods

2.1 Survey design and data collection

This study evaluates data from a convenience sample. This is because the target population that met certain practical criteria, such as easy accessibility, availability at a given time, and willingness to participate, were included for the purpose of this study [20, 21]. In total, 89 artificial insemination technicians (AITs) were included in this study, of whom 57.3% (n = 51) worked in private practice (licensed private AITs) and 42.7% (n = 38) for the government (public AITs). The participants of the survey were from four provinces: Northern (40.4%, n = 36), Eastern (22.5%, n = 20), Southern (20.2%, n = 18), and Western (16.9%, n = 15).

The study applied a retrospective cross-sectional sampling design involving an AIT survey to understand the challenges associated with bovine AI service delivery in Rwanda. The retrospective data was collected from the AIT covering the years 2020 - 2021 (April 2020- April 2021). Interviews were obtained from AITs who consented. AITs were assured of the confidentiality of the data collected since individual identification is not part of the data being reported in this paper. Therefore, a pre-tested semi-structured questionnaire was prepared and used to collect the data from each AIT through face-to-face interviews. Before the beginning of the interview, every respondent was briefed about the objective of the study. The questionnaire was developed in English and was pre-tested on 10 AITs to ensure the objective of the study is clear and to improve the clarity of the questions to the target population [22]. The 10 AITs used in the pre-testing survey were not part of the AITs recruited for the study being reported in the current paper. Furthermore, each AIT was asked to (i) describe the AI inputs and service delivery processes in his/her operational area and (ii) give strategies on how to improve AI service in the future. The aachievements of AITs from providing AI services to farmers were recorded as the cumulative achievement realized in the last three years (2019 up to 2021).

2.2 Data management and statistical analysis

The collected data were entered, stored, and analyzed using the Statistical Package for the Social Sciences (SPSS) version 20.0 for Windows package software [23]. Data analysis employed different analytical methods depending on the nature of the data collected. This was to enable in-depth data mining for better understanding and reporting of challenges associated with the bovine AI service delivery system.

Descriptive statistics were used to estimate the socio-economic characteristics of public and private AITs, challenges to AI service delivery system faced by AITs, and achievement of providing AI services to farmers. These include cross-tabulation, means, standard error of the mean, median, frequencies, percentages, minimum, and maximum. Inferential statistics with the Chi-square test were employed to determine the association between different variables with the AIT status (public and private AITs). The Independent-Samples T-Test was used to compare continuous variables between public and private AITs. Ninety-five per cent confidence interval (95% CI) for proportion was computed by using the EpiTools software (https://epitools.ausvet.com.au/ciproportion?page=CIProportion) [24].

For the purposes of analysis, the different challenges experienced by AITs in delivering AI services to dairy farmers were categorized into four groups relating to (i) AI Centres and/or Sub Centres, (ii) herd management, (iii) herd health in pre-, during, and post-partum periods, and (iv) AITs. Those challenges were classified depending on their frequency of occurrence reported by AITs in the survey questionnaire. Thus, the higher the frequency, the more the challenge is serious. Finally, the study used lucid.app (https://lucid.app/lucidchart) to map out the combined process and influential actors in AI inputs distribution and AI service delivery system models in Rwanda. In all analyses, the statistical significance was set at alpha <5%.

3. Results

3.1 Socio-economic characteristics of public and private AITs for continuous variables

A summary of socio-economic characteristics for continuous variables of public AITs and private AITs is presented in Table 1. The results showed that AI service provision is provided mainly by private AITs (private AI business model, 57.3%, n = 51) with little public AITs service delivery (Government AI business model, 42.7%, n = 38). Overall, the family size was on average 4.3±0.2 members per household and the mean age was 32.5±0.5 years (median 32.0) with 5.2±0.5 (median 4.0) years of experience in AI activity. AITs needed to walk for 1.8±0.1 (median 1.5) and 1.5±0.1 (median 1.0) hours to get AI inputs to the nearest AI centre and AI Sub Centre, respectively. In line with this, the average distance (kilometres) from home to the different farms was 20.8±2.9 (median 10.0) for public AITs and 17.4±2.0 (median 15.0) for private AITs while the average distance for the whole sample was 18.8±1.7 (median 13.0) kilometres.

At the time of this study, the cost of a single AI service (the price of semen and service fees) was at a cost: US$ 3.5±0.1 (median 3.0) when using ordinary conventional semen and US$ 9.5±0.3 (median 9.0) when using sexed semen, but varied according to the different AITs. It was higher among private AITs (US$ 3.8±0.2 and 9.8±0.4 when using ordinary conventional semen and sexed semen, respectively) than among public AITs (US$ 3.2±0.2 and 9.0±0.4 when using ordinary conventional semen and sexed semen, respectively). Participants confirmed that cows becoming pregnant require a greater number of inseminations per conception (1.5±0.1, minimum = 1, maximum = 4.0) and a number of doses of semen per conception (1.6±0.1, median 2.0).

Out of the 12 continuous socio-economic characteristics considered, five were found to be significant ($p<0.05$) between public AITs and private AITs. These were the age of AIT (36.2±0.7 vs. 29.7±0.5), experience in AI activity (4.1±0.9 vs 3.8±0.4), average walking hours from home to AI Centres (1.4±0.2 vs 2.0±0.2), average service fees (US$) for ordinary conventional semen (2.7±0.2 vs 3.3±0.2) and average price (US$) of ordinary conventional semen plus service fees (3.2±0.2 vs 3.8±0.2).

Table 1: Socio-economic characteristics of public and private AITs for continuous variables

