Original Research Article

**Factors Affecting the Adoption of Estrus Synchronization and Artificial Insemination Service in Selected Areas of Southern Ethiopia**

ABSTRACT

|  |
| --- |
| ***Aims:*** *Ethiopia has the largest livestock population in Africa. To enhance the benefit from cattle, AI technologies have long been introduced into the country to improve the genetic potential of indigenous cattle population. However, lack of recording scheme, wrong selection procedures, and poor management of AI bulls associated with poor motivations and skills of inseminators are still a gap in country and region level. This study was, therefore, initiated analyze factors affecting adoption of estrus synchronization and artificial insemination service in selected areas of Southern Ethiopia.*  ***Place and Duration of the study:*** *Southern Ethiopia from 2024.*  ***Methodology:*** *In total, 141 sample households were selected based on a systematic random sampling technique. The bivariate probit regression model was used to analyze the econometric data.*  ***Results:*** *Education level, distance to AI station, heard information on failure of AI, mobile ownership, total family, and extension contact frequency were significant determinants of adoption of artificial insemination and estrous synchronization technology. Delay of AI technicians, shortage of supplementary feed ,insufficient on farm implementation of the services , indiscriminate application of AI without considering body condition ,tendency of farmers not to repeat the service once encountered failure, insufficient equipment and inputs for the delivery of service, efficiency and specialization problems on technicians of AI side, shortage of technicians and limitation of access which is confined to annual launching are constraints for sustainable utilization of AI and ES service.*  ***Conclusion:*** *continuous training for AI and farmers to improve their heat detection skills, focusing on-farm implementation, working to fulfill inputs and equipment with stakeholders, helping AITs to specialize on the area, working on development of improved/supplementary feed, provision of printed guidelines for AITs in local language, raising awareness of farmers, smoothening communication of farmers with AI technicians, and making AI centers functional at every time are recommended.* |

*Keywords: Artificial Insemination, Estrous Synchronization, Adoption, Southern Ethiopia*

1. INTRODUCTION

Agriculture is the back bone of the Ethiopian economy which accounts for approximately 85% of the total population. Ethiopia holds the largest livestock population in Africa. The estimated cattle population in Ethiopia is about 57.83 million, 28.04 million sheep, 28.61 million goats, 1.23 million camels and 60.51 million poultry. Out of 57.83 million cattle the female cattle constitute about 55.38% (32.0 million) and the remaining 44.55% (25.8 million) are male cattle. From the total cattle in the country 98.59% (57.01million) are local breeds and remaining are hybrid and exotic breeds that accounted for about 1.19% (706,793) and 0.14% (109,733), respectively (CSA, 2016).

This number clearly indicates that exotic and hybrid female cattle population still remained insignificant due to unsuccessful crossbreeding through AI. Artificial insemination (AI) has been defined as a process by which sperm is collected from the male, processed, stored, and artificially introduced into the female reproductive tract for the purpose of conception (Webb, 2003). Semen is collected from the bull, deep-frozen and stored in a container with Liquid Nitrogen at a temperature of minus 196 degrees Centigrade and made for use.

Artificial insemination has become one of the most important techniques conducted for genetic improvement of farm animals. It has been widely used for breeding dairy cattle as the most valuable management practice available to the cattle producer and has made bulls of high genetic merit available to all (Webb, 2003; Bearden et al., 2004).

In Ethiopia, AI was introduced in 1938 in Asmara (the current capital city of Eritrea), the then part of Ethiopia, which was interrupted due to the second World War and restarted in 1952 (Yemane et al., 1993). It was again suspended due to unaffordable expenses of importing semen, liquid nitrogen and other related inputs requirement.

In 1967, an independent service was started in the then Arsi Region, Chilalo Awraja under the Swedish International Development Agency (SIDA). The present National Artificial Insemination Center (NAIC) was established in 1984 to coordinate the overall AI operation at national level (GebreMedhin, 2005). The efficiency of the service in the country, however, has remained at a very low level due to infrastructure, managerial, and financial constraints, as well as poor heat detection, improper timing of insemination and embryonic death (Shiferaw et al., 2003).

Reproductive problems related to crossbreed dairy cows under farmers’ conditions are immense (Bekele, 2005). It is widely believed that the AI service in the country has not been successful to improve reproductive performance of dairy industry (Sinishaw, 2005). From the previous little studies, it has been found that AI service is weak and even declining due to inconsistent service in the smallholder livestock production systems of the Ethiopian highlands (Dekeba et al., 2006).

