

Dissertation Ref. No.055/06/2020



**ARTIFICIAL INSEMINATION SERVICE DELIVERY SYSTEM IN THE
ETHIOPIAN DAIRY INDUSTRY: EVALUATION OF SEMEN SUPPLY CHAIN
AND QUALITY**

PhD Dissertation

By

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**Addis Ababa University, College of Veterinary Medicine and Agriculture,
Department of Animal Production Studies
PhD Program in Animal Production**

June, 2020

Debre Zeit, Ethiopia

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ETHIOPIAN DAIRY INDUSTRY: EVALUATION OF SEMEN SUPPLY CHAIN
AND QUALITY



A dissertation submitted to the College of Veterinary Medicine and Agriculture of Addis Ababa University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Animal Production.

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DEDICATION

To myself!

STATEMENT OF AUTHOR

First, I declare that this dissertation is my *bonafide* work and that all sources of materials used for this dissertation have been duly acknowledged. This dissertation has been submitted in partial fulfillment of the requirements for a PhD degree at the Addis Ababa University, College of Veterinary Medicine and Agriculture and is deposited at the University Library to be made available to borrowers under rules of the Library. I solemnly declare that this dissertation is not submitted to any other academic institution anywhere for the award of any academic degree, diploma or certificate.

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The author of this PhD dissertation was born in 1978 in Addis Ababa, Ethiopia. He attended his elementary school from 1984 to 1992 in May Day and Dejazmach Geneme primary and elementary schools in Addis Ababa and completed his secondary education at Medhane Alem Secondary school in 1997.

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He then joined Hawassa University, school of graduate studies in September 2006 to pursue his study for M.Sc degree in Animal and Range Sciences (specialization Dairy Sciences). After his graduation, he served EIAR as a researcher at Debre Zeit Agricultural Research Center till 2016. He then joined the school of graduate studies of College of Veterinary Medicine and Agriculture of Addis Ababa University in 2016 to pursue PhD study in Animal Production. He is married and a father of three sons.

ACKNOWLEDGEMENTS

It is very difficult to be a father, sometimes a single parent, full-time employee and a student at the same time. But the almighty God made this possible with his support and blessings. Thank you, GOD. Without You, nothing would ever have been possible.

I would like to express my sincere gratitude to my supervisors, Dr. Ashenafi Mengistu and Dr. Diriba Geleti for their guidance, technical advice and encouragement from the inception of the research proposal to the end of dissertation writing. I am also grateful to Dr. Zelalem Yilma for his kindness, encouragement, critical review of the research proposal and the dissertation.

I deeply thank Land O'Lakes Venture 37 for financing part of the research activities and allowing me to use the data for academic purpose. A note of thanks is also extended to small but all staff of Land O'Lakes Venture 37: Haimanot, Tewodros, Seare and Bisrat for their support, encouragement, and understanding.

I strongly appreciate, Debebe Admasu, Demelash Aychile, Mequanint Damite, Ahmed Alkadir, Jemal Gidey, Tadesse Gugsa, Tewelde Mehari, Wolde Kebede, Mulugeta Tesfaye, Dereje Dirbaba, Dr. Dereje Birhanu, Kedjela Tessema, Shibre Fekadu, Mamo Gobena, Wondwossen Eshetu and Bula Agegnehu for your significant contribution in the process of data collection and participation in the FGDs.

My special thanks also to Adey Melesse and Aemiro Mussie for your friendship, moral support, and encouragement. My thanks also go to my sister Misrak Fisseha and her husband Seifu Dabesa for covering my medical costs during my stay in India and Yenenesh Temesgen for hosting me during the treatment period.

Last but not the least, I would like to thank my family: my mom, my wife, my kids, my sisters and brothers for their continuous and unparalleled love and supporting me morally and spiritually throughout writing this thesis and my life in general.

LIST OF ABBREVIATIONS

AI	Artificial Insemination
AAIC	Assela Artificial Insemination Center
AGP	Agricultural Growth Program
AIC	Artificial Insemination Center
ATVET	Agricultural, Technical, Educational and Vocational Training
CADU	Chilalo Agricultural Development Unit
CASA	Computer Assisted Semen Analyzer
CR	Calving Rate
CSA	Central Statistical Agency
DAGRIS	Domestic Animal Genetic Resource Information System
DAIDS	Domestic Animal Diversity Information System
DDA	Dairy Development Agency
EIBC	Ethiopian Institute of Biodiversity Conservation
ETB	Ethiopian Birr
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GLM	General Linear Model
HF	Holstein Friesian
KII	Key Informants Interview
LMD	Livestock Market Development
LN ₂	Liquid Nitrogen
LSD	Least Significant Difference
m.a.s.l	Meter Above Sea Level
MoA	Ministry of Agriculture
NAGII	National Animal Genetic Improvement Institute
NAIC	National Artificial Insemination Center
PAID	Public Private Partnership for Artificial Insemination Delivery
PD	Pregnancy Diagnosis
SAS	Statistical Analysis System
SE	Standard Error

SNNP	Southern Nations Nationalities and Peoples
SPC	Service Per Conception
SPSS	Statistical Package for Social Science

TABLE OF CONTENTS

DEDICATIONv

STATEMENT OF AUTHOR vi

BIOGRAPHICAL SKETCH..... vii

ACKNOWLEDGEMENTS viii

LIST OF ABBREVIATIONS ix

TABLE OF CONTENTS xi

LIST OF TABLES..... xvi

LIST OF FIGURES xviii

LIST OF APPENDICESxx

ABSTRACT..... xxi

1. INTRODUCTION1

2. LITERATURE REVIEW7

 2.1. Snapshot of the Ethiopian Dairy Sector7

 2.2. Milk Production System.....8

 2.2.1. Urban Milk Production System 9

 2.2.2. Peri-Urban Milk Production System..... 9

 2.2.3. Rural Milk Production System..... 9

 2.3. Milk and Milk Products Marketing.....10

 2.4. Dairy Cattle Breeds11

 2.5. Artificial Insemination12

 2.5.1. Technology Innovation 12

 2.5.2. Advantages of AI Service 13

 2.5.3. Limitations of AI Service..... 13

 2.5.4. Success of AI Service Delivery System..... 14

 2.5.5. AI Service in Ethiopia and Its Management 15

 2.6. Factors Affecting Efficiency of AI Delivery system17

2.7.	Factors Affecting Adoption of Agricultural Technology.....	18
2.7.1.	Age of the household head.....	18
2.7.2.	Education	18
2.7.3.	Gender of Farmer	19
2.7.4.	Household Income	19
2.7.5.	Farm Size	19
2.7.6.	Farming Experience	20
2.7.7.	Frequency of Contact with Extension or Source of Information	20
2.8.	Semen Handling and Quality	20
2.9.	Liquid Nitrogen Production and Supply Chain.....	22
3.	MATERIALS AND METHODS.....	25
3.1.	Study Areas and Description.....	25
3.1.1.	Amhara Region	25
3.1.2.	Oromia region	26
3.1.3.	Southern Nations Nationalities and Peoples (SNNP) region.....	27
3.1.4.	Tigray region.....	28
3.2.	Study Components	28
3.3.	Data Collection Tools.....	29
3.3.1.	Surveys.....	29
3.3.2.	Key Informant Interviews - KII	30
3.3.3.	Focus Group Discussions (FGDs)	31
3.3.4.	AI Technicians' Field Performance Recording	31
3.3.5.	Calving Survey.....	31
3.4.	Secondary Data	33
3.5.	Semen Quality Analysis	33
3.5.1.	Semen Collection, Processing and Cryopreservation	33
3.5.2.	Sample Size.....	34
3.5.3.	Laboratory Analysis.....	35
3.6.	Data Analysis	36

