A One Health approach towards artificial insemination in cattle in Tanga, Tanzania

Farmers' perceptions and attitudes and AI technicians' practices

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Abstract

Background: Due to the growing African population, the demand for nutrient-rich products of animal origin increases. The Tanzanian government has developed a strategy to transform the agricultural sector into a modern and highly productive sector and one of the objectives is to improve livestock production through upgrading of local breeds by means of artificial insemination (AI).
Objectives: In light of this, one of the aims of this study was to evaluate the AI program in Tanga city. In addition, health status and working procedures of AI technicians were evaluated to identify risk factors of contracting a zoonosis or getting injured and to determine welfare issues to cattle.
Methods: A cross-sectional, questionnaire-based study was performed in Tanga city and surrounding area from May 2018 until June 2018. Both farmers and AI technicians were invited to participate. A multinomial regression analysis was performed
Results: Predictors of adoption of AI are distance to city center, owning less cattle, mentioning less disadvantages of AI and less farming experience. The most important disadvantage mentioned most often was repeat breeding, which was also the reason for most farmers to stop using AI. There are some minor safety hazards to AI technicians but no risk factors could be determined due to the small sample size. No clear association could be found between symptoms of zoonotic infection and hygienic measures.
Conclusion: The results from this study indicate that the AI program in Tanga is not very successful and most likely even decreases production due to the many reports of repeat breeding. Furthermore, accessibility of AI services is an obstacle for farmers to adopt AI and this needs improvement.

Background

The agricultural sector is of key importance to Tanzania's national economy; approximately one third of the gross domestic product (GDP) is accounted for by agriculture but a decline has been noted (Covarrubias, Nsiima et al. 2012). One-fifth of this GDP originates from the livestock sector and most cattle farmers are subsistence-oriented smallholder farmers (Covarrubias, Nsiima et al. 2012). For the period of 2016-2025 the Agricultural Sector Development Strategy (ASDS) has been developed by the government to guide policies in transforming the agricultural sector into a modern, commercial and high productive market which leads to achieving food security and poverty reduction (FAO 2017). The driving factor for this is not just national economic growth but also continental population growth since the predicted enormous population growth in Africa demands more and high quality food sources (Hall, Dawson et al. 2017). One of the ASDS objectives is to improve livestock production through increasing the access to artificial insemination (AI) for upgrading of local breeds and increasing the number of insemination facilities and maintenance of these facilities (FAO 2017). In light of this objective, an active artificial insemination program has been set up in the Tanga region, Tanzania in 2015 which will end in 2020. This program (Public-Private Partnership Artificial Insemination Delivery, PAID) is funded by the Bill and Melinda Gates Foundation but jointly implemented by various organisations such as Animal Breeding East-Africa and carried out in several regions of both Tanzania and Ethiopia.

The use of AI as a method of reproduction in dairy cattle has been of great economic benefit through genetic improvement of milk production, the control of venereal diseases, the reduction of lethal genes and control of inbreeding (Vishwanath 2003). Bovine diseases in which breeding is the most important route of transmission are venereal campylobacteriosis and trichomoniasis. Although surveillance or monitoring of these diseases is lacking, it is assumed that the diseases are widespread in most developing countries (Mshelia, Amin et al. 2010, Michi, Favetto et al. 2016). Studies from Nigeria showed a venereal campylobacteriosis herd-level prevalence of 22.2%-25.5% (Mshelia, Amin et al. 2012, Mai, Irons et al. 2013). These diseases cause reproductive losses in terms of abortions, reduced conception rates and increased calving intervals in cows which can lead to losses in beef herds of 30%-60% of gross margin per cow for venereal campylobacteriosis while trichomoniasis causes a 5%-35% reduction in financial returns per cow (Hum 1996, Michi, Favetto et al. 2016). AI could certainly be a technique to aid in reducing the transmission of these venereal diseases given that semen is tested thoroughly for the pathogens after collection. It is however questionable whether this assumption is always met under field circumstances in developing countries. Another benefit of AI is the possibility to gain from genetic improvements elsewhere and adopt them to create offspring most fitted for the specific environment while also breeding for production traits. Also, the costs of keeping a bull for natural breeding and missed income due to the bull occupying a milking cows place are eliminated when adopting AI. Lastly, the responsibility of proper record keeping is shared by farmer and the administrative section of the AI organisation, which makes record keeping easier and verifiable. Caution has to be taken in selecting for yield traits only, because there is a negative correlation between yield traits and fertility traits (Vishwanath 2003, Rodriguez-Martinez 2012).

Currently there are 600 dairy cattle farmers adopting artificial insemination and another 1000 not adopting artificial insemination in the Tanga district. Results from a previous study among Irish farmers indicate several personal characteristics and structural farm factors to be associated with adoption of AI (Howley, O. Donoghue et al. 2012). Nkya et al. observed that the frequency of AI use depends on the distance from town (Nkya, Kessy et al. 2007). A study conducted in Kenya found that among others, price of AI, years of farming experience, access to dairy hub, proportion of milk sold per day, education and intensification level all affected the preference of farmers for AI (Omondi, Zander et al. 2017). One could theorize that with increased sale of milk and a higher intensification level, a farmer has more financial resources to invest in a new technology and the lower the costs of that new technology the more attractive it becomes. For one litre of fresh milk sold, Tanzanian farmers earn between 0.28 and 0.56 USD (exchange rate of 2500 TSH for 1 USD), depending on whether they sell it themselves on the local market or sell it to the dairy processing plant. The price for one insemination ranges from 4.80-10 USD, with an average of 8 USD per insemination. Depending on the distance from the AI centre it is somewhat more or less. In Tanzania, agricultural extension officers are employed by the government to equip farmers with knowledge and skills on agriculture and livestock keeping. These extension officers can also be trained as AI technicians through the National Artificial Insemination Centre (NAIC), thus becoming public AI technicians. Besides these public AI technicians there are also private AI technicians who work as independent entrepreneurs or are employed by NGO's. Government extension officers receive a fixed salary, while private AI technicians only rely on the net profit they make per insemination. The cost of a straw varies between 1.8-3.6 USD and materials needed, including fuel for within a 10km radius, are estimated at 2.8 USD. With a price of 8 USD per insemination, 1.6-3.4 USD would remain as income for the AI technician. To the best of our knowledge, no evaluation of AI programmes in cattle has been conducted in the Tanga region, which keeps us ignorant of whether these programmes are effectively increasing production and of pitfalls and obstacles in implementing the programmes. It is therefore important to investigate factors affecting the adoption of AI and farmers' perceptions in order to evaluate the adoption of AI. With the results, strategies can be formulated and implemented to tackle obstacles encountered and together with farmers strive to find the best way to provide AI services and encourage farmers to adopt AI. Therefore, the first aim of this study is to investigate farmers' attitudes and perceptions towards the AI program and determine factors affecting adoption of AI.

AI technicians are working in close contact with animals and are thus at an occupational risk for zoonoses. Several zoonoses are known to be present in cattle in Tanzania, of which Brucellosis, Tuberculosis, Leptospirosis and Q-fever are of high relevance for veterinary professionals (Swai and Schoonman 2012, Olea-Popelka, Muwonge et al. 2016). These zoonoses are easily transmitted through inhalation or ingestion of (aerosolized) excreta of infected animals. With good personal protection equipment and hygienic practices, technicians could lower the risk of getting infected which is of paramount importance since, in general, diagnosing and treating diseases in humans in sub-Saharan Africa is not self-evident. So far, no study has investigated the occurrence of zoonoses and related risk factors in AI technicians in the Tanga region. One of the aims of this study is to fill this gap. Safety hazards should also be taken into account when assessing health hazards to AI technicians. Stress in an animal can be caused by close contact between human and animal and/or by separation from the herd when the animal is not habituated. A stressed animal is more likely to lash out, resulting in injuring its handler. If an animal is restrained very thoroughly, the animal might have no possibility to cause injury to the AI technician, but at the same time the animals' welfare could be at stake. This is an unexplored area in both western and resource-limited countries and thus it is good to list common handling and restraining approaches for AI in the Tanga district, Tanzania, discuss how these approaches affect welfare of the cow and how the approaches relate to safety of AI technicians. With the results, problems regarding animal welfare and/or human health can be uncovered and improvements in training and protocols for AI technicians may be made to help prevent these problems in the future.