The problem is more aggravated by lack of recording scheme, wrong selection procedures, and poor management of AI bulls associated with poor motivations and skills of inseminators (Gebre Medhin, 2005). In Southern Ethiopia, despite the effort of the government to increase the dissemination of the service, the status of AI is not satisfactory. Also, the where about of the AI service is not studied in a formal manner in the Southern Ethiopia. Therefore, this study analyzed factors affecting adoption of estrus synchronization and artificial insemination service in selected areas of Southern Ethiopia, and identified constraints in AI and Es utilization and came up with recommendations that could attract the attention of decision makers and stakeholders to gear their effort to the successful AI operation in the study area. Specifically, it was undertaken to identify significant determinants of Artificial Insemination (AI) & estrus synchronization (ES) technologies adoption and assess constraints of AI & ES technologies utilization.

2. methodology

**2.1. Description of the Study Area**

This study was carried out in Wera woreda of Halaba zone, Dale woreda (Sidama region) and Dilla zuria woreda (Gedeo zone).

**2.2. Sampling and Sample Size Determination**

Two stage sampling technique was used in the study. In the first stage, one woreda from each zones (Gedeo, Halaba and Sidama) as the mandate area of Hawassa Agricultural Research Center were selected purposefully based on level of artificial insemination service coverage. Consequently, Dilla Zuria, Wera and Dale were selected from Gedeo, Halaba and Sidama respectively.

In the second stage, two rural kebeles were selected purposively from each woredas based on level of artificial insemination service. Finally, using systematic random sampling technique, 141 household heads (from Gedeo/Dillazuria=51, Halaba/Wera=50, Sidama/Dale=40 were selected for the study.

AI professionals at different administrative levels were also contacted to obtain data on the problems they face in delivering the service to the community.

**2.3. Type of Data and Method of Data Collection**

Both qualitative and quantitative data were collected from primary and secondary sources. Primary data was collected from respondents using structured interview questionnaire. Focus group discussions were arranged in each of the selected kebeles by organizing farmers in to the group of eight members to gather qualitative data using checklists. Experts’ information was also gathered using checklists. Secondary data was obtained from websites and published materials with regard to the subject matter under study.

**2.4. Methods of Data Analysis**

Both descriptive and econometric analysis methods were used. Descriptive statistics such as tables, graphs, charts, percentage, etc. were employed. For econometric analysis part, bivariate probit model was used to analyze factors affecting Estrous Synchronization and Artificial Insemination technology adoption.

The **Bivariate Probit Model** is used there are two binary dependent variables that may be jointly determined, with possible correlation between their error terms.

**2.4.1. Model Structure**

According to Greene (2018), Let Y1∗ and Y2∗ be two latent variables defined as:

Y1∗​=X1′​β1​+ε1​

Y2∗​=X2′​β2​+ε2​

Y1​=1 if Y1∗>0; otherwise Y1​=0

Y1​=2 if Y2∗>0; otherwise Y2=0

Where:

X1​ and X2​ are vectors of explanatory variables (they can be the same or different)

β1 and β2 are vectors of coefficients

ε1 and ε2 are error terms

3. results and discussion

**3.1. Descriptive Statistics**

As the results in Table 1 indicate, majority of the sample respondents were males (90.78%). This result indicates a firm access to and control of resources by males as a household head. Males are known to have control of resources required to conduct agricultural activities either by a contract or as a gift from family when they establish the household of their own after marrying loved ones. Those who reported to have used only artificial insemination were 14.19%. There are cases where the cows are already at the heat stage and require only insemination of the exotic breed semen. Those who used both artificial insemination and estrous synchronization were 42.55%. This happens when district launch the dissemination of the technology. The farmers are required to bring their cows to local AI stations to get the service. Those who didn’t use the technology at all were 43.26%. The alternatives for those farmers or cattle herders are local bull services, and to some extent locally available improved bulls which are available on neighbor farmer’s houses. Those who have heard about the failure of artificial insemination and estrous synchronization technology were 60.99%. Local farmers will inevitably hear about it when the neighbors used the technology and come up with bad news of failure when they meet in pretext of different social gatherings. Almost above half of the sample respondents (55.32%) had access to mobile. Not all development agents afford to reach to every household who require the delivery of extension services. Even if the development agents want to do so, there are constraints like shortage of vehicles and limitation in number of experts. In this circumstance, extension contacts are enhanced by mobile phones. Those who used improved feed were 61.70%. Improved feeds include elephant and desho grasses, and legumes.