4. RESULTS.....	37
4.1. An Overview of Ethiopian Dairy Cattle Population and Productivity Trend	37
4.1.1. The Data Used and Limitations	37
4.1.2. Trend in Cattle Population	38
4.1.3. Trend in Dairy and Milking Cows	41
4.1.4. Trend in Milk Production and Lactation Length	42
4.1.5. Cattle Population Trend in Amhara, Oromia, SNNP and Tigray regions ..	43
4.2. Evaluation of AI Service Input and Equipment Supply System	46
4.2.1. Access to Semen and Liquid Nitrogen.....	46
4.2.2. Source of Semen	47
4.2.3. Semen Quality Check	48
4.2.4. Access to Basic AI Equipment	48
4.2.5. Fuel Allowance and Criteria	51
4.2.6. Semen Production and Supply Chain	52
4.2.7. Liquid Nitrogen Production and Supply Chain	57
4.2.8. Semen Quality along Semen Supply Chain.....	61
4.3. Evaluation of AI Delivery System	65
4.3.1. Characteristics of AI Technicians	65
4.3.2. Characteristics of Farmers	72
4.3.3. Number of Working Days Per Week	76
4.3.4. Site of AI Service and Proportion.....	77
4.3.5. Traveling Distance for AI Service Delivery	78
4.3.6. Distance of Insemination Site from farm Gates.....	79
4.3.7. Demand for AI Service	80
4.3.8. Determining Sire Breed	80
4.3.9. Thawing Practice	81
4.3.10. Price of AI Service.....	82
4.3.11. Mean of Transportation and Communication	83
4.3.12. Access to AI Service.....	84
4.3.13. AI Related Services Provided to Farmers.....	85

4.3.14.	Seasonality of AI service	86
4.3.15.	Preference for AI and Bull Service	89
4.3.16.	Source of Breeding Bull.....	89
4.3.17.	Price of Bull Service	89
4.4.	Evaluation of AI Technicians Performance and Efficiency.....	90
4.4.1.	Number of AI Services Provided.....	90
4.4.2.	Service Per Conception.....	92
4.4.3.	Conception and Calving Rates.....	93
4.4.4.	Performance Reports form NAIC	94
4.5.	Evaluation of Government Led Heat Synchronization and Mass Insemination Campaigns.....	95
4.5.1.	Time of Synchronization Campaigns.....	96
4.5.2.	Number of Animals to be Synchronized and Factors Considered.....	96
4.5.3.	Selection of AI Technicians for Synchronization Campaigns.....	98
4.5.4.	Selection of Animals for Synchronization.....	98
4.6.	Adoption of Dairy Cattle Husbandry and Management Practices	99
4.6.1.	Experience of Farmers in AI Technology.....	99
4.6.2.	Farmers Satisfaction in AI Service Delivery	100
4.6.3.	Dairy Cattle Husbandry and Management Practices	100
4.6.4.	Application of Improved Husbandry Practices.....	103
4.6.5.	Access to Livestock Extension	104
4.6.6.	Dairy Cattle Breeding	104
4.6.7.	Perception on Calf Sex.....	105
5.	DISCUSSION.....	108
5.1.	Evaluation of the Ethiopian Dairy Cattle Population and Productivity Trend..	108
5.2.	Evaluation of AI Service Input Supply and Equipment supply System	112
5.2.1.	Fuel Allowance and Criteria	114
5.2.2.	Semen Production and Supply Chain	115
5.2.3.	Liquid Nitrogen Production and Supply Chain	116
5.2.4.	Evaluation of Semen Quality along Semen Supply Chain	119

5.3.	Evaluation of AI Delivery system.....	121
5.3.1.	Characteristics of AI Technicians.....	121
5.3.2.	Characteristics of Farmers	127
5.3.3.	Number of Working Days Per Week	135
5.3.4.	Demand, Site and Proportion AI service	136
5.3.5.	Traveling Distance for AI Service Delivery	138
5.3.6.	Determining Sire Breed	139
5.3.7.	Thawing Practice	140
5.3.8.	Price of AI Service.....	140
5.3.9.	AI Related Services Provided to Farmers.....	141
5.4.	Evaluation of AI Technicians Performance and Efficiency.....	142
5.4.1.	Performance of AI Technicians and Seasonality of AI Service	142
5.4.2.	Service Per Conception, Conception and Calving Rates	144
5.4.3.	Problems Associated with Reporting.....	145
5.5.	Evaluation of Government led Heat Synchronization and Mass Insemination Campaigns.....	146
6.	CONCLUSION AND RECOMMENDATION.....	149
7.	REFERENCE.....	154
8.	APENDICES	171

LIST OF TABLES

Table 1. Sample size of farmers used for calving survey	32
Table 2. Sampling layout for semen straw samples in Amhara, Oromia, SNNP and Tigray regions	34
Table 3. Semen distributed to Amhara, Oromia, SNNP and Tigray regions from NAIC	57
Table 4. Liquid nitrogen plants available in the country and status	58
Table 5. Post-thaw total and progressive motility, normal and defective morphology of sperm of semen taken at various chains (Mean±SE).....	62
Table 6. Post thaw total motility, progressive motility, normal morphology and sperm number assessed for semen samples taken from various regions of Ethiopia (Mean±SE).....	63
Table 7. Educational status of AI technicians in Amhara, Oromia, SNNP and Tigray regions (2016).....	66
Table 8. Educational status of AI technicians in Amhara, Oromia, SNNP and Tigray regions (2019).....	66
Table 9. Total and average number of AI technicians available in each zone of Amhara region in 2016/17.....	68
Table 10. Number of AI technicians and cattle of breeding age, and animals to AI technician ratio in Amhara, Oromia, SNNP and Tigray regions.....	69
Table 11. Duration of AI technicians training in Amhara, Oromia, SNNP and Tigray regions	70
Table 12. Family size of dairy farming households in Amhara, Oromia, SNNP and Tigray Regions (Mean±SE)	73
Table 13. Income (Mean ETB±SE) from different sources per household per month (July 2018) in Amhara, Oromia, SNNP and Tigray regions	74
Table 14. Cattle herd size (Mean±SE) of the dairy farming households in Amhara, Oromia, SNNP and Tigray regions.....	75
Table 15. Proportion of AI services at the farm gate and woreda/kebele site in Amhara, Oromia, SNNP and Tigray region	78
Table 16. Distance covered by AI technicians during regular and peak season of the year in Amhara, Oromia, SNNP and Tigray regions (Mean±SE).....	79

Table 17. Number of kebeles assigned per AI technician and potential farmers who need AI service in Amhara, Oromia, SNNP and Tigray regions (Mean±SE)	80
Table 18. Thawing temperature, thawing time and time between thawing and insemination in Amhara, Oromia, SNNP and Tigray regions (Mean±SE).....	82
Table 19. Price (ETB) of AI in Amhara, Oromia, SNNP and Tigray regions – July 2018	83
Table 20. Other mode of transportation in AI service delivery system in Amhara, Oromia, SNNP and Tigray regions.....	84
Table 21. Average number of AI services provided per day per AI tech during regular, peak and off season in Amhara, Oromia, SNNP and Tigray regions (Mean±SE).....	90
Table 22. Average number of AI Services Provided Per Month	92
Table 23. Number of cows inseminated, conceived and calved; conception and calving rates in Amhara, Oromia, SNNP and Tigray Regions.....	94
Table 24. Number of animals synchronized, inseminated and conceived in a synchronization campaigns in Amhara, Oromia, SNNP and Tigray regions.....	97
Table 25. Years of bull and AI service use in Amhara, Oromia, SNNP and Tigray regions	105