The current study was conducted in the Tanga district, Tanzania. As mentioned above, the health of animals and humans is closely linked, not only through zoonoses but in developing countries certainly also through the fact that human health is improved when nutrient-rich products of animal origin can be consumed and this requires healthy animals. Apart from this, owning animals in Tanzania greatly contributes to the social status, the way of living revolves around the animals. This knowledge led to the use of a One Health approach which involves four research goals: 1) Investigate current opinions, perceptions and attitudes of farmers towards artificial insemination of cattle and determine factors affecting adoption of artificial insemination, 2) Determine health hazards and risk factors for AI technicians, 3) Determine welfare hazards to cattle presented for insemination, 4) Determine relation between safety of AI technicians and welfare of cattle.

Materials and methods

Study design

A cross-sectional, questionnaire-based study was performed in Tanga city and surrounding area from May 2018 until June 2018. Tanga is situated on the north eastern coast of Tanzania, 5^{o} S 39^{o} E at an altitude of 66 metres above sea level. The annual rainfall ranges from 1200-1400 mm and is divided in a long rain season from March-May and a short rain season from November-December. Hereafter the dry season starts with little rainfall. Daily temperatures range from 20℃-32℃ and relative humidity is 55%-90%.

The study consisted of two parts, one regarding interviewing farmers and the other part consisted of interviewing AI technicians. From 837 farmers digitally registered as adopting artificial insemination in the Tanga district, 60 farmers were randomly selected to be included in the study. Another 60 farmers not adopting AI were selected and invited to participate by the head of the PAID project in Tanga. These farmers were selected based on availability and acquaintance with the head of the project. All farmers were called beforehand, explained the purpose of the study and after verbal consent were asked for a date and time to be interviewed. The interviews mostly took place at the farmers' home and was carried out by one of the two investigators together with a translator, which was either a local AI technician or the head of the project in Tanga. Before carrying out the actual interviews, the interview was pretested on 5 farmers selected by the head of the project and adjusted afterwards. For a written version of the farmers' interview see Supplementary Methods S1. The interview consisted of several sociodemographic questions, followed by general questions about the farm and finished with several questions regarding perception of AI and whether the farmer adopted AI on his farm at the moment. The answers were written down and transferred to a spreadsheet in Excel Office16 afterwards.

The dependent variable in the farmers' dataset was 'type of farmer' divided into the following categories: AI, non-AI or drop-out. AI meaning that the farmer was adopting AI at the time of the interview, non-AI group meaning that farmers had never adopted AI and drop-out meaning that the farmer had adopted AI in the past at least once but was not adopting AI anymore at the time of the interview. Predictors were gender, age, level of education, farming experience, having a job besides farming, having a successor, the type of farming system, distance to city centre, number of cows milked, litres of milk per cow/day and price per litre milk sold, having access to information on AI, number of benefits of AI mentioned, number of disadvantages of AI mentioned and discussing AI with other farmers.

Twenty-one AI technicians were invited to participate in this study. They were selected based on availability. When an AI technician visited the office in Tanga for supplies and materials, they were invited and in most cases interviewed at the office. Before starting the actual interviews, the questions from the interview were discussed with 10 AI technicians in a group discussion specifically focussing on cultural appropriateness to ask certain questions regarding health issues. After adjustments, the twenty-two AI technicians were interviewed and the answers were written down and transferred to a spreadsheet in Excel Office16 afterwards. For a written version of the AI technicians' interview see Supplementary Methods S2. The interview consisted of several sociodemographic questions, followed by questions related to health and symptoms like fever, skin rash. The next part of the interview included questions about hygienic practices while at work and lastly some substantive questions regarding heat detection and working methods were asked.

The dependent variables in the AI technicians' dataset were presence of injury, skin rash, fever, skin ulcerations, vomiting, coughing, diarrhoea, coughing blood, having had fertility problems and having had a zoonotic disease (dichotomous) with 'time needed to inseminate an animal', 'years employed as AI technician', 'level of education', 'separating animal from herd' and 'method of fixating animal' as predictors for presence of injury and the hygienic precautions of wearing protective clothing, footwear, washing hands before and after work, disinfecting hands before and after work, washing hands before handling food/eating and wearing gloves on both hands while working as predictors for the various symptoms mentioned and having had a zoonotic disease.

Data transformation, cleaning and statistical analyses were carried out in IBM SPSS Statistics 25. Due to the small sample size of AI technicians, no useful statistical analyses could be run on this dataset. For the farmers' dataset, multinomial logistic regression analysis was chosen because of more than two categories of the dependent variable and multiple continuous and nominal independent variables. With this analysis, missing values are automatically excluded listwise.

Hypotheses

It is hypothesised that greater distance from the city centre, lower income from milk (either due to lower milk production or lower income price per litre) inaccessibility to information regarding AI, lower level of education, higher age of farmer and longer farming experience, having a job besides farming, not having a successor for the farm, pastoralism as farming system, increased number of disadvantages of AI and not discussing AI with other farmers will be factors that influence adoption of artificial insemination negatively.

Depending upon the occurrence of zoonotic disease in AI technicians, it is expected that not adhering to various hygienic precautions increases the risk of contracting a zoonotic disease/showing symptoms. It is expected that there will be a negative correlation between safety to AI technicians and welfare to cattle meaning that injury in AI technicians is associated with less restrictive fixation of animals, with separating cows from the herd to inseminate them, with less experience of the AI technician and/or with taking longer to perform the insemination.

Results

Farmers perceptions and attitudes towards AI

Of the 120 farmers approached, 100 were interviewed. Among the reasons for unavailability of the remaining 20 farmers were inaccessibility to the farm location, unknown farmers and location, doubles and farmers who did not have time to be interviewed. Of the 100 interviewed farmers, 35 were adopting AI at the moment (AI group), 35 had at some point in the past used AI but did not adopt it anymore (drop-out group) and 22 had never used AI (non-AI group). Eight farmers used both AI and natural breeding, either on separate farms, on separate animals or switched from AI to natural breeding after a certain number of inseminations in a particular animal (mixed group). These 8 mixed farmers were excluded from analyses due to unclear interpretation of results from this group and therefore the final number of respondents was 92.