**Table 1 Summary of discrete variables**

|  |  |  |  |
| --- | --- | --- | --- |
| Variables | | Freq | Percent |
| Sex | Male  Female  Total | 128  13  141 | 90.78  9.22  100 |
| AI only=1, ES=0 | | 20 | 14.19 |
| Both AI=1 and ES=1 | | 60 | 42.55 |
| Both AI=0 and ES=0 | | 61 | 43.26 |
| Use of improved bull services/locally available | | 16 | 11.35 |
| Use of local bull services | | 45 | 31.91 |
| Heard failure of AI and ES | | 86 | 60.99 |
| Mobile ownership | | 78 | 55.32 |
| The use of improved feed | | 87 | 61.70 |

Source: survey result, 2024

As indicated in Table 2, artificial insemination service had significant association with information related to failure of the service (Chi2=7.38) and mobile ownership (Chi2=65.91) at one percent significance level. Estrous synchronization service also had significant association with information on failure of the service (Chi2=11.23) and mobile ownership (Chi2=41.52) at at one percent significance level. More intuitive interpretations are indicated atthe model result part.

**Table 2 Association between discrete variables**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | Value | AI | | | | | Ch2 | ES | | | | | Ch2 |
| Non adopters(61) | | Adopters (80) | | Total | Non adopters(81) | | Adopters (60) | | Total |
|  | | | |  |  |  | |  | |  |  |
| N | % | N | % | N | % | N | % |
| Heard failure | 0 | 16 | 26.23 | 39 | 48.75 | 55 | 7.38\*\*\* | 22 | 27.16 | 33 | 55.00 | 55 | 11.23\*\*\* |
| 1 | 45 | 73.77 | 41 | 51.25 | 86 | 59 | 72.84 | 27 | 45.00 | 86 |
| Total | 61 | 100 | 80 | 100 | 141 | 81 | 100 | 60 | 100 | 141 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Mobile | 0 | 51 | 83.61 | 12 | 15.00 | 63 | 65.91\*\*\* | 55 | 67.90 | 8 | 13.33 | 63 | 41.52\*\*\* |
| 1 | 10 | 16.39 | 68 | 85.00 | 78 | 26 | 32.10 | 52 | 86.67 | 78 |
| Total | 61 | 100 | 80 | 100 | 141 | 81 | 100 | 60 | 100 | 141 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Improved feed | 0 | 19 | 131.15 | 35 | 43.75 | 54 | 2.33 | 27 | 33.33 | 27 | 45.00 | 54 | 1.99 |
| 1 | 42 | 68.85 | 45 | 56.25 | 87 | 54 | 67.67 | 33 | 55.00 | 87 |
| Total | 61 | 100 | 80 | 100 | 141 | 81 | 100 | 60 | 100 | 141 |

Source: survey result, 2024

As shown in Table 3, There is statistically significant mean difference in education (t=-6.99), distance to artificial insemination service stations ((t=5.95), extension contact frequency (t=-3.05), and total family (t=-5.62) between categories of adopters and non-adopters of artificial insemination service at one percent significance level. Education (t=-3.47), distance to the artificial insemination center (t=3.64) and extension contact frequency (t=-3.66) also shown significant mean difference between adopters and non-adopters categories of estrous synchronization.

**Table 3 Association between AI and ES in relation to continuous variables**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variables | AI | | | | | ES | | | | | Total mean |
| Non adopters (61) | | Adopters (80) | | Ttest | Non adopters (81) | | Adopters (60) | | Ttest |
|  | |  | |  |  | |  | |  |  |
| Mean | Std.Err. | Mean | Std.Err. | Mean | Std.Err | Mean | Std.Err. |
| Education | 4.80 | 0.23 | 6.7 | 0.16 | -6.99\*\*\* | 5.43 | 0.23 | 6.48 | 0.17 | -3.47\*\*\* | 5.88 |
| TLU | 1.60 | 0.07 | 1.67 | 0.05 | -0.90 | 1.61 | 0.06 | 1.69 | 0.06 | -0.96 | 1.64 |
| Age | 38.59 | 1.69 | 40.55 | 1.25 | -0.95 | 40.40 | 1.49 | 38.77 | 1.31 | 0.79 | 39.70 |
| Distance to AI | 5.72 | 0.08 | 5.22 | 0.04 | 5.95\*\*\* | 5.58 | 0.07 | 5.24 | 0.05 | 3.64\*\*\* | 5.44 |
| Extension contact freq. | 2.51 | 0.22 | 3.26 | 0.14 | -3.05\*\*\* | 2.56 | 0.17 | 3.45 |  | -3.66\*\*\* | 2.94 |
| Feed per day | 1.82 | 0.05 | 1.78 | 0.05 | 0.65 | 1.83 | 0.04 | 1.75 | 0.06 | 1.12 | 1.79 |
| Total family | 6.06 | 0.19 | 7.59 | 0.18 | -5.62\*\*\* | 6.47 | 0.18 | 7.55 | 0.22 | -3.77\*\*\* | 6.93 |