LIST OF FIGURES

Figure 1. Map of Amhara, Oromia, SNNP and Tigray Regions.....	25
Figure 2. Computer Assisted Semen Analyzer (CASA) used in the analysis of Semen quality	35
Figure 3. Trend in indigenous (left), cross and exotic breed (right) cattle population in Ethiopia from 2004/5 to 2017/18.....	38
Figure 4. Percentage change (from previous year) in indigenous and crossbreed cattle population in Ethiopia from 2004/5 to 2017/18	39
Figure 5. Cumulative percent change in the indigenous and crossbreed cattle population in Ethiopia from 2004/5 to 2017/18.....	39
Figure 6. Proportion of cross and exotic cattle population from total cattle population in Ethiopia from 2004/5 to 2017/18.....	40
Figure 7. Percentage of cows calved from 2005/6 to 2017/18	41
Figure 8. Trend in dairy and milking cow population of Ethiopia from 2004/5 to 2017/18	42
Figure 9. Trend in milk production and lactation length national level, Ethiopia from 2004/5 to 2017/18.....	42
Figure 10. Trend in indigenous cattle population in Amhara, Oromia, SNNP and Tigray regions from 2004/5 to 2017/8	43
Figure 11. Trend in cross breed cattle population in Amhara, Oromia, SNNP and Tigray regions from 2004/5 to 2017/8	44
Figure 12. Trend in exotic cattle population in Amhara, Oromia, SNNP and Tigray regions from 2004/5 to 2017/8	45
Figure 13. Proportion of cross and exotic cattle population from total cattle population in Amhara, Oromia, SNNP, Tigray regions and in Ethiopia from 2004/5 to 2017/18..	46
Figure 14. Availability of basic AI equipment in Amhara, Oromia, SNNP and Tigray regions	50
Figure 15. Criteria considered during fuel allocation in Amhara, Oromia, SNNP and Tigray Regions	52
Figure 16. Bulls used for Semen production – HF breed (left) and Jersey breed (right)..	53
Figure 17. Semen production and distribution from NAIC from 2009/10 to 2017/18	53

Figure 18. Semen production from regional semen production and processing laboratories from Sep 2017 to Oct 2018.....	56
Figure 19. Semen production from NAIC from Sep 2017 to Oct 2018.....	56
Figure 20. Liquid nitrogen plant in Bahir Dar town, Amhara region.....	59
Figure 21. Thirty-five liters liquid nitrogen containers used for transportation and storage	60
Figure 22. Farmers experience in dairying in Amhara, Oromia, SNNP and Tigray regions	76
Figure 23. AI service delivery at kebele site in Tigray region.....	77
Figure 24. Seasonality of AI service provision in Amhara, Oromia, SNNP and Tigray regions	87
Figure 25. Seasonality of AI service in Amhara, Oromia, SNNP and Tigray regions based on the number of AI services provided from October 2016 to December 2018. Q1= June, July and August; Q2 = September, October and November; Q3 = December, January and February; Q4 = March, April and May	88
Figure 26. Overall seasonality of AI service based on the number of AI services provided from October 2016 to December 2018. Q1= June, July and August; Q2 = September, October and November; Q3 = December, January and February; Q4 = March, April and May	88
Figure 27. Number of reported inseminations and confirmed pregnancies from 2009/2010 to 2013/14 in Ethiopia	95
Figure 28. Timing of Synchronization campaigns in Amhara, Oromia, SNNP and Tigray regions	96
Figure 29. Frequency of AI service received in the last twelve months in Amhara, Oromia, SNNP and Tigray regions.....	99
Figure 30. Farmers with improved dairy husbandry and management practices in Amhara, Oromia, SNNP and Tigray regions.....	104
Figure 31. Farmers' perception on calf sex as a result of AI in Amhara, Oromia, SNNP and Tigray regions.....	107

LIST OF APPENDICES

Appendix 1. Questionnaire for AI technicians	171
Appendix 2. Questionnaire for Farmers.....	176
Appendix 3. ANOVA table for semen quality analysis.....	185
Appendix 4. Post thaw total motility, progressive motility, normal morphology and number of cells assessed for semen samples	186
Appendix 5. Correlation among variables	187

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PhD Thesis

Addis Ababa University (2020)

ABSTRACT

A study conducted in Amhara, Oromia, Southern Nations Nationalities and Peoples (SNNP) and Tigray regional states of the country to contribute to increased dairy cattle productivity through providing information on the prevailing AI service delivery and input supply system; and major challenges & opportunities in the AI service delivery system. The research was mainly undertaken using a questionnaire survey, key informants' interview and focus group discussions. Data on-field performance of AI technicians in the study regions received directly from AI technicians using a structured reporting format from October 2016 through December 2018 to evaluate the actual performance of AI technicians. A follow-up calving survey for AI services provided to farmers was conducted in March 2019 to better understand the performance of AI technicians in terms of conception and calving rates. Secondary data on livestock and livestock characteristics from agricultural sample survey reports of the Central Statistical Agency (CSA) were taken from 2004/05 to 2017/18 to analyze the trend of cattle population in the country. A total of 588 sample straws of semen were collected from production, storage, distribution, and end-users (AI technicians) in the four study regions and National Animal Genetic Improvement Institute (NAGII) and analyzed for their motility and morphology using Computer Assisted Semen Analyzer (CASA). With the current growth rate of indigenous (3.7%) and cross breed (15.8%) cattle population of the country will reach to 121.2 million and 5.4 million, respectively in 2029/30. The CSA data demonstrated that the proportion of crossbred and exotic cattle population from the total population in Ethiopia is less than 2 percent with an average percentage of 1.07% for the last thirteen years. There was an increase of only 1 billion liters without change in lactation length (6 months) but with an increase of only 0.138 liters/day/cow over the last thirteen years since 2004/05. The engagement of women in the AI delivery system increased in 2017/18 from 1.8% to 7.2%. About 42% of the total AI technicians considered in this study trained for 45 days while

the other 22%, 32%, and 7% trained for a period of three, six and nine months, respectively. AI technicians in the four study regions served as AI technician for an average of 8.17 years. About 88% and 75% of AI technicians in the four regions reported ready access to LN₂ and semen, respectively. About 96% and 89% of AI technicians in the studied regions were providing AI service at their respective woreda/kebele and farm gate, respectively. However, about 56% and 31% of farmers in the four regional states participated in this study reported that they got insemination services only at woreda/kebele crushes and at their farm gate. Significant difference ($p < 0.05$) observed among regions in the number of kebeles assigned per AI technician with an average of 8 kebeles, 199 potential farmers who need the service per kebele but 92 farmers (46%) who were getting the service. The thawing temperature reported by AI technicians was significantly different ($p < 0.05$) among regions with average thawing temperature of 35.7°C. Months from August to December were categorized as peak season when AI technicians on average provided 6.7 inseminations per day. January, February, June, and July were categorized as regular season for AI service when AI technicians provided daily average insemination of 3.8. March, April, and May are off-season for AI service when on average only 2.2 inseminations per day were provided. Field level actual performance data also showed significant difference ($p < 0.05$) in the number of inseminations provided per AI technician per month among regions and between male and female AI technicians with an overall average insemination of 39.3. The SPC reported by AI technicians was not significantly different among regions ($p > 0.05$) with mean SPC of 2.13. About 2.6 SPC obtained from a follow-up survey conducted with farmers who received AI service in a specified period. The result of post-thaw total motility, progressive motility, normal and defective morphology of semen samples taken from studied regions showed significant difference ($p < 0.05$). The overall average total and progressive motility percentage of semen samples taken from the four studied regions were 38% and 28%. Similarly, the normal morphology of semen samples taken from these regions was 77%.

Keywords: Artificial insemination, Cattle, Farmers, Regions, Semen, Technicians

1. INTRODUCTION

In a country, such as Ethiopia, where there is huge cattle population, the dairy sector can significantly contribute to the wellbeing of the dairying households, the nutrition of consumers, and the economy of the country at large. However, the sector is challenged by technical, infrastructural and policy constraints (Wytze *et al.*, 2012). With the available about 60.4 million heads of cattle and 6.7 million dairy cows (CSA, 2018), the country couldn't be self-sufficient in milk production, rather it has been investing significant sum of foreign currency for importing milk and milk products mainly in the form of powder milk to fill the gap between demand and national supply. The demand for milk and milk products is still growing significantly especially in urban areas, however, the improvement in milk productivity at a country level is low. According to FAO (2002), the rising demand for dairy products in developing countries such as Ethiopia is mainly due to the increase in standards of living, urbanization and population increase.