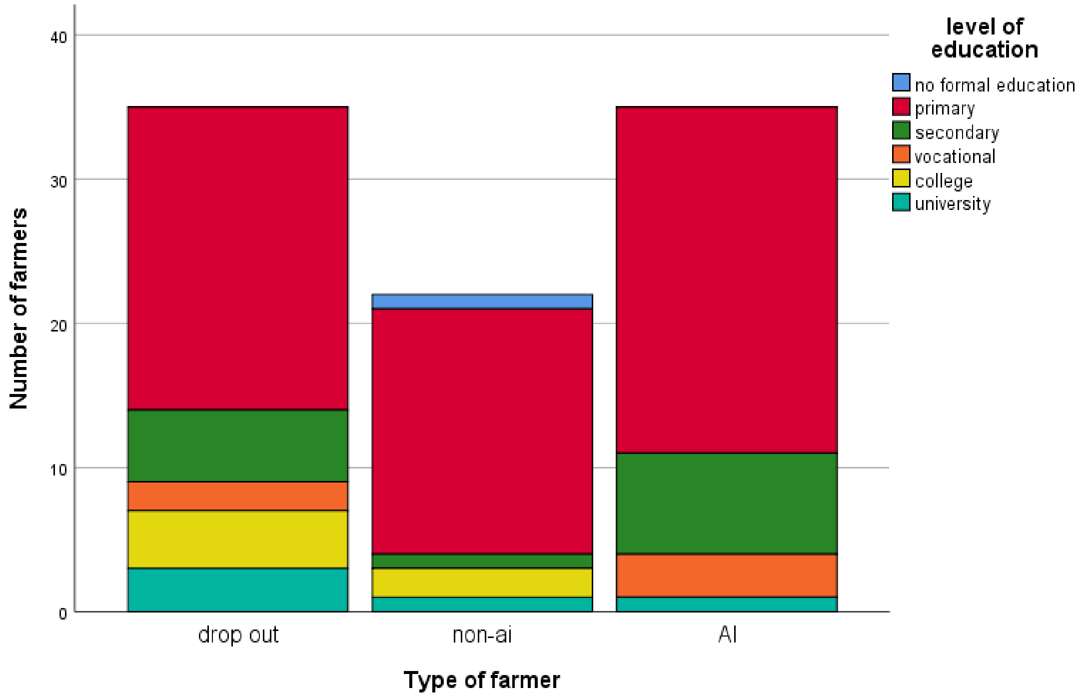

Figure 1: Level of education across farmer groups

Respondents residences were located in 31 wards which were urban wards as well as peri-urban and rural wards. The rural wards were overrepresented in the non-AI group, but as mentioned before the non-AI farmers were not randomly selected. Of all the interviews, 91% was done in Swahili with a local AI technician as translator. Nine percent of the interviews were completely performed in English, without any interference from a translator. Twenty-eight percent of the respondents were female and 72% were male. The proportion of female farmers was remarkably higher in the AI group than the other two groups. In the AI group 43% of the farmers was female while in the drop-out group this was 23% and in the non-AI group it was 13.6%. The mean distance to the city center (with AI center) was 13 kilometers (range: 1-45km) with about half of the farmers living within a 10 km radius and the other half between 11-45km. The mean age was 49 years (20-90 years range) and the mean farming experience is 16 years (0,5-57 years). Sixty-seven percent of the farmers had only finished primary school, 14% had finished secondary school, while 5%, 7% and 5% had finished vocational school, college and university respectively. One farmer reported not to have had any formal education. The level of education represented most across all groups was primary level. Interestingly, the proportion of farmers with an education higher than primary level was highest in the drop-out group and also in the AI group compared to the non-AI group (figure 1).

As much as two third of all farmers interviewed, had one or more jobs beside livestock keeping and on average those farmers spent about 53% of their time on their other jobs. Eighty-seven percent of the farmers has a successor. Two farmers were unsure about having a successor and the other 11% did not have a successor.

More than half of all the farmers (54%) practiced the pastoral farming system while 21% practiced zero-grazing and another 21% practiced a mix of two systems, either between groups of cows or between seasons. Only 4% of the farmers practiced restricted grazing. Most of the 'zero-grazing' farms are within the AI group and the pastoral system represents most of the farms in the non-AI group.

Ninety percent of the farmers answered that they had access to information on AI, only 10% mentioned they did not have access. When asked about discussing the topic of AI with other farmers, 76% answered that they did indeed discuss this topic with other farmers, while 24% did not. Of those farmers who did discuss the topic of AI, around 25% did this occasionally (1-3 times/year), another 25% discussed every three months to every month (4-12 times/year) and the remaining farmers discussed between once every month to every day. Five farmers could not answer this question and were therefore marked as missing values. On average a farmer milked 6 cows at the time of asking (range: 1-210) with most of the farmers milking between 1-5 cows (78%). The average milk production per cow per day was 6 liters (range: 0,5-14L).

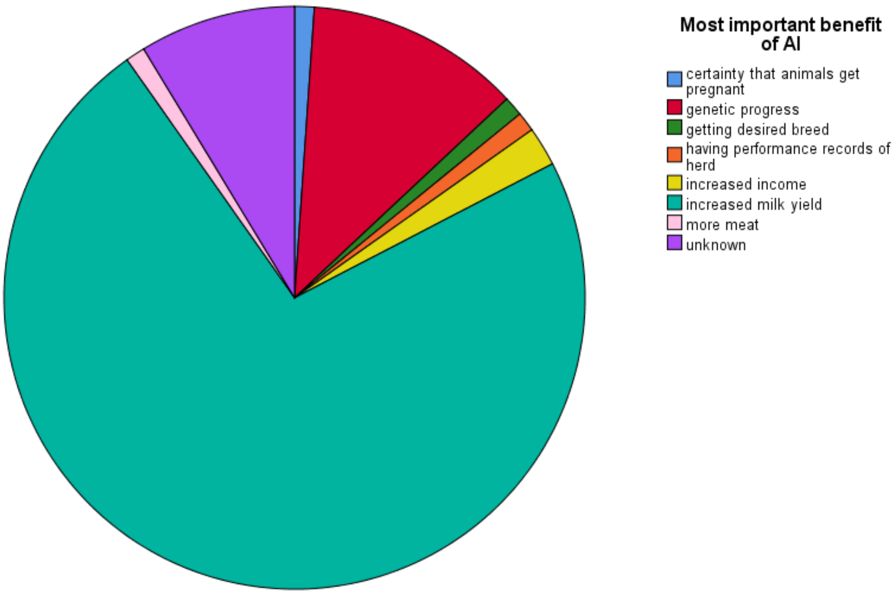

Figure 2: Distribution of most important benefit of AI mentioned by farmers

Seven respondents (8%) did not know any benefits of AI. Of the remaining 92%, 8% could only think of one benefit, 24% had 2 benefits, 34% knew 3 benefits, 21% knew 4 benefits, 3% knew 5 benefits, 2% knew 6 benefits and 1% knew 8 benefits. The distribution of the most important benefit of AI listed by each farmer is shown in figure 2, with increased milk yield being most often mentioned. Figure 3 shows the clustered bar chart for most important benefit of AI by type of farmer. The benefit of increased milk yield is mentioned most often in all groups. Another feature worth mentioning is that the number of farmers not knowing any benefits of AI, is remarkably higher in the non-AI group than in the drop-out group and the AI group.

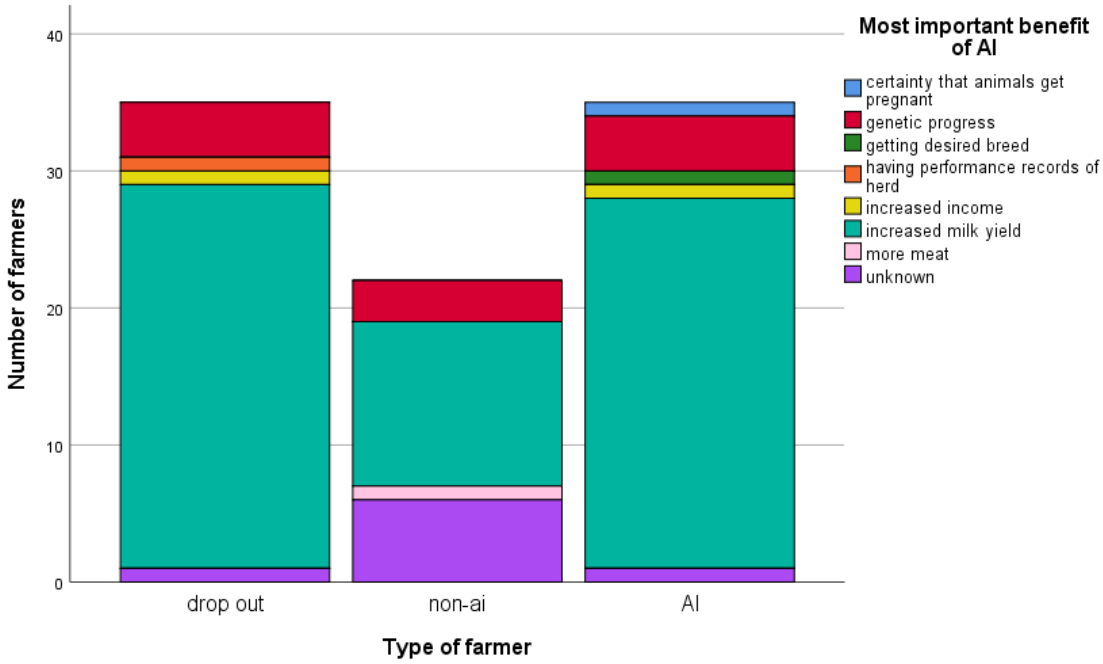

Figure 3: Most important benefit of AI for each group of farmers

Regarding the disadvantages of AI, 6 farmers did not know any disadvantages of AI. The remaining 94% of the farmers mentioned that either there were no disadvantages (7%), mentioned one disadvantage (23%), two disadvantages (50%), 3 disadvantages (12%) or 4 disadvantages (2%). The distribution of the most important disadvantage of AI listed by each farmer is shown in figure 4, with repeat breeding being most often mentioned. Figure 5 shows the clustered bar chart for most important disadvantage of AI by type of farmer. Repeat breeding is mentioned most often in both the AI group and the drop-out group. Costs of insemination is the second most often mentioned disadvantage of AI in the AI group. In the drop-out group costs and loss of local genetic traits in offspring share the second most often mentioned most important disadvantage. In the non-AI group several disadvantages are mentioned nearly equally often.