Source: survey result, 2024

**3.2. Feeding Practices of Sample Respondents**

In cases of Sidama, the majority of feed sources were natural pasture (82.35%), crop residue (65%), and cut and carry technique of the natural pasture (45%). Concentrate feed (42.5%) and improved forage (17.5%) came at the bottom of the rank. This is because the preparation of the concentrate feed at home requires knowledge, whereas purchasing it requires money. Improved forage access is limited. In the same way, natural pasture (82.35%), cut and carry (49.02%) and crop residues (43.14) take the upper hand as the sources of feed in Gedeo zone. In Halaba areas, in addition to natural pasture and crop residue, hay making is customary as the area is cash crop environment.

**Table 4 Summary of feeding Practices**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Feed type | Sidama (N=40) | | Gedeo(N=51) | | Halaba(N=50) | | Total(N=141) | |
| Freq | % | Freq | % | Freq | % | Freq | % |
| Concentrate | 17 | 42.5 | 10 | 19.61 | 14 | 28.0 | 41 | 29.08 |
| Improved forage | 7 | 17.5 | 6 | 11.76 | 5 | 10.0 | 18 | 12.77 |
| Natural pasture | 33 | 82.5 | 42 | 82.35 | 44 | 88.0 | 119 | 84.40 |
| Crop residue | 26 | 65.0 | 22 | 43.14 | 35 | 70.0 | 83 | 58.87 |
| Cut and carry | 18 | 45.0 | 25 | 49.02 | 21 | 42.0 | 64 | 45.39 |
| Hay | - | - | - | - | 46 | 92.0 | 46 | 32.62 |

Source: survey result, 2024

**3.3. Housing and Watering Conditions**

The majority (62.41%) of the respondents reported to have housed their cattle in main house together with family. If possible, separate house construction is of paramount importance to keep the health of livestock safe and dwelling home clean and convenient. The watering frequency of livestock, specifically cattle was once and twice majorly (Table 5).

**Table 5 Housing &watering**

|  |  |  |
| --- | --- | --- |
| **Housing (N=141)** | Freq | % |
| Main house | 88 | 62.41 |
| Separately | 53 | 37.59 |
| **Watering frequency(N=141)** |  |  |
| Once | 74 | 52.48 |
| Twice | 50 | 35.46 |
| Every other day | - | - |
| Freely available | 17 | 12.06 |

Source: survey result, 2024

**3.4. Factors Affecting AI and ES Adoption**

Before running the model, relevant statistical tests were conducted as a precondition. The mean VIF was 1.15, which was evidence not to worry about multicollinearity (Appendix Table 3). Heteroscedasticity was also not prevalent in the data with the test statistics of chi2 (1) = 1.49 and Prob > chi2 = 0.2225 (Appendix Figure 1). This result is interpreted as we fail to reject the null hypothesis for Constant variance as per the result of Breusch-Pagan / Cook-Weisberg test for heteroscedasticity. The overall fitness of the model was good with a number of statistical values. The probability value was highly significant (Prob>chi2=0.0000) with Wald chi2 (22) = 60.00. Ten explanatory variables were used in the model, out of which five were significant on AI side and three were significant on ES side.

**Education level:** It was statistically significant at five percent significance level (*P*=.015) and positively related to AI adoption. Average marginal effects show that as education level increases in one grade level, the probability of adopting artificial insemination increases by 5.99%. The probable reasons might have been that education makes farmers aware and adopt agricultural technologies. This result was in line with the findings which indicated direct positive relationship between education and adoption of estrus synchronization and artificial insemination (Gebre et al., 2022; Adem and Abebe, 2022).

**Distance to AI station:** It was statistically significant at five percent significance level(*P*=.013) and negatively related to AI adoption. Average marginal effects indicates that as distance to AI station increases by one kilometer, the probability of adopting artificial insemination decreases by 10.55%. The implication is that distance becomes a barrier for farmers and prevents easy access to the technology whenever they need. This finding is in line with studies which implicated negative impact of a greater distance of AI stations from farmers home (Tefera, 2014).