Over the past decades, various dairy focused policy elements were designed and implemented by different regimes to improve commercial dairy production through the introduction of exotic and crossbred cattle. As reported in Mohammed *et al.* (2004) three major policies were identified in Ethiopia: the Imperial regime (pre1960-1974), the Derg regime (1974-1991), and the agricultural development led industrialization policy that was adopted since early 1990s. Though, the dairy-related policies in these regimes had a certain degree of continuity in policy elements, the change in the overall productivity of the dairy sector is not significant and satisfactory.

If the national dairy sector policy is properly designed and implemented, the development of the Ethiopian dairy sector can significantly contribute to poverty alleviation, as well as income and employment generation (Mohamed *et al.*, 2004). However, sustainable development of the sector is constrained by several factors including inefficient or unfunctional crossbreeding program, poor husbandry and management practices, seasonal availability of feed and associated poor quality, disease prevalence, and lack of proper extension and other services (Kelay, 2002; Girma and Marco, 2014). Unavailability of enough data that help in planning and implementing dairy sector improvement activities is

also among the major factors that hinder the development of the dairy sector. In some parts of the country, livestock particularly cattle are reared for social status/value rather than for milk production and marketing, this significantly affects the economic potential of the country's dairy sector (UNIDO, 2009).

Among factors mentioned above, uncontrolled breeding and/or the prevailing inefficient Artificial Insemination (AI) service delivery system is identified as major constraints, which in turn significantly affect milk production and productivity. According to a report by Camila (2013), increased milk production efficiency can play an important role in the mitigation of food insecurity. To this effect improving the reproductive performance of dairy cattle has paramount importance for improving milk production at a national level.

FAO (2002) reported that the increased demand for milk and the inability of the world's dairy sector to supply it, led to an increase in prices of dairy products, such as milk powders, butter and cheese. However, there is still big variation in accessing dairy-derived food products among countries and continents. As a result, many developing countries have begun to develop their local dairy sectors for milk self-sufficiency with improving AI service delivery system being one that is proved to play an important role in increasing the overall productivity of cattle breeds. As proven in many countries, an effective and efficient strategy to improve dairy cattle productivity is to breed dairy cows using proven semen via Artificial Insemination (AI).

AI is a technology whereby the semen from genetically superior male cattle is deposited in the female reproductive tract artificially for maximum conception and associated productivity improvement. Though it is now close to seven decades since crossbreeding activities were started in Ethiopia, the proportion of both hybrid and exotic breeds is not greater than 2% out of 60.4 million heads of cattle (CSA, 2018). This indicates that crossbreeding programs undertaken through the application of AI technology over the last several decades in the country has been quite ineffective, which can mainly be justified by the current insignificant proportion of crossbred cattle population. One major factor contributing to such inefficiency is the very low conception rate and the accompanied high

age at first calving that reported to range between 34 months (Hunde et al., 2015) and 44 months (Effa et al., 2006).

The introduction of various exotic dairy breeds particularly Friesian and Jersey in the Ethiopian highlands had proved that these dairy breeds and their crosses are adaptable if adequate management is provided. However, the multiplication of these breeds is constrained by an inefficient AI delivery system, on one hand, and absence of selection based crossbreeding program for improving milk production. Moreover, under most of the smallholder farmer conditions where more than 90% of the cattle population exists, the breeding system has been traditional and can generally be characterized as uncontrolled using locally available bulls.

AI is predominantly provided by the government with a highly subsidized price (less than 6 ETB or less than \$ 0.3) from the public side. The private sector involvement both in terms of input supply and service delivery is not significant as compared to other East African countries such as Kenya (Dickson *et al.*, 2018). Several contributing factors are mentioned in various reports (Desalegn *et al.*, 2009; Gebregiorgis *et al.*, 2016; Tessema and Atnaf, 2015; Zerihun *et al.*, 2013) for the inefficiency of AI service delivery system in the country. The major ones include: lack of the necessary inputs and equipment, unreliable supply of liquid nitrogen, poor quality of semen, lack of basic equipment, inadequate infrastructure, and poor coordination and management system. Lack of motivation and high turnover rate of AI technicians, lack of incentives, lack of recognition for AI technicians, intermittent service delivery system which is off during off working-hours during weekdays, weekends and holidays are also important factors. Moreover, lack of proper record-keeping at the farm level can also be considered as an important factor affecting the country's dairy breed improvement endeavors.

Several scholars attempted to identify the major factors for the inefficient AI service delivery system in different parts of the country. However, these studies lack consistency and did not sample and involve a reasonable number of target population especially of first level actors of the AI supply chain – namely farmers and AI technicians. The challenges or

factors mentioned in many research reports and findings for the inefficiency of AI service delivery were not properly prioritized based on their importance or level of significance that can help in devising appropriate policies and intervention strategies for improvement. Moreover, due attention was not given for the seasonality of the AI service delivery system, as the issue helps in allocating resources based on seasonality of the AI service.

The efficiency of AI technicians (measured in terms of services per conception, and calving rate based on available data), their training needs, skill gaps and level of turnover are not well studied or addressed in previous studies. Farmers' knowledge in terms of management and handling of breeding animals, heat detection, time of insemination is not well studied and documented. Similarly, AI technicians' knowledge and skill gap on semen handling, thawing, deposition of male gamete and general service provision is not well studied. Though, the success of AI delivery system should be measured or evaluated in terms of farmers' satisfaction in the provision of AI as well as conception and calving rates, there is no or limited information on the level of farmers' satisfaction on the AI service delivered to farmers.

Ethiopia does not have a significant level of industrial Liquid Nitrogen (LN₂) production, which can be used for different purposes. Thus, the liquid nitrogen required for semen preservation is mainly obtained from LN₂ production plants installed in selected parts of the country. There are about 23 LN₂ plants installed across the country for efficient AI service delivery. However, reliable access to LN₂ is still a consistent challenge in almost all parts of the country. Most of the machines are outdated and spare parts for these plants per the manufacturer's specifications are not readily available. On the other hand, lengthy government procurement processes and budget constraints at the regional level worsen the problem of timely plant maintenance or repair. There is no scheduled preventative maintenance in part due to a lack of spare parts but also a lack of technical know-how related to that specific equipment. These factors lead to an unreliable supply of LN₂ and associated semen quality deterioration.

Moreover, training in LN₂ plant production and handling is believed to be less rigorous, as a result there is significant post-production loss of LN₂ in the country. The frequency of refilling and the amount of LN₂ used per a specified period and associated number of inseminations is not known. Industry standards in Africa are closer to 6 liters per month for three inseminations per technician/day. However, there is a lack of accurate data to quantify the level of post-production loss of LN₂ at different levels starting from production through end-users and its impacts on the efficiency of AI technicians.

Though significant efforts have been made to improve crossbreeding activities in the country through various interventions, the proportion of crossbred cattle population is still significantly very low. Unreliable supply of semen and liquid nitrogen, lack of basic AI equipment, poor infrastructure, lack of knowledge and skill, intermittent service delivery, poor management system, lack of proper recording system and poor handling of semen are among the major challenges for efficient AI delivery system in the country. Therefore, providing information on the trend of dairy cattle population, semen and liquid nitrogen production and supply chain, seasonality of AI service delivery, performance of AI technicians and efficiency of AI service delivery system, adoption of dairy cattle husbandry and management practices, knowledge of AI technicians and farmers on AI and status of government led heat synchronization and mass insemination campaigns is vital to improve the AI service delivery system of the country.

Major Objective:

The major objective of this study is to contribute to increased dairy cattle productivity through providing information on the prevailing AI service delivery and input supply system; and major challenges & opportunities in the AI service delivery system.