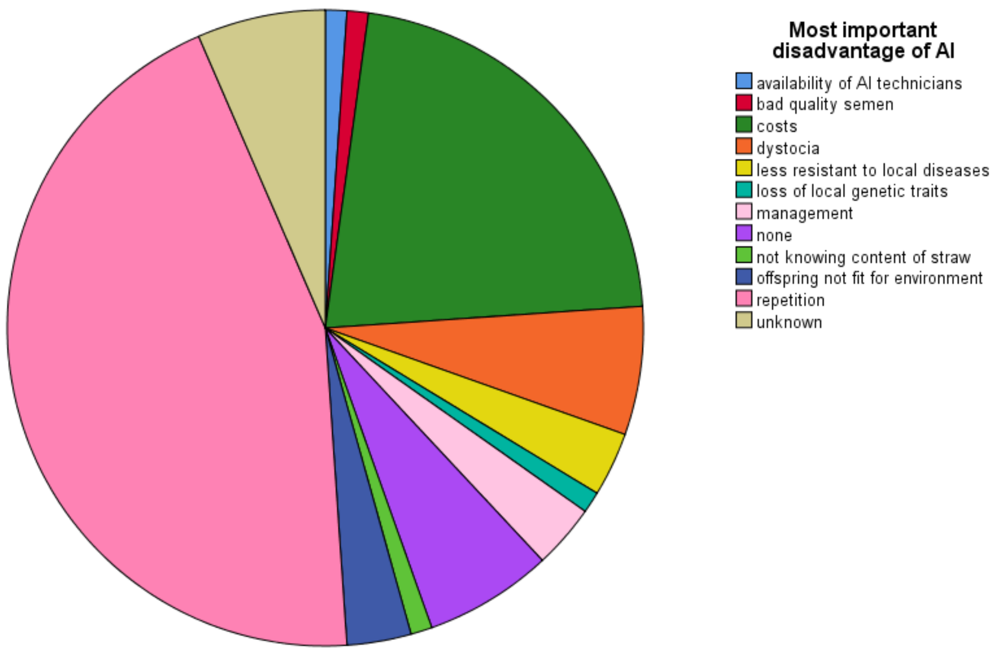

Figure 4: Distribution of most important disadvantage of AI mentioned by farmers

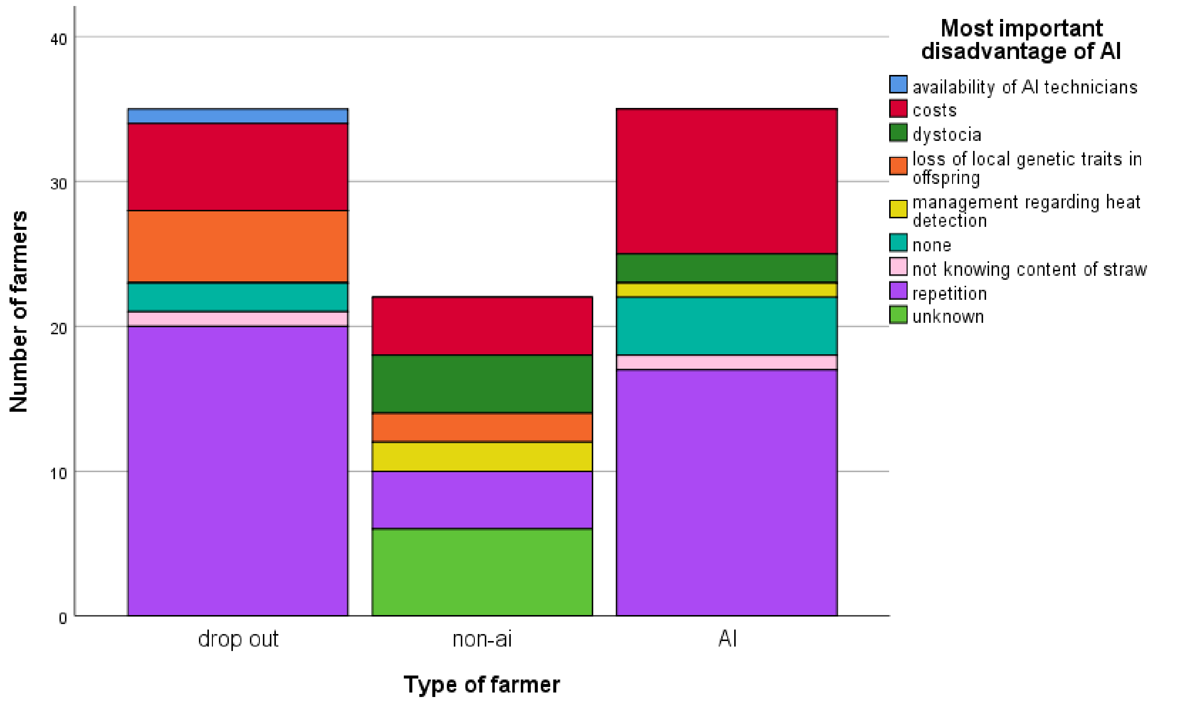

Figure 5: Most important disadvantage of AI for each group of farmers

Farmers from the non-AI and drop-out group were also explicitly asked what their reason is for not adopting AI. In figure 6 the reasons are presented for both groups. The reason most farmers (18) have for not adopting AI in the drop-out group is repeat breeding, while in the non-AI group this reason is only mentioned by 2 farmers. Inferior semen quality and death of a cow produced by AI were only mentioned in the drop-out group and lack of knowledge, herdsmen not checking for heat signs and less resistance to local diseases in offspring are reasons only mentioned in the non-AI group.

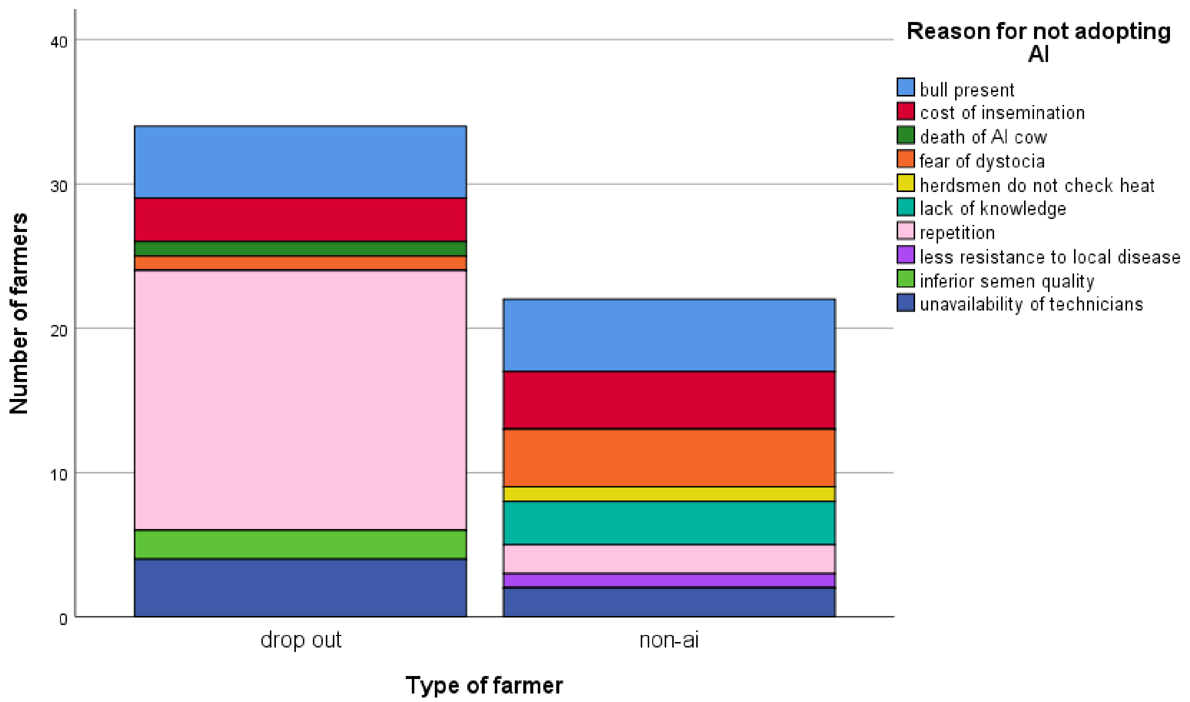

Figure 6: Reasons for not adopting AI among drop-outs and farmers not adopting AI

Multinomial logistic regression for predictors of AI adoption
A multinomial logistic regression analysis was performed with backward elimination of each least significant variable (p>0.05). Missing values were excluded listwise, leaving 84 valid cases. The possible predictors included were: number of cows owned, number of disadvantages mentioned, number of advantages mentioned, age, level of education (lower or equal to primary level or higher than primary level), farming experience (0-10 years, 11-16 years, 17-20 years and >20 years), farming system (pastoralist or other) and distance to city center (0-10km or >10km). The likelihood ratio tests of the initial model are given in Table 1.