Characteristics	Status of AITs								t-value	P-value	Overall sample (n = 89)			
	Public (n = 38)				Private (n = 51)									
	Mean±SE	Median	Min	Max	Mean±SE	Median	Min	Max			Mean±SE	Median	Min	Max
Age of AITs (years)	36.2±0.7	36.0	31.0	51.0	29.7±0.5	29.0	25.0	37.0	-7.83	0.001	32.5±0.5	32.0	25.0	51.0
Experience in AI (years)	4.1±0.9	5.0	1	29	3.8±0.4	3.5	1	13	-3.629	0.001	5.2±0.5	4.0	1.0	29.0
Household size (number)	4.1±0.3	4.0	0.0	9.0	4.4±0.3	4.0	1.0	12.0	0.52	0.607	4.3±0.2	4.0	0.0	12.0
Average walking hours from home to														
- AI Centres	1.4±0.2	1.0	0.0	5.0	2.0±0.2	2.0	2.0	5.0	2.3	0.024	1.8±0.1	1.5	0.1	5.0
- AI Sub Centres	1.4±0.2	1.0	0.0	5.0	1.5±0.2	1.0	0.0	5.0	0.2	0.830	1.5±0.1	1.0	0.1	5.0
Average distance from home to the different farms (Kms)	20.8±2.9	10.0	3.0	60.0	17.4±2.0	15.0	0.0	55.0	-0.99	0.324	18.8±1.7	13.0	0.1	60.0
Average Service Fees (US$)														
- *Conventional semen*	2.7±0.2	2.5	1.0	4.5	3.3±0.2	2.5	1.0	7.5	2.38	0.020	3.0±0.1	2.5	1.0	7.5
- *Sexed semen*	4.0±0.4	3.5	1.0	10.0	4.7±0.4	4.0	1.0	15.0	1.18	0.240	4.4±0.3	4.0	1.0	15.0
Average Price of conventional semen + service fees (US$)	3.2±0.2	3.0	1.5	5.0	3.8±0.2	3.0	1.5	8.0	2.8	0.020	3.5±0.1	3.0	1.5	8.0
Average Price of Sexed semen + service fees (US$)	9.0±0.4	8.5	6.0	15.0	9.8±0.4	9.0	6.0	20.0	1.33	0.186	9.5±0.3	9.0	6.0	20.0
Number of AI service per conception (n)	1.5±0.1	1.0	1.0	4.0	1.5±0.1	1.8	1.0	2.0	0.19	0.849	1.5±0.1	1.0	1.0	4.0
Number of dose of semen per conception (n)	1.6±0.1	1.0	1.0	5.0	1.7±0.1	2.0	0.0	4.0	0.84	0.401	1.6±0.1	2.0	0.0	5.0

*SE = Standard Error Mean, Min = minimum, Max = maximum, AITs = artificial insemination technicians, US$ = The United States dollar, AI = artificial insemination, Kms = kilometres.

3.2 Socio-economic characteristics of public and private AITs for dummy variables

Table 2 presents the socio-economic characteristics of dummy variables of the sample AITs. In AI practice, more private AITs are technicians than professionals (52.8 vs 4.5%) whereas more public AITs are professionals than technicians (32.6 vs. 10.1%, p = 0.001), and males dominate (87.6%) AI activity. The AI service is provided by AITs (10.1%) that are members of dairy cooperatives and AITs (89.9%) that are non-members of dairy cooperatives (p = 0.006). The dairy farmers can use any available AIT; the farmer calls the AIT when required (89.9%) or the farmer visits the AIT in his/her station (10.1%). The AIT comes to inseminate the cow on heat using ordinary conventional semen (91.0%) or sexed semen (9.0%) depending on the farmer's choice. The AIT is paid immediately after service by the farmer (95.5%) or paid on a contract basis, especially for AITs (4.5%) that have established contracts with certain farmers. The majority (57.3%) of AITs said that there are no conditions attached to the payment of AI service (i.e.: whether conception is successful or not, the AIT gets paid). However, when conception after the first service is not successful, the majority (89.9%) of the AITs reported that farmers decided to use AI again, whereas 10.1% of the sample AITs said that farmers shifted to bull service. For those using AI again, the follow-up insemination is done by paying either semen only (61.3%) or service fees only (38.7%).

Less than half of the respondents (44.9%) judged the overall availability of AI inputs, including liquid nitrogen and other consumables as poor. Moreover, 7.9% (n = 7) of the respondents indicated that they were not available at weekends and holidays to deliver AI service. In contrast, 92.1% (n = 82) of the sample AITs reported a contradictory view as they provided AI service on weekends and holidays. When the AITs were not available, 71.4% of the AITs decided to reorient the cases to other AITs available in the area, whereas 28.6% of the AITs decided to pass the date without serving the cows and wait for the next oestrus cycle.

More than half (69.7%) of the sample AITs attended all the AI calls and about a third (30.3%) did not. In decreasing order of probability of being considered a key reason for not attending all the AI calls, the top four main reasons were: (i) cost not compensated (40.4%, 95% CI: 30.9-50.8), (ii) large area of operation (24.7%, 95% CI: 16.9-34.6), (iii) no time/high workload (20.2%, 95% CI: 13.2-29.7), and (iv) lack of means of transport (14.6%, 95% CI: 8.7-23.4) (Table 3). Over a third of the public AITs (34.8%) had additional income from non-AI activities, as compared to about 29.2% of private AITs ($p<0.05$). The result also indicates that 13 (14.6%) public AITs had access to credit services and 25 (28.1%) had no access. On the other hand, 11 (12.4%) private AITs had access to credit and 40 (44.9%) had not.

Table 2: Socio-economic characteristics of public and private AITs for dummy variables

Variable	Response	Status of AITs		Chi-square. value	P-value	Total sample (n = 89)
		Public(n = 38)	Private(n = 51)			
		% (n)	% (n)			% (n)
Gender	Female	4.5 (4)	7.9 (7)	0.206	0.650	12.4 (11)
	Male	38.2 (34)	49.4 (44)			87.6 (78)
Access to loan/credit	Yes	14.6 (13)	12.4 (11)	1.767	0.184	27.0 (24)
	No	28.1 (25)	44.9 (40)			73.0 (65)
Membership in dairy cooperatives	Yes	0.0 (0)	10.1 (9)	7.460	0.006	10.1 (9)
	No	42.7 (38)	47.2 (42)			89.9 (80)
Level of education	Technician	10.1 (9)	52.8 (47)	43.760	0.001	62.9 (56)
	Professional	32.6 (29)	4.5 (4)			37.1 (33)
Semen mostly used	Conventional semen	41.6 (37)	49.4 (44)	3.276	0.070	91.0 (81)
	Sexed semen	1.1 (1)	7.9 (7)			9.0 (8)
Mode of payment of AI service	Immediately after service	41.6 (37)	53.9 (48)	0.536	0.464	95.5 (85)
	On contract	1.1 (1)	3.4 (1)			4.5 (4)
Conditions attached to the payment of AI service	Yes	20.2 (18)	22.5 (20)	0.592	0.442	42.7 (38)
	No	22.5 (20)	34.8 (31)			57.3 (51)
Other means of earning income	yes	34.8 (31)	29.2 (26)	8.854	0.003	64.0 (57)
	No	7.9 (7)	28.1 (25)			36.0 (32)
Availability on weekends and holidays	Available	36.0 (32)	56.2 (50)	5.746	0.017	92.1 (82)
	Not available	6.7 (6)	1.1 (1)			7.9 (7)
Decision taken by the AITs when not available on weekends and holidays	Pass the date without serving the cows	14.3 (1)	14.3 (1)	2.917	0.088	28.6 (2)
	Reorient the cases to other AIT available in the area	71.4 (5)	0.0 (0)			71.4 (5)
Judgement of overall availability of inputs including liquid nitrogen and other consumables	Good	21.3 (19)	33.7 (30)	0.685	0.408	55.1 (49)
	Poor	21.3 (19)	23.6 (21)			44.9 (40)
Remedies taken by the farmers when cows return on heat after first AI service	Use AI again	38.2 (34)	51.7 (46)	0.013	0.911	89.9 (80)
	Use breeding bulls	4.5 (4)	5.6 (5)			10.1 (9)
Means of communication with farmers	Farmer visit us on station	2.2 (2)	7.9 (7)	1.716	0.190	10.1 (9)
	Farmer call us	40.4 (36)	49.4 (44)			89.9 (80)
Attending all the AI calls	Yes	23.6 (21)	46.1 (41)	6.506	0.011	69.7 (62)
	No	19.1 (17)	11.2 (10)			30.3 (27)