Specific Objectives:

1. Analyze the trend of dairy cattle population and productivity of the country
2. Evaluate AI service provision and input supply system
3. Evaluate AI technicians' performance and efficiency

4. Evaluate the efficiency of Government led Heat Synchronization and Mass Insemination campaigns
5. Assess adoption of dairy cattle husbandry and management practices

2. LITERATURE REVIEW

2.1. Snapshot of the Ethiopian Dairy Sector

Due to its high livestock population and diverse agroecological conditions, Ethiopia has huge potential for the development of the livestock sector in general and for that of the dairy sector in particular. The livestock sector contributes to the livelihoods of 60-70% of the population and 30% of agricultural employment. About 12.8 million households hold cattle for various purposes. According to Yilma *et al.* (2011), in 2010, the dairy sector created an estimated 1.8 million full-time jobs. A study conducted by Land O'Lakes (2010) indicated that the growth in the dairy sub-sector will create up to 73,000 new dairy related jobs by the year 2020.

Smallholder dominated and subsistence-oriented production system is the major characteristics of the Ethiopian dairy sector. The dairy sub-sector contributes 63% to total value of ruminant output (Land O'Lakes, 2010). Major dairy development efforts started in the 1940s by the Ethiopian Government and its development partners with primary focus on breed improvement and health services provision, introduction and development of improved feed, promotion of milk processing and marketing, and capacity building through infrastructure development and training (Getachew, 2003). Though there have been efforts on policy and development interventions over the past few decades, the development of the dairy sub sector of the country could result in limited impact on commercialization of the sector and the growth of the sector is not as expected. These reports indicate that there are positive signs of take-off of the formal dairy sub-sector because of the favorable economic environment: a market-oriented policy with liberalized markets and encouraging private sector investments in the dairy industry mainly following policy reforms after 1991.

The dairy industry in Ethiopia currently meets only small percent of the domestic demand; the shortfall in demand for dairy products has been met by imports from other countries. The value of imported milk and milk products is increasing from about \$7.63 million in 2014 to \$ 14.74 million in 2018 (ITC, 2019). Though many reports indicated that a large market for milk exists in East African countries and milk consumption in the region is increasing rapidly, available reports revealed that per capita milk consumption in Ethiopia

is decreasing mainly because of increased demand associated with increased human population and price escalation of milk and its derivatives. The per capita consumption of milk and milk products in the Ethiopia is very low when compared with other African countries and world average (Nathaniel *et al.*, 2014). For instance, the per capita consumption of milk in Kenya in 2004 was 117 liters per year (SDP, 2004) which was the highest in Africa. Rwanda Dairy Development (2016) also reported a 64-liter per capita consumption of milk for Rwanda in 2015.

2.2. Milk Production System

The milk production of the country is characterized by its traditional ways of production. Almost 98% of the milk is produced from indigenous cattle breeds managed under smallholders' condition that is characterized by subsistence type of milk production system. The milk production system in the country is classified based on different criteria in different reports. For instance, Getachew and Gashaw (2001) classified the milk production system of the country into five (traditional pastoral livestock farming, traditional highland mixed farming, smallholder dairy farming, urban and peri-urban dairy farming, and the specialized commercial intensive dairy farming) based on agro-ecology characterization, socio-economic structures of the population and the type of breed and species used for milk production. On the other hand, Alejandro *et al.* (2010) reported four dairy production systems: a small commercial sector consisting of large private farms and state farms (which are not currently existing) (0.03% of the national milk production), small urban/peri-urban systems raising crossbred or both crossbred and local cattle with better access to milk market (14.3% of the national milk production), smallholder mixed farming systems in the highlands using indigenous breeds (63.3% of the national milk production), and pastoral/agro-pastoral system in the low lands (22.4% of the national milk production). In recently published Livestock Master Plan (LMP, 2014), dairying is classified as Improved Family Cattle Dairy (IFD) production in mixed rainfall sufficient (MRS) typology zone and Specialized Dairy Production Systems (SP Dairy). Tsehay (2002), on the other hand, broadly categorized the milk production system of the country into three major types: the urban milk production system (the city of Addis Ababa, and

regional cities), the peri-urban milk production system (proximity to Addis Ababa and regional cities) and the rural milk production system (farmers in the villages).

2.2.1. Urban Milk Production System

This production system has relatively better access to dairy inputs (feeds, veterinary drugs and vaccines) and services (health, extension and AI services) as compared to the other two production systems. AI service delivery system is relatively better with availability of private AI technicians. Farmers have choices of straws of superior genetics both local and imported. There is critical land shortage in this production system and waste disposal is serious issue. In the urban milk production system, the producers deliver milk to consumers or consumers may collect it at the producer's gate. Payment to producers is generally on a monthly or biweekly basis. This production system is traditional with house-to-house milk marketing system, and it can have some health risks to consumers as milk quality is not controlled. Moreover, price is high even when quality of milk is low.

2.2.2. Peri-Urban Milk Production System

Peri-urban milk production includes smallholder and commercial dairy farmers working in the proximity of Addis Ababa and other regional cities. Most of the improved dairy stock in Ethiopia is used for this type of production. This production system is characterized by better access to feed resources, and the market for milk and milk products. AI service is predominantly provided by public AI technicians and it is believed to be inefficient. Bull service is available as an alternative to AI service but the genetics and level of productivity of bulls is not certain or known.

2.2.3. Rural Milk Production System

Rural milk production is subsistence type of production and is the predominant milk production system accounting for over 98% of total national milk production (Staal and Shapiro, 1996). Largely the system is based on low producing indigenous breeds of zebu cattle. Livestock are kept under traditional management conditions and generally obtain most of their feed from native vegetation, aftermath grazing and crop residues. The smallholder dairy system makes up the largest part of the dairy production system and can

be characterized by its low input levels, feeding and management practices and use of indigenous cattle breeds, which have low potential for milk production (Felleke, 2003). The landholding size of smallholder farms is decreasing from 2.0 hectares in early 2000 (Getachew and Gashaw, 2001) to 0.9 hectares in 2015 (George, 2015). The land is mainly used for food crop production and the rest for livestock production through grazing. Artificial insemination service is not readily available to most of the dairy producers in this production system, if available it is off for most of the time due to lack of the necessary inputs mainly semen and liquid nitrogen.

2.3. Milk and Milk Products Marketing

The two major constraints in the dairy value chain in most East African countries are poor dairy farm productivity and substandard quality of products (Susan and Fabien, 2015). There are two milk marketing systems commonly known as informal (unorganized) and formal (organized). The informal milk marketing system dominates in most parts of the country especially in the rural areas where 95% of the raw milk is channeled through this system. The formal milk marketing system is localized in Addis Ababa and major cities and towns of regional states and only 5% of the milk is channeled through this marketing system (AGP-LMD, 2013). Milk producers have no or very limited role in price setting and there is no quality-based payment system rather the competition among milk collectors or processors is unfair, milk rejected by one collector can be accepted by another. This is happening mainly due to poor infrastructure, clumsy quality control and regulation system, and lack of market information.

Getachew and Gashaw (2001) indicated that the major factor that impedes increased milk production at the producer level is the stagnant price level paid to producers, which discourages others willing to join the milk marketing system and will continue as a threat for the development of the dairy sector of the country unless appropriate measures are taken. This situation still exists in many parts of the country especially of the peri-urban and rural production system. The price of milk is determined and fixed by the milk collectors without fair participation of milk producers. It is believed that there are high transaction costs that can reduce the actual price received by the producers and increase

the price of milk and its derivatives for the consumers. This situation discourages producers to produce more marketable milk and consumers to reduce their consumption level. On the other hand, there is a critical problem of institutional support to facilitate the marketing of milk and milk products (Getachew and Gashaw, 2001). The authors also reported that the price of raw milk is varied based on the geographical location of producers, season of the year and duration of the fasting period. Poor road access is the most significant constraint for milk marketing and milk is rarely collected or transported from producers further than 10 km away from a paved road (AGP-LMD, 2013). Market-oriented milk production system is not practiced except in the periphery of urban and peri-urban areas. The major marketable milk products include fresh milk, sour milk (*ergo*), butter, different type of cheese mainly of cottage type cheese (*ayib*), pasteurized milk, UHT milk, flavored and plain yogurt and various cheese types (AGP-LMD, 2013).