Table 1: Likelihood ratio tests of initial model

	Model Fitting Criteria	Likelihood Ratio Tests		
Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	100,365[a]	,000	0	.
Number_cows	110,017	9,652	2	,008
No.disadvantages	107,800	7,435	2	,024
Age	107,308	6,943	2	,031
No.Benefits	103,333	2,967	2	,227
Farming experience	121,977	21,612	6	,001
Distance to center	118,110	17,745	2	,000
Farming system	106,989	6,624	2	,036
Education category	102,533	2,168	2	,338

After backward elimination, the final model included the number of cows owned, number of disadvantages mentioned, farming experience and distance to city center (see table 2 and table 3). There was no collinearity between independent variables based on the magnitude of parameter estimates and standard deviations. From this model, it can be concluded that farmers in the drop-out group as well as the non-AI group are more likely to own more cows compared to the AI group. For an increase in number of cows owned by a farmer by one cow, the odds of being a drop-out increase with 1,70 (CI: 1,17-2,45) and the odds of being in the non-AI group increase with 1,74 (CI: 1,20-2,52) compared to the AI group. For every disadvantage of AI mentioned, farmers are 3,34 times more likely to be in the drop-out group compared to the AI group (CI: 1,43-7,79). For the non-AI group farmers are 3,15 times more likely to be in this group for every disadvantage mentioned compared to the AI group (CI: 1,12-8,84). The odds of being in the drop-out group are 9,71 times smaller compared to the AI group if living within a 10km radius from the city center compared to living >10km from the city center (CI: 0,02-0,51). For the non-AI group, the odds are 50 times smaller or 1/0,02 (CI: 0,002-0,17). Farmers are 8 times less likely to be a drop-out compared to being in the AI group if the farmer had been farming for less than 11 years (CI: 0,02-0,83). There was no significant association between farming experience and the comparison of the non-AI and AI group.

Table 2: Likelihood ratio tests for final model

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	114,105[a]	,000	0	.
Number of cows owned	126,551	12,445	2	,002
No.disadvantages	123,781	9,676	2	,008
Farming experience	127,269	13,163	6	,041
Distance to center	132,641	18,536	2	,000

Table 3: Parameter estimates for final model

Type of farmer[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
Drop-out	Intercept	-1,289	1,259	1,049	1	,306			
	Number of cows owned	,528	,188	7,921	1	,005	1,695	1,174	2,449
	No.disadvantages	1,205	,433	7,738	1	,005	3,335	1,427	7,794
	[farming experience=0-10 years]	-2,077	,962	4,656	1	,031	,125	,019	,827
	[farming experience=11-16 years]	-,697	,999	,487	1	,485	,498	,070	3,530
	[farming experience=17-20 years]	-,070	,954	,005	1	,941	,932	,144	6,043
	[farming experience=>20 years]	0[b]	.	.	0	.	.	.	.
	[distance to center=0-10km]	-2,278	,822	7,677	1	,006	,103	,020	,514
	[distance to center=>10km]	0[b]	.	.	0	.	.	.	.
Non-ai	Intercept	-1,233	1,575	,613	1	,434			
	Number of cows owned	,554	,190	8,514	1	,004	1,740	1,199	2,524
	No.disadvantages	1,146	,527	4,718	1	,030	3,145	1,118	8,842
	[farming experience=0-10 years]	-,722	1,158	,388	1	,533	,486	,050	4,704
	[farming experience=11-16 years]	-1,601	1,358	1,391	1	,238	,202	,014	2,886
	[farming experience=17-20 years]	-1,780	1,411	1,592	1	,207	,169	,011	2,677
	[farming experience=>20 years]	0[b]	.	.	0	.	.	.	.
	[distance to center=0-10km]	-3,924	1,097	12,802	1	,000	,020	,002	,170
	[distance to center=>10km]	0[b]	.	.	0	.	.	.	.

a. The reference category is: AI.

b. This parameter is set to zero because it is redundant.

Health and safety hazards to AI technicians and risk factors

Twenty-one AI technicians were interviewed of whom 12 spoke English and did not require a translator to be present. Nineteen AI technicians were male and two were female. Three private AI technicians were also interviewed, the other 18 were public AI technicians employed by the project. Seven AI technicians were not active in the field anymore. Five AI technicians had finished primary school, 7 had finished secondary and another 7 had finished college. Two AI technicians held a university degree. The mean age was 52 years (range:30-67 years) and the average duration of employment was 10 years (range: 0.6-31 years). Regarding the average number of animals inseminated per week, most of the AI technicians, 11, inseminated 1-4 animals/week, 7 AI technicians inseminated 5-9 animals/week, one AI technician inseminated between 10-14 animals per week and two AI technicians inseminated 15-19 animals per week.

Seven AI technicians reported to have had some type of injury during their employment. For five AI technicians it was only bruises on extremities, but one AI technician was kicked on the head resulting in a swollen eye and wound which had to be sutured and another has had an unspecified bone fracture of the underarm. Each of the symptoms of skin rash, fever and coughing was reported by one AI technician respectively. The AI technician who reported the period of fever stated to have had several periods of fever and that he was diagnosed with malaria as an explanation of the bouts of fever. None of the AI technicians reported any history of severe skin abnormalities, vomiting, diarrhoea, coughing up blood or fertility problems. Figure 7 summarizes the presence of these hazards in the AI technicians. Because there was only one case of skin rash, fever and coughing no statistical analyses could be run with these data.

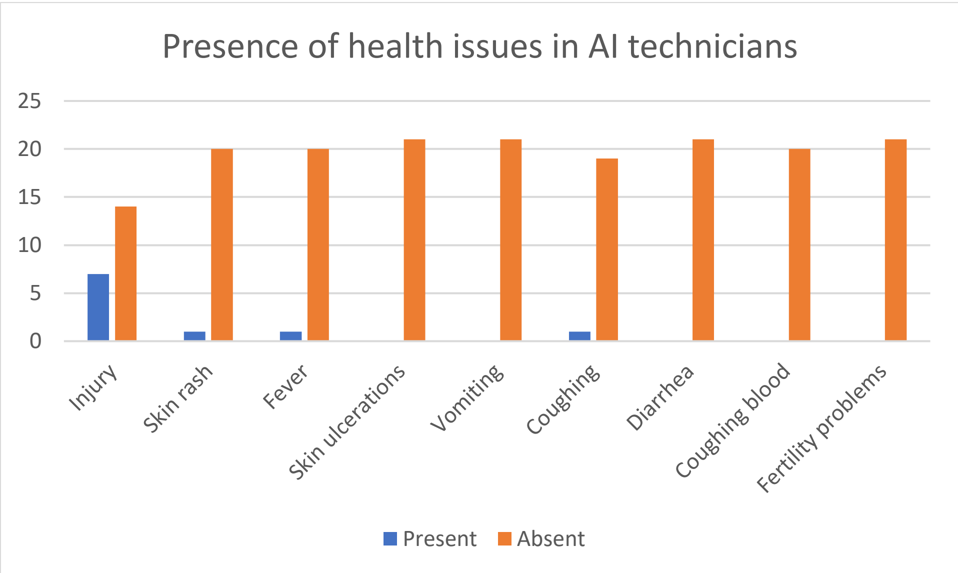

Figure 7: Presence of health issues in AI technicians

As shown in figure 8, 13 and 17 out of 21 AI technicians always wear respectively protective clothing and footwear. Nineteen and 21 AI technicians always wash their hands respectively before and after work while only 5 and 6 AI technicians respectively disinfect their hands before and after work. All AI technicians wash their hands before handling food or eating. This latter is culture-based; it is a custom to wash hands before and after eating. Three AI technicians always wear gloves on both hands (a long examination glove combined with short glove or long gloves on both hands), while the majority of 18 AI technicians only wear one long examination glove.