3.3 Other characteristics of public and private AITs

Table 3 indicates other characteristics of variables with three levels of public AITs and private AITs. The number of cows inseminated per day varied for the different AITs. They said that on average, they daily inseminated 1 to 5 cows (91.0%), 6 to 10 cows (7.9%), and 11 to 15 cows (1.1%). For transportation to the different farms, most AITs (65.2%) said they used a motorcycle) and few used a car (1.1%). The average distance to the farms varied for the different AITs: 1-10 km (28.1%), 11-20 km (25.8%), 21-30 km (13.5%), and 31-40 km (10.1%). Holstein-Friesian and Jersey were the most specific breeds of semen requested by the farmers and used by AITs, 52.8 and 42.7%, respectively.

In the sample AITs, more than half (66.3%) were using mini straws, less than a third (23.6%) of the AITs were using medium straws and 10.1% were using both straws (mini and medium). Over half (88.8%) of the sample AITs said they used a thermometer to check the temperature of the thawing water, 6.7% used their fingers and 4.5% didn't check the thawing temperature at all. 49.4% of the sample AITs used a stopwatch to check the thawing time, 25.8% used a counting method, and the remaining (24.7%) of the sample AITs didn't check the thawing time at all, they only estimated the thawing time. The site of semen deposition in the reproductive tract of the cow was mostly the cervix (92.1%). Among sample AITs, 64.0% said that the average annual percentage of cows that return on heat after the first AI service ranged between one and twenty. The call basis (74.2%) was the most common method of AI service delivery to dairy farmers. In sample AITs, 60.7% reported that they had on average monthly income from AI service of less than US$ 30, 32.6% had between US$ 30 and 50, and 6.7% had over US$ 50. Furthermore, 31.5% of the sample AITs said that they spent 26 to 50% of their time on livestock-related activities, whereas 20.2% spent 0 to 25%. Overall, 42.7 and 57.3% of public and private AITs, respectively, spent their time on livestock-related activities.

Table 3: Other characteristics of public and private AITs

Variable	Response	Status of AITs		*Chi-square*	Overall sample (n = 89)	
		Public (n = 31)	Private (n = 58)		% (n)	95% CI
		% (n)	% (n)			
Average monthly income from AI Service (US$)	<30	30.3 (27)	30.3 (27)	4.014^{ns}	60.7 (54)	50.3-70.2
	30 to 50	9.0 (8)	23.6 (21)		32.6 (29)	23.7-42.9
	>50	3.4 (3)	3.4 (3)		6.7 (6)	3.1-13.9
Methods of AI service delivery to dairy farmers	Stationed (farmers visit AIT office)	2.2 (2)	4.5 (4)	3.671^{ns}	6.7 (6)	3.1-13.9
	Daily run	4.5 (4)	14.6 (13)		19.1 (17)	12.3-28.5
	On call basis	36.0 (32)	38.2 (34)		74.2 (66)	64.2-82.1
Transportation system to deliver AI service	Stationed	0.0 (0)	5.6 (5)	16.813*	5.6 (5)	2.4-12.5
	On foot	5.6 (5)	12.4 (11)		18.0 (16)	11.4-27.2
	Bicycle	0.0 (0)	10.1 (9)		10.1 (9)	5.4-18.1
	Motorbike	37.1 (33)	28.1 (25)		65.2 (58)	54.8-74.3
	Car	0.0 (0)	1.1 (1)		1.1 (1)	0.2-6.1
Average number of cows inseminated per day	1-5	40.4 (36)	50.6 (45)	3.850^{ns}	91.0 (81)	83.3-95.4
	6-10	2.2 (2)	5.6 (5)		7.9 (7)	3.9-15.4
	11-15	0.0 (0)	1.1 (1)		1.1 (1)	0.2-6.1
Average annual percentage (%) of cows that return on heat after first AI service	1-20	24.7 (22)	39.3 (35)	1.089^{ns}	64.0 (57)	53.7-73.2
	21-40	13.5 (12)	13.5 (12)		27.0 (24)	18.8-37.0
	>40	4.5 (4)	4.5 (4)		9.0 (8)	4.6-16.8
Time spent on dairy activities (%)	0-25	7.9 (7)	12.4 (11)	2.428^{ns}	20.2 (18)	13.2-29.7
	26-50	14.6 (13)	16.9 (15)		31.5 (28)	22.8-41.7
	51-75	6.7 (6)	15.7 (14)		22.5 (20)	15.0-32.2
	76-100	13.5 (12)	12.4 (11)		25.8 (23)	17.9-35.8
Methods of checking the temperature of the thawing water	Use thermometer	36.0 (32)	52.8 (47)	1.9922^{ns}	88.8 (79)	80.5-93.8
	Use fingers	3.4 (3)	3.4 (3)		6.7 (6)	3.1-13.9
	Do not check at all	3.4 (3)	1.1 (1)		4.5 (4)	1.8-10.9
Methods of checking thawing time	Use a stopwatch	14.6 (13)	34.8 (31)	7.300*	49.4 (44)	39.3-59.6
	Only estimating	15.7 (14)	9.0 (8)		24.7 (22)	16.9-34.6
	Counting	12.4 (11)	13.5 (12)		25.8 (23)	17.9-35.8
Distance (Kms) cover daily to deliver AI service	1-10	10.1 (9)	18.0 (16)	4.683^{ns}	28.1 (25)	19.8-38.2
	11-20	7.9 (7)	18.0 (16)		25.8 (23)	17.9-35.8
	21-30	6.7 (6)	6.7 (6)		13.5 (12)	7.9-22.1
	31-40	6.7 (6)	3.4 (3)		10.1 (9)	5.4-18.1
	>40	11.2 (10)	11.2 (10)		22.5 (20)	15.0-32.2
Site of semen placement at AI	Cervix	1.1 (1)	4.5 (4)	2.740^{ns}	5.6 (5)	5.4-12.5
	Uterine body	41.6 (37)	50.6 (45)		92.1 (82)	84.6-96.1
	Both horns of uterus	0.0 (0)	2.2 (2)		2.2 (2)	0.6-7.8
Type of straw mostly used	Mini straws (0.25 ml)	28.1 (25)	38.2 (34)	0.793^{ns}	66.3 (59)	55.9-75.3
	Medium straws (0.5 ml)	9.0 (8)	14.6 (13)		23.6 (21)	15.9-33.4
	Both	5.6 (5)	4.5 (4)		10.1 (9)	5.4-18.1
Breed of semen requested by farmers	Jersey	20.2 (18)	22.5 (20)	1.972^{ns}	42.7 (38)	32.9-53.1
	Holstein-Friesian	21.3 (19)	31.5 (28)		52.8 (47)	42.5-62.9
	Sahiwal	0.0 (0)	2.2 (2)		2.2 (2)	0.6-7.8
	Fleckvieh	1.1 (1)	1.1 (1)		2.2 (2)	0.6-7.8
Reason for not attending all the AI calls	No time/high workload	12.4 (11)	7.9 (7)	11.360*	20.2 (18)	13.2-29.7
	Cost not compensated	12.4 (11)	28.1 (25)		40.4 (36)	30.9-50.8
	Lack of means of transport	5.6 (5)	9.0 (8)		14.6 (13)	8.7-23.4
	Large area of operation	12.4 (11)	12.4 (11)		24.7 (22)	16.9-34.6