2.4. Dairy Cattle Breeds

Ethiopia is endowed with diverse dairy cattle genetic resources due to its varied environmental conditions. It is indicated that there is a total of 32, 27 and 31 cattle breeds reported by Domestic Animal Genetic Resource Information System (DAGRIS), the Ethiopian Institute of Biodiversity Conservation (EIBC), and Domestic Animal Diversity Information System (DADIS), respectively (Yilma *et al.*, 2011). Abraham and Abebe (2018) also reported 28 cattle breeds in the country. Abergelle, Abigar, Abyssinian Highland Zebu, Abyssinian Short Horned Zebu, Adwa, Afar, Ambo, Anuak, Arado, Arsi, Bale, Barka/Begait, Begaria, Borana, Danakil, Fogera, Gofa, Gojam Highland Zebu, Hamer, Harar, Horro, Irob, Jiddu, Jemjem Zebu, Jijiga Zebu, Kereyu, Medenes, Mursi, Smada, Somali Boran, Raya Azebo, Red Bororo, Sheko and Tigre are identified breeds in the country (Abraham and Abebe, 2018; Albero and Solomon, 1982; FAO, 1998). However, little has been known or detail information is unavailable on most of these breeds. Most of them are not dairy type breeds or have low genetic potential for milk production. However, some of the indigenous breeds such as Fogera, Begait (Barka) and Borana have promising potential for milk production (Yilma *et al.*, 2011).

Crossbreeding activity started a few decades ago through importing European breeds mainly of Holstein and Jersey and current reports indicated that there are about 0.22% exotic and 1.54% hybrid from the total cattle population available in the country (about 60.4 million heads) (CSA, 2018). The breeding of cattle is uncontrolled which is taking place in the field without any kind of selection. According to Nathaniel *et al.* (2014), the country has no functional dairy sector policy. Until very recently, the dairy breeding policy was not endorsed and implemented in the country which help to guide the breeding and breed development activities in the country (Nathaniel *et al.*, 2014). According to the same report, Ethiopia received the first 300 Friesian and Brown Swiss dairy cattle breeds in 1947 under the Relief Program of the United Nations Relief and Rehabilitation Administration (UNRRA) and used as a nucleus herd or foundation stock established in 1955 at Holeta. This was the first attempt in dairy cattle breed improvement program of the country. In 2017/18 (after 70 years of the first exotic cattle importation in 1947) the pure exotic cattle population reached 135,105 heads (CSA, 2018), a cumulative increase of 134,805 heads with an annual increase of only 1,926 heads.

2.5. Artificial Insemination

2.5.1. Technology Innovation

Artificial Insemination (AI) is a technique by which semen or spermatozoa (male gamete) collected from a male animal of proven performance and desired characterizes is introduced artificially into the body of the uterus (insemination) at the time of heat to get the female pregnant. Artificial insemination is widely used for livestock breeding to improve the productivity of both beef and dairy around the world, and a necessary tool in sustainable farm animal breeding (Gamborg and Sandoe, 2005). Foote (2002) reported the first successful insemination that was performed in a dog, which resulted in three pups after 62 days of insemination. This first successful insemination was conducted in 1780 by Abbe Lazzaro Spallanzani (an Italian Physiologist and Priest) (Foote, 1999). However, AI was established as a practical procedure in Russia in 1899 in domestic farm animals, dogs, foxes, rabbits, and poultry.

About one-fifth of the world's female dairy cattle population is bred by using AI (Thibier and Wanger, 2002). AI is introduced in Africa in the 1950s and 1960s and many African countries developed AI programs in the 1970s. From 25 developing countries where AI almost practically was not used 16 were found in Africa where only less than 2% of female cattle are inseminated at their breeding age (Abdallah, 2011). As reported by Nathaniel *et al.* (2014) the national percentage of AI use in Kenya is leading from Africa at 18%.

2.5.2. Advantages of AI Service

AI has paramount importance in improving productivity through fast genetic improvement by using semen of genetically proven bulls. It is believed to be an effective reproductive technology that can accelerate the genetic gain through selection pressure on males. As indicated in Annett (2012), the milk production of Holstein cattle has been doubled in 40 years due to AI-supported selection. AI technology allows us to produce an increased number of off-spring from a superior male animal. Apart from these AI can help us to prevent venereal and other diseases transmission that have economic importance. Increased use of AI as a breeding method for dairy production can accelerate the dairy improvement programs and schemes because AI enables to use outstanding male animals to produce many offspring in a given time (Ntombizakhe, 2002). AI also used to accelerate the spread of superior genes in a very short time interval as it enables us to serve more animals using semen from superior genetics. It also helps maximum use of outstanding sires. As compared to natural mating, the spread of diseases is not a problem in AI and cost and other challenges of bull management can be avoided or eliminated. It is possible to cover a wide geographical area using AI. AI is a relatively cost-effective method to produce heifers when compared with natural mating. The rate of return on AI when compared with natural service is also more attractive.

2.5.3. Limitations of AI Service

For efficient delivery of AI service availability of enough number of trained and skilled inseminators plays paramount importance. AI technicians need to have the required knowledge and skill to provide insemination service which results in a better conception rate. Semen is normally packed into straws that enable to control the freezing and thawing

process which in turn leads to improved sperm cell recovery. However, mishandling of straws is the major disadvantage of the straw system (Harold *et al.*, 2011) that can occur at any point in the semen supply chain. Liquid nitrogen is among the important inputs to successful AI service delivery that can keep the quality of semen for a significant period.

Farmers' knowledge and skill in heat detection is also an important factor for successful AI service delivery. AI service should be provided at the appropriate time as it is a time-sensitive activity. Therefore, both farmers and AI service providers should be able to know the appropriate time of insemination for maximum conception rate. Moreover, an appropriate recording system needs to be in place to track and measure the success of AI service delivery and the overall improvement in a given dairy herd. AI has a relatively lower conception rate as compared with natural mating, which mainly relates to heat detection accuracy as well as semen concentration per insemination vs mating. Besides, AI service needs to avail appropriate equipment and reliable infrastructure for effective semen transport.

2.5.4. Success of AI Service Delivery System

The success of AI can ultimately be measured by the increase in the number of crossbred dairy animals and an increase in milk production (Ntombizakhe, 2002). The same author reported that the success of AI service delivery is influenced by the reliability of services, source of bulls or semen, lack of training of staff and farmer, and relative advantage of AI with other methods.

Successful AI service delivery, among others, requires successful and efficient heat detection by farmers as the animals should be inseminated while they are still in heat. To this effect, training of farmers on heat detection methods is of high importance. Besides, an efficient record-keeping system should be in place as it is a prerequisite for an efficient AI service. Ntombizakhe (2002) recommended that AI service delivery should be linked with efficient performance or progeny testing programs. Semen should be produced and used from genetically superior bulls to avoid any detrimental effects on the genetic value of herds using AI. Better offspring can only be produced from better sires.

2.5.5. AI Service in Ethiopia and Its Management

AI service delivery started in Ethiopia in the 1950s by teaching institutions and 1960s by the then ‘Dairy Development Agency’ (DDA) using fresh and imported semen (Getachew and Gashaw, 2001). The same report indicated that the first AI center in the country is Assela Artificial Insemination Center (AAIC), which was established in 1972 by Chilalo Agricultural Development Unit (CADU) with ten Friesian bulls imported from abroad to collect semen. This indicates that Ethiopia started crossbreeding activity far behind its neighboring Kenya where formal breeding started in 1903 with the establishment of the government-owned dairy experimental farm and AI was introduced in 1935 (Margaret, 2005).