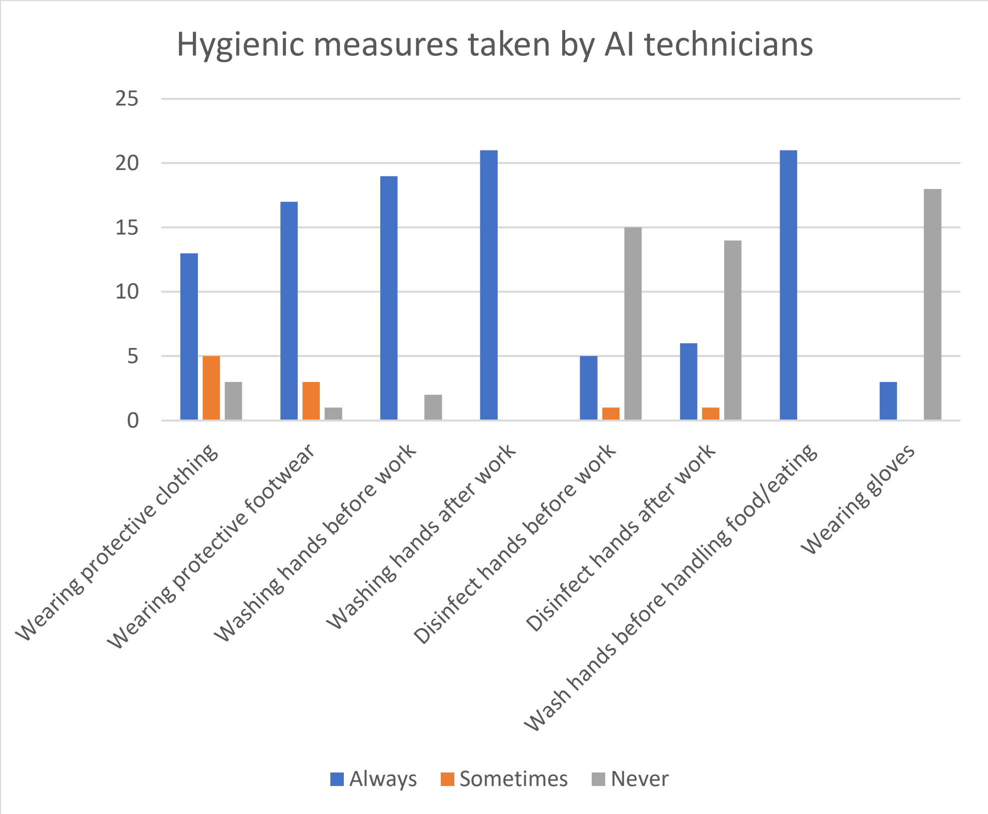

Figure 8: hygienic precautions taken by AI technicians

A summary of the interaction of injury with number of animals inseminated per week, is given in table 4. Seven out of 14 AI technicians who were not injured, inseminated 0-4 animals per week. Five AI technicians did 5-9 cows per week, none of the not-injured AI technicians did 10-14 animals/week and two of the injured AI technicians inseminated 15-19 animals per week. In the group of injured AI technicians, 4 inseminated 0-4 animals/week, 2 inseminated 5-9 cows per week, one inseminated 10-14 animals/week and none of the injured AI technicians had 15-19 cows to inseminate per week. There seems to be a slight tendency towards injury as the number of animals inseminated/week decreases but this was not statistically significant (Fisher's exact test: 2,646, p=0,595, 95%CI: 0,585-0,604).

Table 4: interaction of injured with frequency of inseminating animals

		Number of animals inseminated per week				Total
		0-4	5-9	10-14	15-19	
Injured	no	7	5	0	2	14
	yes	4	2	1	0	7
Total		11	7	1	2	21

Welfare hazards to cattle presented for insemination

Time needed to inseminate one animal, from restraining to releasing the animal, was between 2-7 minutes for 19 AI technicians. The other two AI technicians needed 10 and 30 minutes to inseminate one animal. Because of this small sample size and unequal distribution across categories, no additional analyses could be performed on this subset of data. Eighteen AI technicians reported to separate the cow that has to be inseminated from the herd, while two reported not to do so and one reported to sometimes do this. Nine AI technicians reported that it depends on the farm whether they tie the animal to a tree or put it in a crush. Six AI technicians reported to always use the crush, 3 AI technicians tied the animal to a tree with additional restraining by grabbing the nose or tying a hindleg, 2 AI technicians only tied the animal to a tree and one AI technician used a crush with additional restraining. Due to the fact that the answers of the AI technicians to how they fixate the animal are not mutually exclusive, no conclusions can be drawn from combining information on having had an injury and the fixation method used.

The farmers adopting AI were also asked how they fixate the cow that has to be inseminated. In table 5 a summary of the different fixation methods is given. Most farmers (14) use a wooden crush, ten farmers tie the cow to another object (tree, pole) and grab or pinch the nose while the animal is inseminated. Six farmers only tie the animal to an object, without additional restraining while three farmers tie the animal while also tying up one or both hindlegs. One farmer reported to only hold the animal in the nose and another farmer reported to use the crush or tie the animal to a tree.

Table 5: Frequency of fixation methods used by farmers

Fixation method	Number of farmers
Crush	14
Tied + nose	10
Tied	6
Tied + leg	3
Held in nose	1
Crush or tied	1

Discussion

Perceptions and attitudes of farmers towards artificial insemination of cattle and predictors of artificial insemination

The distance to the city center is a major predictor for adoption of AI. We chose for city center instead of asking farmers about the distance to the service provider because this varied since farmers were served by multiple AI technicians depending on availability. Moreover, each AI technician has to stop by the project's office in the city center to get straws and disposables and most AI technicians can only preserve a couple of straws at a time causing the office to be the focus of AI technicians' presence. This result agrees with previous work from Mwanga, Mujibi et al. (2019) in which a negative correlation was found between distance to the service provider and AI use in Tanzania. It is commonly accepted that the underlying cause of this finding is that infrastructure is far from optimal causing long distances to be problematic in terms of the AI technician getting at the farm at all let alone getting there within the window of insemination. The type of farming system could be a factor contributing to the effect of distance on choice of breeding method. Farmers who practice zero-grazing or restricted grazing are concentrated in the urban area as opposed to farmers who practice the pastoral farming system in the peri-urban or rural areas. Although the number of milking cows owned seems likely to be highly related to the type of farming system and distance from the city center (Nkya, Kessy et al. 2007), no collinearity between these variables was found in our model.

Results from this study indicate that farmers who adopt AI, tend to own less milking cows than farmers who use natural breeding or have used AI in the past. This is contrary to findings from Mwanga, Mujibi et al. (2019) who found equal numbers of milking cows owned in both farmers adopting AI and farmers using natural service in Tanzania. A possible explanation for this difference could be that in the interview in the present study, the farmers were asked about the number of cows being milked at that moment while the study from Mwanga, Mujibi et al. (2019) asked for the average number of cows being milked. An explanation for our result could be that less cattle represents intensification and animals under these conditions can be more closely watched for heat and therefore the moment of insemination would be more accurate which results in less repeat breeders. Besides, with less milking cows owned, the price of inseminating the milking herd as a whole is more affordable and at the same time the cost of purchasing a bull for only a few cows is relatively higher on short-term, while that bull would occupy a milking cow's place. This explanation is in line with findings by Mugisha, Kayiizi et al. (2014) who found a strong inverse relationship between AI use and size of grazing land in Uganda, whereby farmers holding small land sizes (and thus intensifying their holdings) were more likely to use AI.

Mentioning less disadvantages compared with drop-out farmers was also a predictor for adopting AI. In combining this result with the specific types of disadvantages mentioned by drop-out farmers, this is because this type of farmer has clearly had a negative experience with AI and knows more disadvantages than farmers who do still adopt AI. Years of farming experience as a predictor for adopting AI compared to drop-out farmers can simply be explained by the fact that people who have been farmer for a short period cannot have dropped out of the AI program already. Although experience may be a representation of age, we did not find age to be a predictor for adoption of AI compared to drop-out farmers. On the other hand, in comparing adoption of AI with not adopting AI among farmers, age is significantly negatively associated with adopting AI which could be due to younger farmers being more open to new developments whereas older farmers are firmly anchored in their traditions (data not shown due to overall likelihood ratio test significance level below 0.05). This is in accordance with a study by Howley, O. Donoghue et al. (2012) who also found age to be negatively associated with adoption of AI in farmers. However, from the point of view of agricultural technology adoption in Sub-Saharan Africa there are contradictory studies which argue that age represents experience and that experienced farmers are more likely to adopt new technologies (Feder 2017).