*Significant at $p < 0.05$. NS: not significant at $p > 0.05$

Figure 1 shows the percentage of challenges in AI service as reported by the sample AITs. The y-axis represents the percentage of all 28 challenges, and the left of the x-axis shows the challenges that were raised by AITs. In decreasing order of probability of being considered a foremost challenge in AI service, the top four challenges were irregular and interruptions supply of liquid nitrogen and other AI consumables (95.5%), followed by the presence of uterine infections (metritis/endometritis) (95.5%), conception failure (91.0%), and poor herd management practices by farmers (76.4%). Overall, of the 28 challenges, 25.0% (n = 7) were raised by up 50.0% of the sample AITs as challenges in AI service delivery. These challenges belong to AI Centres and/or sub Centres (group 1 of challenges of AI service: irregular and interruptions supply of liquid nitrogen and other AI consumables (95.5%) and inappropriate storage of semen (59.6%), herd management (group 2 of challenges of AI service: poor herd management practice by farmers (76.4%), inadequate feed resources and suboptimal feeding practices (73.0%), and poor heat detection (60.7%), herd health in pre-, during, and post-partum periods (group 3 of challenges of AI service: uterine infections (95.5%), and AITs (group 4 of challenges of AI service: conception failure (91.0%).

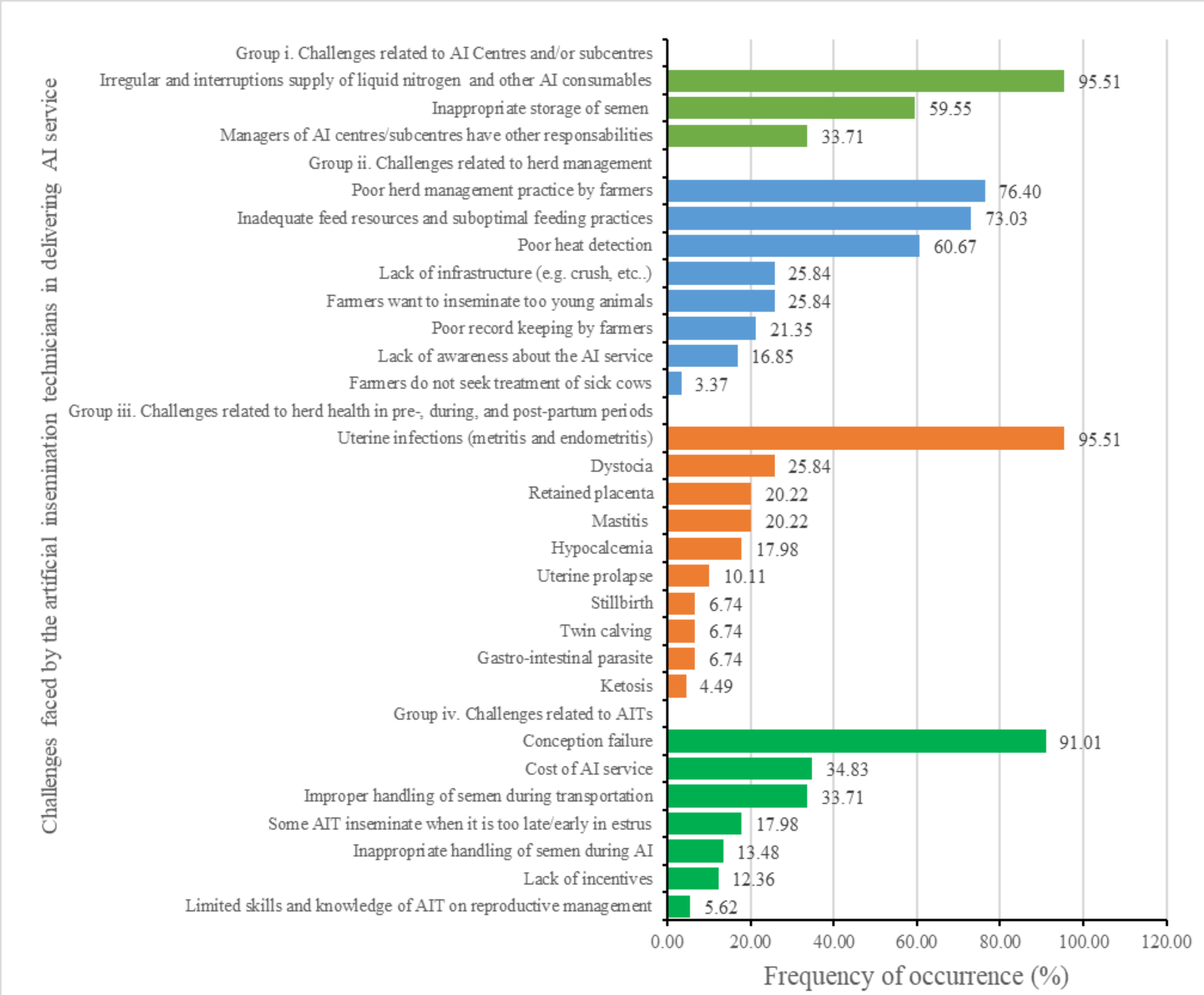

Fig 1: Challenges faced by the artificial insemination technicians in delivering AI service

Figure 2 shows the achievement of AITs in providing AI services to farmers in the last three years. From the current assessment, out of 89 sample AITs, 27.0% reported that access to credit was the highest achievement from providing AI service to dairy cattle, followed by agricultural investment (25.8%), access to health insurance (23.6%), and livestock investment (20.2%). The lowest achievements were organizing wedding ceremonies and the establishment of an agri-livestock inputs shop with 3.4% each. More (14.6%) public AITs had access to credit compared to private AITs (12.4%).