**Heard failure on AI:** It was statistically significant in case of AI at ten percent (*P*=.050) and in case of ES at one percent(*P*=.002) and was negatively related to the adoption of both AI and ES. Average marginal effects show that for those who heard failure information on AI relative to those who didn’t hear, the probability of adopting artificial insemination and estrous synchronization decreases by 12.40% and 19.30% respectively. The probable implication is that farmers may be discouraged from participating in technologies they don’t trust its efficiency if they get bad information and misled by their neighbors. Study by Tefera (2014) indicated access to AI information as significantly enhancing adoption likelihood of AI.

**Mobile ownership:** It was statistically significant at one percent significance for both AI and ES (*P*=.000) and was positively related to the adoption of both AI and ES. Average marginal effects show that for those who mobile phones relative to those who didn’t have, the probability of adopting artificial insemination and estrous synchronization increase by +25.52% and 31.88% respectively. The implication is that better communication with development agents in all available means of communication helps them to adopt technologies.

**Total family:** It was statistically significant at ten percent significance level (*P*=.065) and positively related to AI adoption. Average marginal effects show that as total family size increases by one, the probability of adopting artificial insemination increases by 4.59%. The probable reasons might have been that the household with more family member better afford to take their cattle to AI stations even if some of the family members are assigned for different tasks (Tefera, 2014).

**Extension contact frequency:** It was statistically significant at one percent significance level (*P*=.005) and positively related to ES adoption. Average marginal effects show that as extension contact frequency in a year increases by one, the probability of adopting estrous synchronization increases by 8.74%. The implication is that extension contact in frequent sequence helps to better adopt agricultural technologies (Adem and Abebe, 2022).

**Table 6 model results for determinants of AI and ES adoption**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Coefficient | Standard error | Z | P>Z |
| **AI** |  |  |  |  |
| Education level\*\* | .4190592 | .1729024 | 2.42 | 0.015 |
| TLU | .5138085 | .5101419 | 1.01 | 0.314 |
| Age | .0371479 | .128222 | 0.29 | 0.772 |
| Age2 | -.0004925 | .0014289 | -0.34 | 0.730 |
| Distance to AI station\*\* | -.7380225 | .2978158 | -2.48 | 0.013 |
| Heard failure on AI\* | -.8678716 | .4431766 | -1.96 | 0.050 |
| Extension contact frequency | .272517 | .216883 | 1.26 | 0.209 |
| Mobile ownership\*\*\* | 1.785664 | .4235055 | 4.22 | 0.000 |
| Feed per day | -.4264517 | .5365805 | -0.79 | 0.427 |
| Total family size\* | .3215362 | .1740078 | 1.85 | 0.065 |
| Improved feed use | -.5404535 | .3712164 | -1.46 | 0.145 |
| \_cons | -2.024185 | 3.397803 | -0.60 | 0.551 |
|  |  |  |  |  |
| **ES** |  |  |  |  |
|  |  |  |  |  |
| Education level | .0909314 | .0944739 | 0.96 | 0.336 |
| TLU | .4414554 | .3385956 | 1.30 | 0.192 |
| Age | .0887229 | .0978356 | 0.91 | 0.364 |
| Age2 | -.001323 | .0011238 | -1.18 | 0.239 |
| Distance to AI station | -.5926788 | .3742401 | -1.58 | 0.113 |
| Heard failure on AI\*\*\* | -.9179505 | .2968202 | -3.09 | 0.002 |
| Extension contact frequency\*\*\* | .4157865 | .1479243 | 2.81 | 0.005 |
| Mobile ownership\*\*\* | 1.516663 | .3240382 | 4.68 | 0.000 |
| Feed per day | -.6049717 | .3862417 | -1.57 | 0.117 |
| Total family size | .094197 | .103569 | 0.91 | 0.363 |
| Improved feed use | -.3695884 | .2963995 | -1.25 | 0.212 |
| \_cons | -.6188812 | 3.202917 | -0.19 | 0.847 |
|  |  |  |  |  |
| /athrho | 13.81741 | 1171.21 | 0.01 | 0.991 |
|  |  |  |  |  |
| rho | 1 | 4.67e-09 | CI -1 1 | |
|  |  |  |  |