Our finding that level of education is not associated with adopting AI is in contradiction with the results of a multi-country investigation from 2016, which also included Tanga region (Mwanga, Mujibi et al. 2019). The authors of this study found that farmers who used AI had on average longer formal schooling years than those who used bull service. A possible explanation for this could be that in this study, only the highest level of education achieved was asked and not the years of attending school.

Although there was no association in the present study between farmers discussing AI with other farmers and adopting AI or not, Mwanga, Mujibi et al. (2019) found a clear grouping of farmers into spatial clusters which coincided with the preferred method of breeding. Due to the nature of the question in our interview these results cannot be compared completely since our question did not explicitly ask about neighbors. It could be that the farmers discussing among each other, were not living close to each other.

That most farmers mentioned increased milk yield as most important benefit of AI is interesting because this reflects the assumption of many farmers that offspring with a high percentage of exotic (e.g. non-indigenous, highly productive dairy breeds like Holstein Friesian, Jersey, Ayrshire) blood will be unconditionally highly productive. This is a dangerous assumption in the sense that farmers will become disappointed with the offspring and lose interest in AI, but moreover it is dangerous because if not controlled, more and more farmers will get crossbreeds with high proportions of Holstein-Friesian blood without considering negative consequences like adaptability to the local environment. Farmers will also be less focused on non-genetic factors influencing the productive performance of a cow thus not improving their management. After all, feed, water consumption, climate and interactions between these factors play an important role in the productive performance of a cow (Sinha, Kamboj et al. 2017). Unfortunately as witnessed by me, farmers in Tanzania do struggle to obtain nutrient-rich fodder, provide ad lib water and take precautions to avert heat stress in their cattle. Here lies an important task for AI technicians and veterinarians to educate farmers on the complexity of breed improvement and the various factors involved and advise them according to their breeding goals. Breed improvement research projects should take this into account and contain farmer's training on this issue.

The vast majority of farmers (45%) mentioned the repeat breeding as the main disadvantage of AI and it was the main reason to drop-out of the AI program. This is in accordance with results from others who found a negative association between the number of services before conception and choice of AI as a breeding service in Uganda and Tanzania (Mugisha, Kayiizi et al. 2014, Mwanga, Mujibi et al. 2019). Reasons for this finding include: farmers and/or AI technicians adhering to unreliable heat signals thus wrong timing of heat detection and insemination, emaciated or diseased cows that are inseminated, fraudulent AI technicians (due to arriving too late and knowingly performing the insemination anyway or swindling with straw contents) or incorrect storage conditions of semen due to unreliable availability of liquid nitrogen. Lyimo et al. found that improper heat detection of farmers, poor nutrition and tick-borne diseases were the most important reasons for a lower reproductive performance in crossbred dairy cattle in the Tanga region (Lyimo, Nkya et al. 2004). Nkya et al. confirm the reasons mentioned before as important constraints mentioned by smallholder farmers (Nkya, Kessy et al. 2007).

The costs of insemination being too high and the fear of dystocia as reasons for preferring natural breeding over AI are corroborated by the works of others (Mugisha, Kayiizi et al. 2014). There seems to be a lack of studies investigating the risk of dystocia in cows inseminated with sires with different levels of exotic blood compared to local sires. However, dystocia is not caused by the act of insemination and carefully choosing the type of sire and gradually increasing the level of exotic blood over several generations will likely avoid dystocia due to oversized calves. The question arises at which level of exotic blood breeding in should stop. From the field it is said that offspring should have no more than 75% of exotic blood because at

this point adaptation to the climate will get lost, resulting in offspring succumbing to heat stress. Some farmers did mention their crossbred cattle dying suddenly and they prefer natural breeding over AI because of loss of local genetic traits like heat tolerance, tick resistance and efficiently digesting low quality forages in offspring of AI. It has indeed been reported previously that in areas with predominantly crossbred or even purebred exotic cattle, calf mortality is higher compared to areas with a larger proportion of cattle being local Zebu and that this may in part be due to less resistance to local diseases (Nkya, Kessy et al. 2007). The thermotolerance of *B. indicus* breeds is related to a lower basal metabolic rate due to a reduced size of internal organs and decreased tissue resistance to heat flow from body core to skin but moreover cellular resistance to elevated temperature has been proven, which indicates the presence of 'thermotolerance genes' (Hansen 2004). To the best of our understanding no study has investigated the relation between the genetic proportion of a high-yielding breed and heat stress resistance, but there is one study that investigated the relation between the proportion of Holstein breed and production performance. This study, carried out in Brazil, found a proportion of 38%-90% Holstein blood (the remaining proportion being Zebu) to correspond with the highest-performing cows (Fraga, Silva et al. 2016). No mention was made about durability of each combination of proportions Holstein and Zebu blood and it could be that cows who died after one month, would still be classified as highly productive due to the corrections used. Therefore, this 'ideal' proportion of Holstein blood should be carefully interpreted and also extrapolated to sub-Saharan Africa with caution due to possible climate differences.
A limitation of this study is that the non-AI farmers were not randomly selected but selected based on availability. This may have shifted the results in favor of a more pronounced aversion to AI. The presence of translators, while interviewing, was necessary but not favorable since due to the possibly perceived status difference, farmers could have given socially more acceptable answers or answers they thought the investigators or translators wanted to hear. Another important issue to address is that many farmers outsource the day-to-day livestock-related activities. While we interviewed the farmer owning the animals, it could be that the person taking care of the animals differed in his methods from what the farmer was reporting to us. In our analyses we did not account for the breed of cattle, which varies across several variables. For instance, nearly all crossbreds were in the zero-grazing system while all the local purebreds were of the pastoralist system. Herds of crossbreds were also smaller than local breeds, which indicates that farmers owning local purebreds are less likely to adopt insemination than farmers owning crossbreds. Farmers who did not adopt AI at the moment of the interview but were positive about adopting it in the future, were assigned to the non-AI group or drop-out group depending on whether they had used it previously. Future plans were not taken into account while grouping the dependent variable. This may have resulted in non-AI and drop-out group to be more positive about AI than when the future plans were taken into account. Since most farmers have a very short-term focused mindset, it is difficult to include this parameter in the study.

Hazards to AI technicians and related risk factors
The relatively high mean age of the AI technicians in this study can be explained by the fact that compared to the general Tanzanian population, there are no children in this group since in order to be an AI technician you would need to have finished at least secondary school. About 44% of the general Tanzanian population is made up of children under the age of 15 (UN World Population Prospects 2019). There are safety hazards to AI technicians in the form of injury as a result of kicking of the cow, but most were not serious injuries. No risk factors could be determined due to the small sample size, although the number of animals inseminated/week was suggestive, which would lead one to interpret that less experienced AI technicians in terms of frequency of inseminations performed are at higher risk of getting injured, stressing the need for emphasis on taking safety precautions and being able to read the animal in training AI technicians. Increasing the number of inseminations performed per week to a certain extent could possibly aid in reducing the risk of getting injured while also having a financial benefit for the AI technician. On the other hand, each time an insemination is performed, there is a chance

of injury, therefore increasing the number of inseminations per week could possibly also lead to an increased chance of being injured. Due to the small number of AI technicians in this study the effect of this interaction is not clear. It should be further investigated with substantial numbers of AI technicians. Very few AI technicians reported any of the symptoms that could indicate infection with a zoonosis. The one AI technician mentioning having had recurrent periods of fever also stated that it was due to malaria but the diagnostic method was not known. Since zoonoses are often mistakenly diagnosed as malaria (Crump, Morrissey et al. 2013), there is a chance that this AI technician was actually infected by a zoonosis. One major drawback of this study design is the presence of recall bias; AI technicians had to answer the questions over their entire period of employment which could have led to underreporting of symptoms. This would match with none of the AI technicians reporting an episode of diarrhea or vomiting, which would be expected to be at least fairly common due to food poisoning or infection given the climate and suboptimal preservation conditions for food. On the other hand, AI technicians might have developed a certain level of immunity to pathogens often encountered. Despite the pretesting of the questionnaire, it is still likely that individuals were hesitant to report health issues, especially fertility problems. Another major drawback of the study design is using symptoms as proxy's for an infection with zoonoses. Fever for instance, is a symptom which can be caused by a broad spectrum of diseases which also include non-zoonotic diseases. Future research should focus on detection of antibodies or antigens in AI technicians to get a proper diagnosis. Lastly, it is likely that this sample size was too small to detect any symptoms of previous infection, especially when the prevalence is not high, which is expected in AI technicians (Omer, Assefaw et al. 2002, Swai and Schoonman 2009).