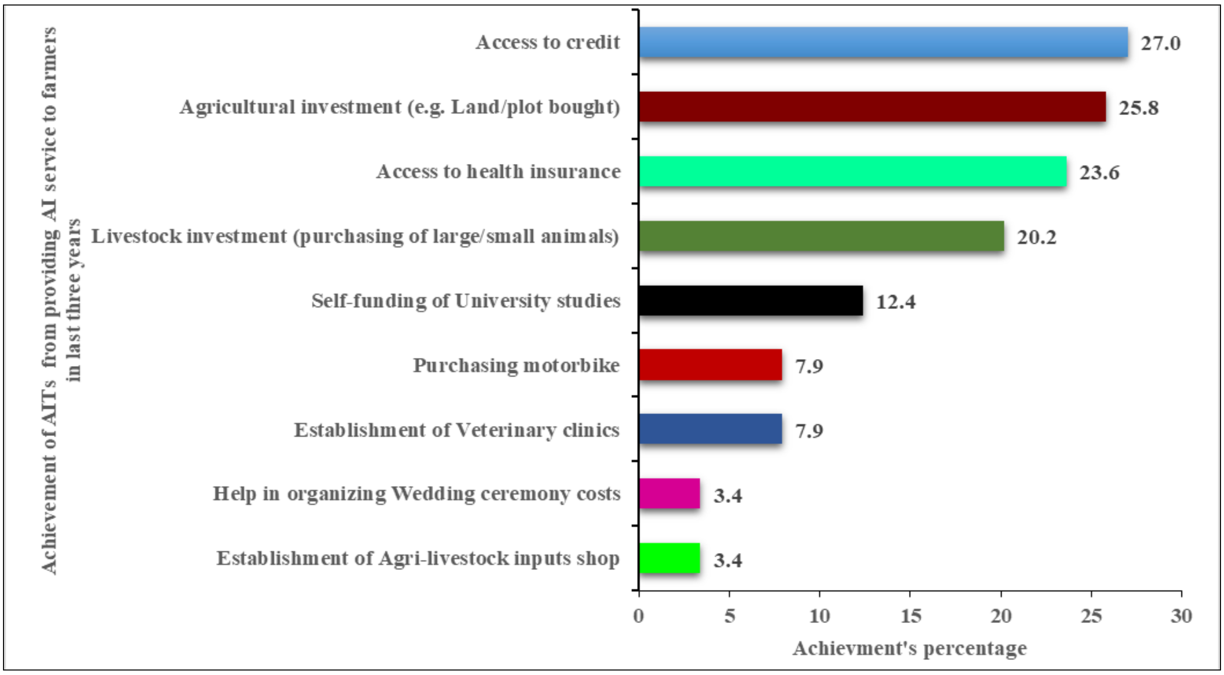

Fig 2: Achievement of AITs from providing AI service to farmers in the last three years

Figure 3 depicts the process and influential actors in AI inputs distribution and AI service delivery system models in Rwanda. Bovine AI in Rwanda is mediated by both public and private actors. There is one National Artificial Insemination Centre (NAIC). AI inputs such as AI kits, gloves, sheaths, lubricant, etc.) are imported. Semens are imported but also produced locally. For the latter, they are collected, evaluated, and packed at NAIC. Liquid nitrogen is locally produced. From NAIC, AI inputs are transported and distributed to AITs (AIS1), AI Centres (AIS2) and Sub Centres (AIS3). Any delay or factor causing the interruption of the distribution channel may cause an irregularity in AI service delivery. In that case, individual AIT (RAI1), AI Centres (RAI2), and/or AI sub Centres (RAI3) managers may get AI inputs from NAIC for their respective operational areas. AI inputs are distributed to public and private AITs (AIS4-AIS12, DAI1-DAI8) who act as service providers at the farm level (DAIS1 & 2). Bovine AI is a time-based activity. Thus, to avoid postponing the time of AI for the next cycle, and depending on the field conditions, AITs can get AI inputs from nearby AITs (AIS10 & 11).

A request for AI service by farmers is either directly oriented to public AIT (RAIS1) or private AIT (RAIS2) or through or indirectly via intermediates such as AI Centres and/or AI sub Centres (RAIS4) or even to farmers who have previously experienced the use of Bovine AI (adopters of AI technology) for breeding purposes (RIAI and DIAI). Those intermediate actors, especially AI Centres and/or AI sub Centres, may contact public or private AIT (RAIS5- RAIS8) available in the area to deliver AI services to farmers. If service is requested to AIT, whether public or private, the service is immediately provided (DAIS1- DAIS5). There are cases where the service provider contacted is not available at the time of the AI service. For example, a public AIT with a high workload may contact a private AIT to deliver AI services in his absence or vice vasa (RAIS9).