Source: survey result, 2024

**Table 7 Average marginal effects**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Varable | Average marginal effects | | | |
| Expression: Pr(AI=1), predict(pmarg1)  dy/dx w.r.t. : Xs | | Expression: Pr(ES=1), predict(pmarg2)  dy/dx w.r.t. : Xs | |
| Educ | 0.0598798 | +5.99% |  |  |
| DistAI | -0.1054567 | -10.55% |  |  |
| Herdfailure | -0.124011 | -12.40% | -0.1929607 | - 19.30% |
| Mobile | 0.2551552 | +25.52% | 0.3188148 | +31.88% |
| Totfam | 0.0459446 | +4.59% |  |  |
| Extcont |  |  | 0.0874017 | +8.74% |

Source: survey result, 2024

**3.5. Ranked Constraints in ES & AI Utilization**

As Table 8 indicates, limitation of access confined to casual launching (71.63%), insufficient equipment and inputs for running the services of AI and ES (66.67%) and shortages of AI technicians (64.53%) take the upper hand in one up to three in rank. It is important to prioritize and work on each of the ranked constraints to ensure the continuous utilization and sustainability of the service.

**Table 8 Summary of Ranked Constraints in ES & AI Utilization**

|  |  |  |  |
| --- | --- | --- | --- |
| Constraints in ES and AI utilization | Freq | % | Rank |
| Delay of AI technicians after farmers had detected heat | 84 | 59.57 | 5 |
| Shortage of supplementary feed | 72 | 51.06 | 7 |
| Insufficient on farm implementation of the services | 75 | 53.19 | 6 |
| Indiscriminate application of AI on every available cows without considering body condition | 66 | 46.80 | 8 |
| Tendency of farmers not to repeat the service once encountered failure | 57 | 40.43 | 9 |
| Insufficient equipments and inputs for the delivery of service | 94 | 66.67 | 2 |
| Efficiency and specialization problems on AITs side | 89 | 63.12 | 4 |
| Shortage of AITs | 91 | 64.53 | 3 |
| Limitation of access which is confined to annual launching | 101 | 71.63 | 1 |

Source: survey result, 2024

**4. CONCLUSION AND RECOMMENDATIONS**

Education level, distance to AI station, heard information on failure of AI, mobile ownership, total family, and extension contact frequency were significant determinants of adoption of artificial insemination and estrous synchronization technology. Delay of AI technicians after farmers had detected heat , shortage of supplementary feed insufficient on farm implementation of the services , indiscriminate application of ai on every available cows ,tendency of farmers not to repeat the service once encountered failure ,insufficient equipment and inputs for the delivery of service , efficiency and specialization problems on technicians of AI side, shortage of technicians and limitation of access which is confined to annual launching are constraints for sustainable utilization of AI and ES service.

As per the result, AI technicians and farm owners need continuous training to improve their heat detection skills, increase their knowledge, and obtain a successful program. Focusing on-farm implementation in place of annual launching to increase accessibility of the technology and to minimize distance barriers is required. Also working to fulfill inputs and equipment with stakeholders is required to increase the efficiency of the service. Expanding professional schemes of opportunity for AITs to specialize on the area either in short term training/ long term education opportunity are necessary measures to fill the gap of knowledge. Working on development of improved/supplementary feed is also required as feed goes hand in hand with better body condition for efficiency of the technology. Provision of printed guidelines for AITs in local language is important as it helps to ease barriers. Raising awareness of farmers who discontinued usage in frustration on re using the technologies after failures is necessary for continuation of the service. Where possible, AITs need to avail their phone number to those who afford to call to their farm. The number of AITs needs to be availed at kebele level as many are delivering service by touring from urban seat of offices to rural areas in inconvenient conditions. Local AI stations should be functional at every time-of-service requirement.

Consent (where ever applicable)

Study participants were informed that their personal identity will not be disclosed in any form in this study and the information they provided was used solely for the purpose of the study. Ahead of the study, their willingness to participate was asked and the objectives of the study were clearly indicated.

References

Adem, N., & Abebe, A. (2022). Determinants of adoption of artificial insemination for dairy production: In case of Zala Woreda, Gofa Zone, Southern Ethiopia. *Archives of Current Research International, 22*(1), 7–15.

Bearden, H. J., & Willard, S. T. (2004). *Applied animal reproduction* (6th ed.). Pearson Prentice Hall.

Bekele, T. (2005). Calf sex ratios in artificially inseminated and natural mated female crossbred dairy herd. In *Proceedings of the 13th Annual Conference of the Ethiopian Society of Animal Production* (pp. 225–230). Addis Ababa, Ethiopia.

Central Statistical Agency (CSA). (2017). *Agricultural sample survey 2016/17: Volume II – Report on livestock and livestock characteristics (Private Peasant Holdings)*. Statistical Bulletin No. 585. CSA.