Welfare hazards to cattle presented for insemination

Although a crush works very practical for animal handlers, being driven and handled in a crush can be a stressful event for cattle, depending on the individual animal's character (Grandin 1993). Maintaining visual and physical contact is very important in avoiding agitation while presented with environmental change. This indicates that in general it is best to not separate cows from the herd when performing insemination but once a cow has been in a crush for several times and remains calm, there is no reason not to use this method of fixation. Cows that do not keep calm even after several times, will not get habituated to this challenge and should be removed from the herd or fixated while in close contact with the herd. If cattle are already used to human handling, they experience less stress while fixated than if they are untamed. Since farmers and herdsman in the studied area live in close contact with their animals (e.g. milking by hand, herd the animals or keep them in their backyard), it can be assumed that the general level of excitation is low when insemination is performed and welfare is at best only slightly diminished. Since the method of fixation is farm-dependent and not AI technician-dependent, the relationship between safety hazards of AI technicians and welfare of cattle could not be determined.

Conclusion

There are safety hazards to AI technicians, but most are not very serious. No risk factors for safety hazards could be determined due to the small sample size. For the same reason no clear association was found between symptoms of zoonotic infection and hygienic measures. Future research should focus on accurately diagnosing present or previous infections in AI technicians through validated laboratory tests and relating the results of these tests to hygienic measures taken. Welfare hazards to cows presented for insemination are low in general and the relationship between animal welfare and safety of AI technicians could not be determined due to the fixation method being farm-dependent and not AI technician-dependent. Predictors of adoption of AI are distance to city center, owning less cattle, mentioning less disadvantages of AI and farming experience. Randomly selecting farmers adopting AI, not adopting AI and having dropped out of using AI should be included in future research and the research area should be increased for more reliable results. Also, predictor variables should be made measurable or pulled from a register to gain more accurate data. The most important benefit of AI mentioned by the vast majority of farmers was an increased milk yield reflecting the focus on production while other influences might be neglected. The most important disadvantage of AI mentioned by many farmers and the main reason for farmers to drop-out of the AI program is repeat breeding which is most likely caused by improper heat detection of farmers, diseased cows and unviable semen related to incorrect storage conditions due to unreliable availability of liquid nitrogen. This is an area of research that has high priority since repeat breeding results in lower production through an increased calving interval while the reason for wanting a higher adoption rate of AI among farmers in the first place, was to increase production. Reasons for farmers not adopting AI to prefer natural breeding over AI are having a bull present, costs of insemination and fear of dystocia.

Recommendations

AI services should be made more accessible to farmers living further away from the city. As is the case in several other countries in sub-Saharan Africa, a better infrastructure is part of the solution. Having several dairy hubs with farmer's cooperation from which AI services could be provided, would contribute to making AI services more accessible. In the past, farmers have already been encouraged to form a cooperation in order to set fair milk prices (Nkya, Kessy et al. 2007) and the dairy industry has built milk collection centres in remote areas which could serve as a starting point for the dairy hubs but a lack of resources for purchase of additional liquid nitrogen and liquid nitrogen tanks remains. On a national level, long-term solutions should be sought to make liquid nitrogen continuously available. If farmers would see the added value of the dairy hub and build a strong cooperation they might be able to provide the resources together or with help from the dairy industry. AI technicians would then be farmers living close to the particular dairy hub who are ideally chosen by the other farmers in the cooperative to strengthen mutual loyalty and commitment. The cause of the repeat breeding should be further investigated in order to solve this major problem. Farmers and AI technicians should continuously be educated about heat detection methods and farmers should also be educated about breed improvement and given the choice between several sires depending on the breeding goals of the farmer. Future research projects should incorporate this aspect in training for farmers. More research is needed to determine what the ideal proportions of exotic blood would be, given certain environmental conditions and whether there are other ways to breed a highly productive cow which is also resistant to ticks, heat tolerant and can efficiently digest low quality forage.

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Attachments

Supplementary methods S1 and S2

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S1: Farmers questionnaire on perception and attitude towards artificial insemination of dairy cattle

Question	Answer
Personal characteristics	
Name	
District	
Village	
Sexe	Male/female
Age	
Highest level of education?	No formal education, primary, secondary, vocational, university
For how long have you been a livestock farmer?	
Do you have any other job besides being a livestock farmer?	
If yes, how much time spent doing off-farm work?	
How many children do you have?	
If you are unable to continue farming, is there someone who will take care of your farm?	
What is the type of farming system you use?	Zero grazing, restricted grazing, pastoral or mixed (depending on season)
Distance to city center	… km
Number of cows owned	
Number of cows being milked at the moment	
Milk yield/cow/day	
Margin/L milk	
Do you have access to information on artificial insemination?	Yes/no
If yes, where?	
Do you adopt AI on your cows?	
Why did you start using AI?	
If you don't adopt AI, why not?	
How many cows do you adopt AI on?	
How much do you pay for one insemination?	
How many cows do you adopt insemination for?	
What are possible benefits of artificial insemination?	Healthier cattle Healthier farmer and family Increased milk yield Increased fertility of cows Healthier calves Better record keeping …..
What is the most important benefit?	
What are possible disadvantages of artificial insemination?	Costs

	Time-consuming Bulls become less worth Training and special equipment are required Lower milk yield Lower fertility of cows ……
What is the most important disadvantage?	
Do you want to farm sustainably/without harming environment?	
Do you discuss AI with other farmers?	
If yes, how many times/year?	
If yes, how? (formal meetings/informal)	
How do you fixate the animal that is presented for AI?	
Emailaddress or phone number	

S2: Inseminators questionnaire on health and safety of inseminators and health and welfare of cattle

Questions
Name
Sexe
Age
Years in practice as inseminator
Active/inactive
If inactive, why?
Highest level of education
Have you ever had a skin rash during employment?
If yes, how many times
Have you ever had an episode (more than two days) of fever during employment?
If yes, how many times
Have you ever had skin ulcerations during employment?
If yes, how many times
Have you ever had an episode of (more than 2 days) of vomitin?
If yes, how many times
Have you ever had an episode (more than 2 days) of diarrhea during employment?
If yes, how many times
Have you ever had an episode (more than 7 consecutive days) of severe coughing during employment?
If yes, how many times
Have you ever coughed up blood during employment?
If yes, how many times
Have you ever had any fertility problems during your employment?
If yes, has the cause be determined?
Have you ever been diagnosed with or highly suspected of having an infectious disease during employment?
If yes, which one?
How many animals do/did you inseminate/week on average?
How long does it take to inseminate one cow on average? Time from fixation to release
Have you ever been injured due to inseminating cows?
If yes, how many times have you been injured?
What type of injury did you contract?
Do you wear gloves on both hands?
Do you wear protective clothing over own clothes while working?
Do you wear protective footwear while working?
Do you change clothes when leaving a farm?
Do you change footwear when leaving a farm?
Do you always clean your boots when leaving a farm?
If yes, how?
How often do you wash your work clothing?
Do you wash your hands before starting work on each farm?
Do you wash your hands after work is done on each farm?
Do you disinfect your hands before starting work on each farm?
Do you disinfect your hands after work is done on each farm?

If your hands/underarms become dirty while working, do you wash them in between cows?
Do you always wash your hands before handling food/eating?
What do you think is more likely to happen to you: get infected with a zoonotic disease or get injured due to inseminating cattle?
If zoonotic, which one? If injury, what type?
Are you worried that you might be a factor in spreading diseases from farm to farm?
If yes, why? If not, why not?
Are the cows to be inseminated, separated one by one from the herd?
How do you fixate the cow?