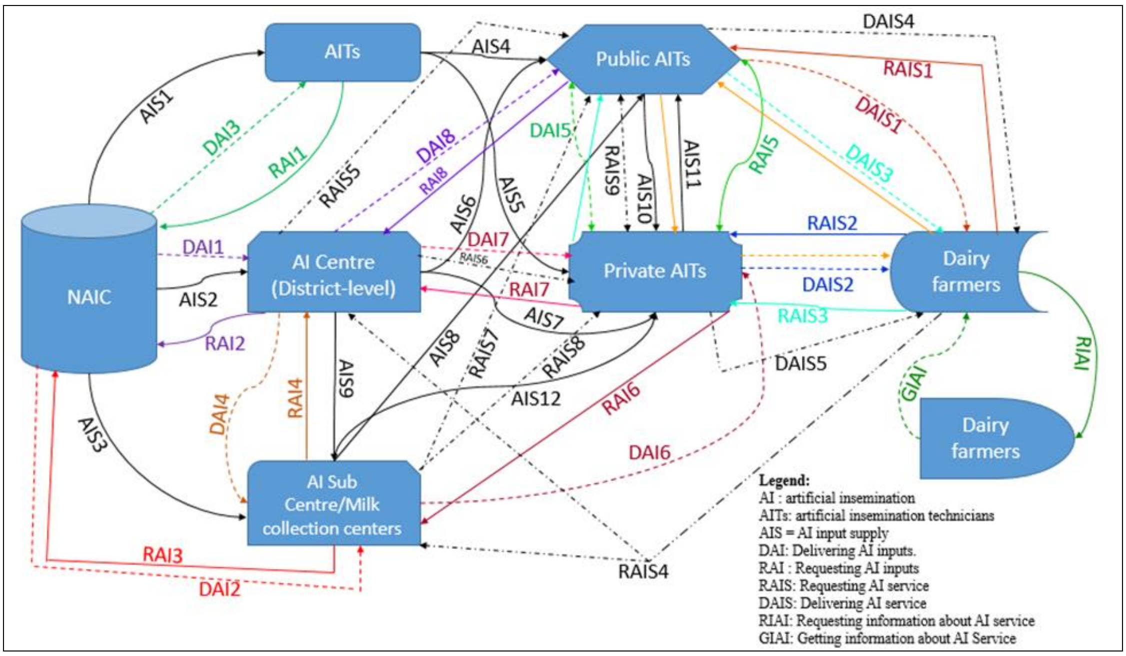

Fig 3: The process and influential actors in AI inputs distribution and AI service delivery system models in Rwanda

Table 4 presents the awareness of the time of AI service among the sample AITs. When cows or heifers show heat in the morning, most AITs (76.4%, 95% CI = 66.6-84.0) inseminate them the same day in the afternoon while few AITs (4.5%, 95% CI = 1.8-10.9) inseminate them as the AIT ordered. On the other hand, when cows or heifers show heat in the afternoon, 5.6% of the sample AITs inseminate them as a heat sign is seen on them, 4.5% as AIT ordered them, 76.4% in the morning of the next day, and 13.5% inseminate them the same day in the afternoon.

Table 4: Awareness of time of artificial insemination service in the study population (n = 89)

Time of AI service	When cows or heifers show heat at morning		When cows or heifers show heat at afternoon	
	% (n)	95% CI	% (n)	95% CI
As heat sign is seen on them	12.4 (11)	7.0-20.8	5.6 (5)	2.4-12.5
As AI technician ordered	4.5 (4)	1.8-10.9	4.5 (4)	1.8-10.9
Morning of the next day	6.7 (6)	3.1-13.9	76.4 (68)	66.6-84.0
The same day afternoon	76.4 (68)	66.6-84.0	13.5 (12)	7.9-22.1

*AI = artificial insemination, 95% CI = 95% confidence interval for proportion

Based on challenges experienced by AITs in delivering AI service to dairy cattle, sample AITs recommended some strategies on how to improve AI service in the future (Table 5). Therefore, the top five strategies that need special attention were: (i) NAIC to provide AI inputs regularly and without interruption to AI Centres and/or Sub Centres and AITs (100.0%, 95% CI = 95.9-100.0), (ii) initiate an incentive scheme model (in-kind and/or cash) to AITs best performers (97.8%, 95% CI = 92.2-99.4), (iii) improve general herd management, feeding and breeding practices by farmers (95.5%, 95% CI = 89.0-98.2), (iv) encourage the private sector to be involved in the AI service delivery (94.4%, 95% CI = 87.5-97.6), and (v) prepare a breeding guide for farmers on how and what traits to think of-when selecting semen for AI (93.3%, 95% CI = 86.2-96.9).

Table 5: Strategies to improve AI service in the future

Strategies to improve AI service in the future	Frequency	Percentage	95% CI
Provide AI inputs regularly and without interruption	89	100.0	95.9-100.0
Develop and establish a performance-based incentive system for AITs	87	97.8	92.2-99.4
Improve general herd management, feeding and breeding practices	85	95.5	89.0-98.2
Encourage the private sector to be involved in the AI service delivery	84	94.4	87.5-97.6
Prepare a breeding guide for farmers on how and what traits to think of when selecting semen for AI	83	93.3	86.1-96.9
Conduct AI technology utilization promotion campaign through electronic and print media, AI field days, and field demonstration in collaboration with different partners	80	89.9	81.9-97.6
Improve heat detection	75	84.3	76.6-91.3
Facilitate AITs to obtain means of transport	75	84.3	76.6-91.3
Develop compulsory further training and refresher courses for AITs	63	70.8	60.6-79.2
Develop minimum standards and standard operating procedures for AI to improve the procedures and quality of the AI service under Rwandan field conditions	60	67.4	57.1-76.3
Establish an on-farm information and communication technology (digital) platform for capturing data from farmers activities and giving feedback	59	66.3	55.9-75.3
Put in place a record-keeping system for genetic material and control mechanism for AI services including a quality-based pricing system for such services.	58	65.2	54.8-74.3

*95% CI: 95% confidence interval for percentage

4. Discussion

The present study was one of the first in Rwanda conducted to assess challenges associated with artificial insemination (AI) service delivery in dairy cattle. Thus, the results could be useful for the development of a wider network of dairy farmers (adopters and non-adopters of AI technology) and help give AITs, decision-makers, researchers, and different partners more control over their objectives for increasing animal productivity, profitability, and sustainability in the country. In the current study, the major challenges of the AI delivery system were stated in their order of importance. The overall most outstanding challenges of AI service delivery were irregular and interruptions supply of liquid nitrogen and other AI consumables (95.5%), high prevalence of uterine infections (metritis/endometritis) (95.5%), conception failure (91.0%), poor herd management practices by farmers (76.4%), inadequate feed resources and suboptimal feeding practices (73.0%), poor heat detection (60.1%), and inappropriate storage of semen (59.5%). These findings contradict those reported in Ethiopia by Woretaw *et al.* (2015), in which the overall most outstanding challenges of AI service reported were conception failure (38.3%), dystocia (32.5%), conception failure (20.0%), and unavailability of AITs (19.5%). Also, the current findings differ from the findings previously reported by [26] in Ethiopia, in which the most serious challenges of AI service were a shortage of AITs (31.3%), conception failure (18.0%), insufficient distribution of AI Centre in the country (16.7%), poor awareness creation in dairy farmers about the AI service (16.7%), high prevalence of diseases (15.6%), deficiency of AI inputs (10.4%), and inadequate budg*et al*location (8.3%). This dissimilarity may be due to differences in awareness of the communities about AI technology, agro-ecological zones, production systems, and attention given to AI technology by responsible entities [25]. This indicates that decision-makers need to give proper attention to AI technology to improve the situation of AI activity in the study areas and also at the national level and encourage the private sector and non-government organizations to be involved in the AI service sector, but with strict control by an active breeding policy. This can help improve AI technology dissemination and accessibility.