Dekeba, A., Ayalew, W., Hedge, P. B., & Taddese, Z. (2006). Performance of the Abernossa Ranch in the production of Ethiopian Boran × Holstein crossbred dairy heifers in Ethiopia. *Ethiopian Journal of Animal Production, 6*(2), 33–53.

Gebre, Y. H., Gebru, G. W., & Gebre, K. T. (2022). Adoption of artificial insemination technology and its intensity of use in Eastern Tigray National Regional State of Ethiopia. *Agriculture & Food Security, 11*, 44. <https://doi.org/10.1186/s40066-022-00384-3>

GebreMedhin, D. (2005). *All in one: A practical guide to dairy farming* (pp. 15–21). Agri-Service Ethiopia Printing Unit.

Greene, W. H. (2018). Econometric analysis/Limdep user’s manual.

Shiferaw, Y., Tenhagen, B. A., Bekana, M., & Kassa, T. (2003). Reproductive performance of crossbred dairy cows in different production systems in the central highlands of Ethiopia. *Tropical Animal Health and Production, 35*(6), 551–561. <https://doi.org/10.1023/A:1027377722576>

Sinishaw, W. (2005). Study on semen quality and field efficiency of AI bulls kept at the National Artificial Insemination Center. *Debre Zeit, 53*(2), 135–138.

Tefera, S. S. (2014). *Determinants of artificial insemination use by smallholder dairy farmers in Lemu-Bilbilo District, Ethiopia* (Doctoral dissertation, Egerton University).

Webb, D. W. (2003). *Artificial insemination in cattle*. University of Florida, Gainesville. IFAS Extension, DS 58, 1–4.

Yemane, B., Chernet, T., & Shiferaw, T. (1993). *Improved cattle breeding*. National Artificial Insemination Centre.

Definitions, Acronyms, Abbreviations

|  |  |
| --- | --- |
| Acronym | Meaning |
| AI | Artificial Insemination |
| AITs | Artificial Insemination Technicians |
| CSA | Central Statistical Agency |
| ES | Estrus synchronization |

APPENDIX

**Appendix Table 1 coefficients of model results**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Coeff. | Std. Err. | Z | P>Z | CI |  |
|  |  |  |  |  |  |
| AI |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| Educ | .4190592 | .1729024 | 2.42 | 0.015 | .0801767 | .7579417 |
|  |  |  |  |  |  |  |
| TLU | .5138085 | .5101419 | 1.01 | 0.314 | -.4860512 | 1.513668 |
| Age | .0371479 | .128222 | 0.29 | 0.772 | -.2141627 | .2884585 |
| Age2 | -.0004925 | .0014289 | -0.34 | 0.730 | -.0032931 | .0023082 |
| DistAI | -.7380225 | .2978158 | -2.48 | 0.013 | -1.321731 | -.1543143 |
| Herdfailure | -.8678716 | .4431766 | -1.96 | 0.050 | -1.736482 | .0007385 |
| Extcont | .272517 | .216883 | 1.26 | 0.209 | -.1525659 | .6975999 |
| Mobile | 1.785664 | .4235055 | 4.22 | 0.000 | .9556085 | 2.61572 |
| Feedperday | -.4264517 | .5365805 | -0.79 | 0.427 | -1.47813 | .6252268 |
| Totfam | .3215362 | .1740078 | 1.85 | 0.065 | -.0195129 | .6625854 |
| Impfeed | -.5404535 | .3712164 | -1.46 | 0.145 | -1.268024 | .1871173 |
| \_cons | -2.024185 | 3.397803 | -0.60 | 0.551 | -8.683757 | 4.635387 |
|  |  |  |  |  |  |  |
| ES |  |  |  |  |  |  |
| Educ | .0909314 | .0944739 | 0.96 | 0.336 | -.094234 | .2760968 |
| TLU | .4414554 | .3385956 | 1.30 | 0.192 | -.2221798 | 1.105091 |
| Age | .0887229 | .0978356 | 0.91 | 0.364 | -.1030313 | .2804772 |
| Age2 | -.001323 | .0011238 | -1.18 | 0.239 | -.0035256 | .0008797 |
| DistAI | -.5926788 | .3742401 | -1.58 | 0.113 | -1.326176 | .1408183 |
| Herdfailure | -.9179505 | .2968202 | -3.09 | 0.002 | -1.499707 | -.3361936 |
| Extcont | .4157865 | .1479243 | 2.81 | 0.005 | .1258601 | .7057129 |
| Mobile | 1.516663 | .3240382 | 4.68 | 0.000 | .8815594 | 2.151766 |
| Feedperday | -.6049717 | .3862417 | -1.57 | 0.117 | -1.361991 | .152048 |
| Totfam | .094197 | .103569 | 0.91 | 0.363 | -.1087945 | .2971885 |
| Impfeed | -.3695884 | .2963995 | -1.25 | 0.212 | -.9505207 | .211344 |
| \_cons | -.6188812 | 3.202917 | -0.19 | 0.847 | -6.896483 | 5.658721 |
|  |  |  |  |  |  |  |
| /athrho | 13.81741 | 1171.21 | 0.01 | 0.991 | -2281.713 | 2309.348 |
|  |  |  |  |  |  |  |
| rho | 1 | 4.67e-09 |  | -1 | 1 |  |
|  |  |  |  |  |  |  |