Until very recently, the main supplier of semen in Ethiopia is the then National Artificial Insemination Center (NAIC), which recently rebaptized as ‘National Animal Genetic Improvement Institute’ (NAGII). NAIC is established under the Ministry of Agriculture (MoA) in 1981 to organize and coordinate the overall dairy cattle improvement through crossbreeding. Recruiting bulls of high pedigree records locally for semen production; importing semen and bulls of high pedigree records; collecting, processing, preserving and distribution of semen; producing and dispatching liquid nitrogen (LN₂); training of AI technicians and farmers; and monitoring and evaluation of the overall AI service are among the key mandates and responsibilities of NAIC (Felleke *et al.*, 2010). Apart from the importation and production of semen from selected bulls at its Bull Dam farm located at Holetta, NAIC produces and distributes liquid nitrogen to sub-centers located in different regions of the country. At the end of 2016, additional four semen production and processing centers were established regionally at Bahir Dar, Nekemite, Hawassa and Mekelle using Holstein Friesian bulls imported from the Netherlands and Jersey young bulls recruited from South Africa. These regional AI centers are established to coordinate the AI service delivery at their respective regions, and input supply system.

Data obtained from NAIC revealed that about 2.85 million straws of semen produced from 2009/10 to 2013/14 of which about 2.76 million straws distributed, and 988,073 confirmed pregnancies reported from regional livestock bureaus. In 2013/14, 758,243 straws were

produced from NAIC from different breeds and 310,217 inseminations performed in the country (Land O'Lakes, 2015). The number of inseminations is much less than that of Kenya where 650,000 (50% more) inseminations performed during the same year (Nathaniel *et al.*, 2014). Though Land O'Lakes (2015) reported semen production to be in an increasing trend, in 2017/18, 907,2017 straws (an additional 19% compared with that in 2013/14) were produced at NAIC and the four regional semen production centers of which nearly 80% was produced from NAIC (Unpublished reports from NAIC and Regional Centers).

Currently, AI is predominantly provided by the public sector. Unlike that of neighboring countries such as Kenya where 95% of inseminations are performed by private AI technicians and cooperatives (Nathaniel *et al.*, 2014), the private sector involvement in the importation of proven genetic material and service provision is insignificant. It is only 'Addis Livestock Production and Productivity Improvement Service' (ALPPIS) that is involved in importing and distributing superior semen from abroad whereas in Kenya there are about 14 local and international companies that are involved in production, importation and distribution of semen (Nathaniel *et al.*, 2014). According to the 2018/19 Land O'Lakes International Development Fund annual report (Unpublished), about six private companies have been engaged in the AI service delivery system since 2017/18 through the support of a five-year program called 'Public-Private Partnership for Artificial Insemination Delivery' (PAID). The same report indicated that these six private companies absorbed about 40 private AI technicians as franchisees or employees to provide AI service in Addis Ababa, Amhara, Oromia, SNNP and Tigray regions.

In Ethiopia, AI is provided with highly subsidized prices and predominantly by public AI technicians. However, the service is believed to be unavailable all the time due to lack of transportation facilities to visit farmers and the supply of other necessary inputs. A recent unpublished study conducted by Land O'Lakes (2015) revealed that only 37% of AI technicians reported that they have ready access to transportation facilities mainly of motorbike. Reliability of the AI service delivery system can also be seen in terms of reliable supply of liquid nitrogen, but many reports indicate that there is critical shortage of liquid

nitrogen at national level due to the frequent malfunctioning of liquid nitrogen plants, which can in turn affect the quality of semen thereby affecting conception rate. As reported by Ntombizakhe (2002), unreliable AI service delivery would result in low use or low adoption rate of AI because farmers can't rely on the AI service delivery system that can be interrupted due to various reasons.

2.6. Factors Affecting Efficiency of AI Delivery system

Though significant efforts were made by the government and its development partners in the last four to five decades, the impact of AI on the proportion of crossbred dairy cattle is not at the expected level, remaining well below 2% (CSA, 2018). After several decades of dairy development efforts in Ethiopia, the average milk yield per cow per day remained low at around 1.37 liters with an average lactation length of 180 days (CSA, 2018). Besides, calving intervals of dairy cows on Ethiopian smallholder farms is commonly about 25 months (Kelay, 2002). With these current performance level, AI service delivery in Ethiopia can generally be characterized as inefficient.

As mentioned in Lopez (2013), the body condition of the animal, housing elements, season (temperature and humidity), heat detection practice, cyclicity of the animal, site of semen deposition and efficiency of AI technician are among factors which can significantly affect the success of insemination. There are some previous attempts to identify major constraints and bottlenecks for AI service delivery in the country. Shortage or unavailability of artificial insemination technicians; lack of motivation and high turnover rate of AI technicians; intermittent service delivery system which is off during off-hours, weekends, and holidays; lack of incentives, basic AI equipment, and necessary inputs; poor heat detection; poor quality of semen, lack of transport facility and other infrastructure, lack of awareness, management problem, inefficiency of AI technicians, low experience of AI technicians, conception failure and disease problems are the major problems associated with ineffective AI service system (Gebregiorgis *et al.*, 2016; Nuraddis *et al.*, 2014; Zerihun *et al.*, 2013; Azage *et al.*, 2012; Tessema and Atnaf, 2015; Sisay *et al.*, 2017). Moreover, there are no functionally effective and separate responsible bodies both at regional, Zonal and woreda level to coordinate the AI services delivery (Desalegn *et al.*,

2009). Non-systematic crossbreeding, poor infrastructure and market system and lack of finance and trained manpower were also mentioned as challenges for the success of AI in Ethiopia (Addisu, 2013).

2.7. Factors Affecting Adoption of Agricultural Technology

As indicated by Pankaj and Nayaran (2016), knowledge on factors affecting the adoption of agricultural technologies will help in enhancing the process of need-based and demand-driven technology generation and then facilitate the adoption of technologies. There are a number of factors that influence the extent of adoption of technology such as characteristics or attributes of technology; the adopters, which is the object of change; the change agent (extension worker, professional); and the socio-economic, biological, and physical environment in which the technology take place (Audrey, 2014). The following are some of the major factors which are believed to affect AI technology adoption.

2.7.1. Age of the household head

Age of the household head found to negatively influence the adoption of agricultural technologies such as sorghum and peanuts in different countries (Adesiina and Baidu-Forson, 1995, Dehninet *et al.*, 2014; McNamara *et al.*, 1991; Peter *et al.*, 2012). It is said to be a primary latent characteristic in adoption decisions. The general notion found from the introduction of most new technologies both within agriculture and outside of it is that older generations are the last to adopt them, while the younger generations typically embrace them more quickly. As reported by Audrey (2014) older farmers may not want to jeopardize a particulate practice by trying out a completely new method perhaps because of investing several years in a particular practice. A negative correlation, on the other hand, between age and AI technology adoption reported by Abdallah (2011) in Tanzania and Joseph and Ango, (2014) in Nigeria.

2.7.2. Education

Education is thought to create favourable mental attitude for the acceptance of new practices especially of information- and management-intensive practices (Abdallah, 2011; Borden *et al.*, 2017; Waller *et al.*, 1998; Joseph and Ango, 2014; Caswell *et al.*, 2001).

Pankaj and Nayaran (2016) also reported that the level of adoption of the technology was determined by the level of education. Education is expected to reduce the amount of complexity perceived in a technology thereby increasing a technology's adoption rate. Better educated farmers are more likely to adopt recommended technologies.

2.7.3. Gender of Farmer

Most reports showed mixed evidence regarding the different roles men and women play in technology adoption. Doss and Morris (2001) in their study on factors influencing improved maize technology adoption in Ghana; and Fleming and Yala (2001) studying coffee production in Papua New Guinea showed insignificant effects of gender on adoption. As mentioned in the report of Bisanda & Mwangi, (1996), there is a strong relationship between the gender of the household head and adoption of technology. Abdallah (2011) reported a negative relationship between gender and AI technology adoption in Tanzania where women farmers had a higher adoption rate.