In the present study, out of 89 respondents, 95.5% reported irregular and interruptions of liquid nitrogen and other AI consumables as a major challenge encountered at AI Centres and/or Sub Centres. This indicates that those AI inputs ready to be distributed to AI service providers are not always available at AI Centres and/or Sub Centres; which may result in low quality of frozen semen and inappropriate AI technique during service delivery. This finding corroborates those reported by Menta (2019), in which 71.1% of respondents revealed a shortage of liquid nitrogen and other AI inputs as a constraint to AI service delivery. In contrast, the finding disagrees with those previously reported in some studies [8, 18, 26], where 33.3%, 30.6%, and 21.4% of respondents, respectively, claimed liquid nitrogen and other AI input shortages in their operational areas. The irregular and interruption in supplying liquid nitrogen and other AI consumables reported by the sampled AITs can be explained as resulting from poor production potential and a limited number of liquid nitrogen plants, low involvement of private institutions/entities in supplying AI inputs, and accessibility to AI Centres and/or Sub Centres. This is because less than half of the sampled AITs (44.9%) judged the overall availability of inputs, including liquid nitrogen and other consumables, as poor. Also, large operational areas and lack of means of transport were reported by 24.7% and 14.6% of AITs, respectively, as key reasons for not attending all the AI calls. Furthermore, in their studies, Ibrahim *et al*. (2014) and Juneyid *et al*. (2017) reported some challenges associated with the shortage supply of AI inputs such as the long distance to be covered by AITs from their respective operational areas to nearby AI Centres and/or Sub Centres, as well as insufficient budg*et al*location and poor collaboration of government institutions with the private sector in AI service delivery.

The study further revealed inappropriate storage of semen at AI Centres and/or Sub Centres. Out of 89 AITs interviewed, 59.6% reported inappropriate storage of semen, which might be explained by the inadequate quantity or shortage of liquid nitrogen produced and distributed by NAIC to different AI Centres and/or Sub Centres and by the fact that managers of AI Centres/Sub Centres have other duties and responsibilities. This is associated with reduced motility and viability of the semen [3] which results in conception failure. Therefore, handling of frozen semen during transportation and management during storage need to be upgraded to achieve an improved and high quality of semen to be used during AI service. Also, AI Centres and/or Sub Centres should be open throughout the day time and on weekends as well [28] to facilitate an easier access to AI inputs.

The current study revealed that general farm management practices impact the success rate of bovine AI. Poor herd management is a major constraint to bovine AI, as indicated by 76.4% of respondents. This shows that appropriate animal husbandry best practices for optimum production and efficient reproduction are not well adopted by farmers. Although record-keeping is a farm management practice/decision influencing the success rate of bovine AI; a previous study conducted by Chatikobo *et al*. (2009) in Rwanda reported that 94.9% of farmers don’t keep records and the few records kept were incomplete, inaccurate, and not updated. Therefore, record keeping has been associated with the conception rate. In their study, Nishimwe *et al*. (2015) showed that the pregnancy rate of 66% and 42% was observed in cows from farmers who keep records and in farmers who do not keep records, respectively [10]. This demonstrates that record keeping is a very crucial management practice in dairy farm sustainability and profitability. In their study, Zwart *et al*. (1996) observed that insufficient AI-recording makes it difficult to conduct proper AI work and good management of reproductive performance. In line with this observation, Philipsson and Jorjani (2009) reported that with the inefficiency of accurate registration of key breeding parameters, it is completely not possible to use semen from the best bulls to the best cows. Hence, it recommends that smallholder farmers should be encouraged through extension services and training to practice record-keeping for their animals. Moreover, the low conception rate raised by AITs could be explained as resulting from intrinsic and extrinsic factors such as poor semen quality due to shortage of liquid nitrogen supply and poor semen handling practices, reproductive diseases, absence of incentives for AITs, poor heat detection, and improper timing of AI [8].

The motivation of AIT as far as AI service is concerned, may be influenced by income generated by AI activity, workload and other incentives offered to AITs. The majority of AITs (91.0%) inseminate at least 1 to 5 cows per day at an average price of US$ 3.5 when conventional semen is used. This finding was similar to that observed in Kenya, but the price was higher than the price (US$ 0.80) reported in India and lower than some previously reported prices in Tanzania (US$ 11.2), and Nicaragua (US$ 10.0) [32]. This is an indication that the average costs vary greatly across the countries and are more likely influenced by the population from which the sires were selected. Generally, semen imported is priced higher than that produced locally. The difference in a single AI service between countries could be due to different national policies governing the use of imported semen, prevailing exchange rates, and the number of actors involved in the distribution chain of AI inputs [32, 33].

In most cases, AITs reach farms after running a distance of 18.8 km on a motorcycle (65.2%). Although AITs offer AI services even on weekends and holidays (92.1%), the average monthly income from AI activity is still low (less than US$30) as indicated by 60.7% of respondents. The cost of AI service remains a limiting factor to AI, as demonstrated by 34.8% of respondents. This is an indication that AI as an isolated activity can not generate enough revenue to survive. This is in agreement with the findings of Valeta and Boelema (2015) in Zambia, who reported that AI service provision is not viable due to low numbers of smallholder farmers using AI. Thus, this must be increased to a level that will make it economically viable for any AI service provider to embark on AI service provision as a business. Consequently, to satisfy their households (made up of 4.3±0.2 members per household) needs, the majority of AITs (64.0%) were engaged in income-generating activities other than AI and reduced time spent on AI activities and livestock in general. This suggests the need for developing and establishing a performance-based incentive system for AITs.

The study also revealed that more private AITs had a long distance to deliver AI services and more monthly income than public AITs. This indicates that private AITs stand a great chance to provide more business-oriented and efficient services to complement public AITs, whose services are often very limited in coverage and, most cases, they are engaged in non-related livestock activities. The current findings are supported by results from previous studies conducted in Zambia [19] and Ethiopia [34] indicating that the private sector AI business model is the most efficient business model than Government and Cooperative AI business models. This is probably because the private AITs, usually animal health service providers, also include AI as one of their offerings. Most of them have their own transport and can reach the farmsteads with the farmer paying stand-alone travel expenses in addition to the AI service fee [35].

The distance in hours that the AITs travelled to get the AI inputs from the AI Centre was assessed. AITs living near the AI centre have a location advantage and can contact the AI centre manager more easily than those who live in more distant areas. In line with this, the nearest and farthest farms are located at 0.1 and 60.0 kilometres, respectively. This may indicate that the farthest farmers have to spend more time and money on getting an AIT, thus making the service less accessible and more expensive, especially on transport fees. It can also indicate that the sample AITs cover a wide area with many farmers in mountainous areas, hence inhibiting prompt access to remote areas [22] which poses a challenge in terms of timely insemination. There will be a need to bridge the gap by training new AITs and equipping them and posted in areas where the AI service is not adequately and efficiently reaching the dairy farming community.