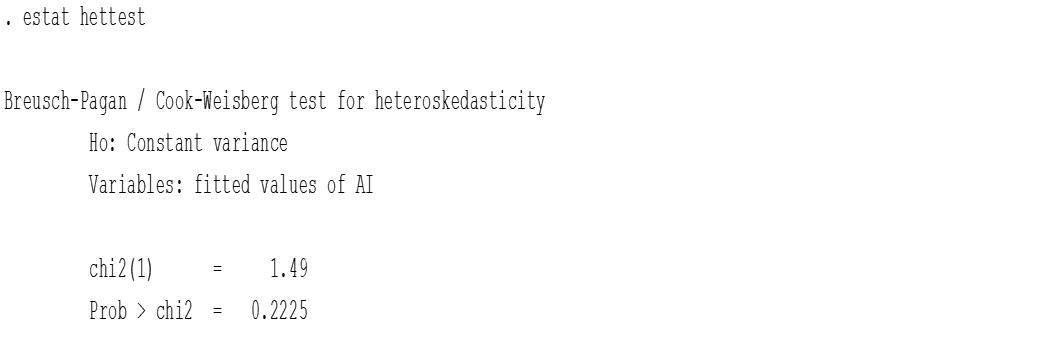
**Appendix Table 2 mfx results**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| variable dy/dx | Std. Err. | z | P>z | [ 95% | C.I. ] | X |
|  |  |  |  |  |  |  |
| Educ .0320747 | .03295 | 0.97 | 0.330 | -.032514 | .096664 | 5.87943 |
| TLU .155717 | .11768 | 1.32 | 0.186 | -.074941 | .386375 | 1.64219 |
| Age .0312957 | .03419 | 0.92 | 0.360 | -.03571 | .098301 | 39.7021 |
| Age2 -.0004667 | .00039 | -1.19 | 0.233 | -.001234 | .0003 | 1721.26 |
| DistAI -.2090589 | .12814 | -1.63 | 0.103 | -.460201 | .042083 | 5.43506 |
| Herdfa~e\* -.3289128 | .10563 | -3.11 | 0.002 | -.535945 | -.121881 | .609929 |
| Extcont .1466627 | .0488 | 3.01 | 0.003 | .051011 | .242314 | 2.93617 |
| Mobile\* .4810954 | .08532 | 5.64 | 0.000 | .313864 | .648327 | .553191 |
| Feedpe~y -.2133951 | .13452 | -1.59 | 0.113 | -.47704 | .05025 | 1.79433 |
| Totfam .0332266 | .03628 | 0.92 | 0.360 | -.037877 | .10433 | 6.92908 |
| Impfeed\* -.1324707 | .10728 | -1.23 | 0.217 | -.342745 | .077803 | .617021 |
|  |  |  |  |  |  |  |

**Appendix Table 3 Tests of multicollinearity**

|  |  |  |
| --- | --- | --- |
| Variable | VIF | 1/VIF |
|  |  |  |
| Mobile | 1.35 | 0.738337 |
| Educ | 1.29 | 0.777129 |
| DistAI | 1.24 | 0.803398 |
| Totfam | 1.18 | 0.850078 |
| Impfeed | 1.10 | 0.909422 |
| Extcont | 1.10 | 0.911575 |
| TLU | 1.09 | 0.921490 |
| Age | 1.07 | 0.934513 |
| Feedperday | 1.05 | 0.954330 |
| Herdfailure | 1.03 | 0.970818 |
|  |  |  |
| Mean VIF | 1.15 |  |

**Appendix Figure 1 Tests of heteroskedasticity**

****