In the present study, inadequate feed resources and suboptimal feeding practices were raised as impeding AI service delivery. This finding agrees with that reported by Bereda *et al*. (2014) in which 40.8% of respondents classify feed shortages as one of the major constraints opposing dairy farming. Inappropriate feeding practices at the farm level may be attributed to the shortage of land for cultivation of improved forage, limited materials, knowledge and skills for conservation of seasonally available feeds [36]. In their study, Chatikobo *et al*. (2009) reported that among farmers who practise zero-grazing in the Eastern province of Rwanda; only 10.0% provide commercial dairy meals. Also, Nyabinwa *et al*. (2021) observed that the dominant feeding practice was Napier grass (*Pennisetum purpureum*) fodder with limited supplementation. These inadequate and suboptimal feeding practices were linked to reproductive diseases which reduce the conception rate. In their study, Nyabinwa *et al*. (2021) observed that endometritis results from unhygienic cowshed, selective feeding practices for the breeds, and a low level of feed supplementation. The current finding should inform AITs and animal health service providers that awareness and education targeted to uterine infections is needed to improve the reproductive performance of dairy cows. Similarly, the limited feed resources can be managed through intercropping Napier grass (*Pennisetum purpureum*) with legume forages and training dairy producers in a low-cost and simple way of conserving grass-legume pastures as silage or hay. This might improve fodder supplies for the dairy herds.

The study further revealed that the major diseases that were interfering with the proper and successful accomplishment of the AI service were uterine infections, dystocia, retained placenta, mastitis, gastro-intestinal parasites, ketosis, hypocalcemia, uterine prolapse, stillbirth, twin calving. From this list and per the classification of postpartum clinical diseases of dairy cows previously described by Twagirayezu *et al*. (2021), uterine diseases and calving related problems were the highest and lowest impeding the delivery of AI service, respectively. This could be linked to do-it-yourself interventions by farmers, such as self-calving assistance without seeking help from animal health service providers, non-use of gloves, providing unhygienic assistance during calving, and inadequate feeding practices in the transition period. These malpractices are mostly associated with physical trauma and bacterial contamination of the female genital reproductive tract, and negative energy and protein balance of the cows [39, 40, 41], and uterine diseases, non-uterine diseases, and calving problems may develop subsequently [37, 38, 42] and have a negative impact on reproductive performance of dairy cows [43]. This observation would suggest limited knowledge of herd health in pre-, during, and post-partum periods among farmers, which implies attention to managing these diseases is likely needed at the farm level. Corroborating the current observation are the findings of Twagirayezu *et al*. (2021) and Nyabinwa *et al*. (2020).

In the present study, 27.0% of the sample AITs had access to credit services and 73.0 had no access. This finding could be explained by the challenges faced by AITs in delivering AI services to dairy farmers. Therefore, access to credit is one approach not only to facilitating AITs to invest in reliable transport that would improve their mobility in mountainous operational areas and efficiency in responding to all AI calls, but also investing in other agri-livestock businesses. Thus, there is a need to improve access of AITs to financial services.

The current findings show that 89.9% of the sample AITs attended AI service after being called by farmers. This indicates that AITs are often dependent on case-based interventions where an AIT waits and responds only to calls from farmers with cow/heifer (s) on heat, and his or her role stops at inseminating the cow/heifer on heat. This demonstrates that dairy farmers are usually not well supported by AI service providers [45]. In their study, Nwata *et al*. (2011) suggested a herd-health monitoring programme where regularly scheduled visits should be made to holistically assess and give advice or interventions on the health, welfare and productivity of dairy herds. Another study by Omondi *et al*. (2016) reported that farmers prefer an AI service that includes follow-ups to ensure conception occurs. This demonstrates that low conception rates and numerous repeats are among the reasons supporting poor AI adoption rates. Therefore, to overcome some of the challenges that have so far impeded the efficient dissemination and accessibility of AI technology among dairy farmers, the herd-health monitoring programme model can be adapted and adopted by AI service providers for better and more timely service delivery at farmers' doorsteps for improved health, productivity, profitability, and sustainability of dairy herds in Rwanda. This is supported by the findings reported in Columbia [48], where cooperation between dairy farmers and veterinarians was beneficial for preventing and controlling disease on farms. Moreover, Nyabinwa *et al*. (2020) in Rwanda and Tayebwa *et al*. (2015) in Uganda found that improved extension service and advisory support in pre-, during-, and post-partum periods are the most effective strategies to manage endometritis in dairy herds. Therefore, despite the decline in the demand for AI services in recent years, dairy farmers are willing to use AI if the quality of the services is improved.

Regarding the possible strategies to improve AI service in the future, availing AI inputs regularly and without interruption (100.0%), developing and establish a performance based incentive system to AITs (97.8%), improving general herd management, feeding and breeding practices (95.5%), encouraging private sector to be involved in the AI service delivery (94.4%), preparing a breeding guide for farmers on how and what traits to think of-when selecting semen for AI (93.3%), conducting AI technology utilization promotion campaign through electronic and print media, AI field days, and field demonstration in collaboration with different partners (89.9%), improving heat detection (84.3%), facilitating AITs to obtain means of transport (84.3%), developing compulsory further training and refresher courses for AITs (70.8%), developing a minimum standards and standard operating procedures for AI to improve the procedures and quality of the AI service under Rwandan field conditions (67.4%), establishing an on-farm information and communication technology (digital) platform of capturing data from farmers activities and giving feedback (66.3%), and establishing a record keeping system for genetic material and control mechanism for AI services including a quality based pricing system for such services (65.2%) were the possible strategies suggested by AITs. This indicates that AI service provision should be improved and active breeding policy and strategy should be given the highest priority for increased productivity, profitability, and sustainability of the dairy herds. These findings are in agreement with those reported by Ibrahim *et al*. (2014) and Ndambi *et al*. (2017).

5. Conclusion

Irregular and interruptions supply of liquid nitrogen and other AI consumables, the high prevalence of uterine infections (metritis/endometritis), poor herd management practices by the farmer, and conception failure are the overall most outstanding challenges associated with the AI service delivery system. There is a need to avail AI inputs regularly and without interruption, initiate an incentive scheme model for AITs best performers, and improve general herd management, feeding and breeding practices. These strategies, among others, should be considered for prioritisation in extension services and research to overcome the challenges that have so far impeded efficient dissemination and accessibility of AI technology among dairy farmers. This could improve AI service delivery, increase productivity, profitability, and sustainability of the dairy herds. Further study should be carried out taking into consideration this baseline information to point out the constraints to the improvement of AI services in Rwanda and the profitability of the AI technology.

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