2.7.4. Household Income

Many previous studies found household total income to have a positive relationship with the adoption of agricultural technologies (Watcharaanantapong *et al.*, 2014; Walton *et al.*, 2010). Investing in relatively new, innovative technologies carry higher entry costs and more risk than already established technologies (Diederer *et al.*, 2003). In this study, farm income is hypothesized to have a positive relationship with the adoption of AI technology. However, a negative relation was reported between off-farm income and adoption of AI technology (Peter *et al.*, 2012 and Sime *et al.*, 2014).

2.7.5. Farm Size

It is believed that farm size is the first and probably the most important factor determining agricultural technology adoption. The impact of farm size on adoption-related to factors such as the cost of the technology, risk perceptions, human capital, credit constraints, labor requirements are reported by several authors. Borden *et al.* (2017) Kaaya *et al.* (2005); Joseph and Ango, (2014) and Abdallah (2011) reported a negative relationship between herd size and adoption of AI technology. As mentioned in Abdallah (2011), in large size

farms AI required a high level of management in terms of feeding, heat detection, and other routines and thus communication with AI technicians. Masoud and Asghar (2011), on the other hand, observed a positive relationship between farm size and adoption of AI technology.

2.7.6. Farming Experience

Various reports indicate that farming experience can positively influence the level of different agricultural technology adoption (Pankaj and Nayaran, 2016; Kavia et al., 2007; Makokha et al., 2007). Households with past market-oriented farming experiences can better control the risks and thus adoption might be positively associated. A report conducted in the Oromia region of Ethiopia demonstrated that as experience increased by a year, intensity of dairy technology adoption increased by 4.5×10^{-1} (Dehninet *et al.*, 2014). Abdallah (2011) observed significant difference between AI adopters and non-adopters where adopters had higher dairying experience than the non-adopters. In contrary to this theory, a negative relationship reported between experience and adoption of AI technology (Sime et al., 2014; Joseph and Ango, 2014; Kaaya et al., 2005; Masoud and Asghar, 2011). This is mainly because experienced farmers are resistant to adopt new technology.

2.7.7. Frequency of Contact with Extension or Source of Information

A report by Abdallah (2011); Pankaj and Nayaran (2016); Lionberger (1960), Bose (1964) and Dongol (1979) revealed that there is a positive and significant influence of the frequency of contact of farmer with personal locality and source of information on adopting a given agricultural technology. Dehninet et al. (2014) on the other hand reported that the availability of extension service increased the probability of technology adoption by 30%.

2.8. Semen Handling and Quality

It is believed that cryopreserved semen has a similar performance with fresh semen in the process of artificial insemination (Morado *et al.*, 2015). Semen storage and handling practices can potentially impact on semen quality prior to and at insemination and therefore there is a need to assess how this is being performed at field condition. Besides, due to the

poor handling of liquid nitrogen, the loss and quality deterioration in semen is significant resulting in low conception rate, which in turn leads to devastating consequences for farmers and artificial insemination programs. The problem is likely worse in the developing world such as Ethiopia primarily because training is less rigorous and mishandling of semen causes a large number of pregnancies to be missed seriously affecting lifetime productivity. In Ethiopia, data on the level of semen straws discarded due to poor handling of liquid nitrogen is lacking and the quality of semen along the value chain is not well studied and documented.

Scientific experiments have shown that semen cells are damaged within few seconds of exposure to ambient temperature due to heat shock, which in turn significantly reduces fertility (Albert and Pamela, 1988; Daniel et al., 2016; Pawshe et al., 2017; Stoja et al., 2016). Semen handling and exposure under smallholder AI delivery systems remain a serious problem that reduces conception rates. This is mainly due to the exposure of the semen straws from the semen holding canister to ambient temperature while removing semen straws for the purpose of Artificial Insemination or auditing the number of semen straws. Very short exposures to ambient temperatures can cause large temperature fluctuations within the straws.

Among factors that determine the success of the AI delivery system (heat detection, inseminator efficiency and fertility of the cow), semen fertility is the final determinant of success in AI service delivery. Semen quality can be deteriorated during the process of production, filling and sealing, and freezing most importantly during semen handling and transportation. As indicated in many reports, it might not be appropriate to evaluate the fertility of bulls by examining the semen only for sperm concentration and motility. Instead, there is an array of other methods used to evaluate the quality of sperm cells. These include morphology, membrane and acrosome integrity and the ability to interact with the oocyte and layer enclosing it. Measurements of any of these single sperm quality attributes can only be used to eliminating samples of very poor quality rather than indicating the fertilizing capacity of the sperm cells (Graham et al., 1980; Stålhammar et al., 1994; Hirano et al., 2001).

2.9. Liquid Nitrogen Production and Supply Chain

According to a research report released from Worthington industries (<http://worthingtonindustries.com>), AI technicians in developed countries are taught to never remove semen straws from their liquid nitrogen containers for more than eight seconds, unless they are being thawed for immediate usage. Some practice a five-second rule, and the most experienced professionals practice a three-second rule. Though all the three rules of removing semen straws from containers can help in avoiding exposure-induced damage, the rules are not well followed in the developing countries such as Ethiopia, where such information is lacking or not communicated among AI technicians.

In a recent study conducted by Land O'Lakes, four major problems are identified as bottleneck for sustainable production of liquid nitrogen in the country (Land O'Lakes, 2017, Unpublished).

Lack of spare parts as per the manufacturers' specifications is the major problem in the country. This is mainly due to outdated machines where parts are no longer manufactured, the government's lengthy purchasing process and budget constraint.

Absence of preventive maintenance to the liquid nitrogen plants is another challenge for most of the liquid nitrogen plants installed across the country. Preventive maintenance of the liquid nitrogen plants as per the manufacturer's recommendation is among the most important factors that enable sustainable production of liquid nitrogen plants from the installed plants. However, scheduled preventative maintenance is not consistent across the plants due in part to a lack of parts but also a lack of know-how related to that specific equipment.

The third problem is a *significant level of post-production loss of liquid nitrogen*. 23 LN2 production plants are operating in the country at different capacities that should easily meet the demand. However, it was identified that one of the major challenges in the supply of liquid nitrogen for AI technicians was post-production losses. Research reports revealed

that a public A technician who use a 2-liter LN2 container has to refill on average once every two days amounting to between 20 and 25 liters per month with an average of 3 inseminations per day. Industry standards in Africa are closer to 6 liters per month for the same number of inseminations per technician per day Land O'Lakes (2017, Unpublished).

The last but not the least challenge is *lack of technical know-how to identify the problem of liquid nitrogen plants and their maintenance*. The trainings provided to liquid nitrogen plant technicians are short-term lasting one week to a month on a specific model offered by the manufacturer. This doesn't help them to have the required skill and knowledge that enable them to maintain the plants when required.

Though Ethiopia holds the largest cattle population in the continent, the proportion of improved dairy cattle breeds is insignificant (< 2%) and therefore the annual milk production remains very low, which is far below the national demand. This could mainly be attributed to policy, technical, infrastructural, management and implementation related problems. Milk production in the country can't substantially be increased without implementing appropriate crossbreeding programs and increasing the population of improved dairy cattle breeds. Thus, analyzing and projecting the trend of dairy cattle population using available data is of paramount importance to plan and implement crossbreeding activities with clear and attainable goals and objectives.

A significant proportion of milk in the country is produced under smallholder milk production system where marketing infrastructure for milk and milk products is not well developed and the quality of milk under such conditions is questionable. Milk commercialization or producing milk at the commercial level using improved cattle breeds in this regard is very essential.

To attain the required level of milk production through an increased number of crossbred cattle population appropriate breeding technology should be designed and implemented in the country. As it is proved in many countries, AI is an old but still efficient breeding technology that when properly designed and implemented in developing countries such as

Ethiopia can bring the desired change in productivity parameters. Though AI has been practiced in the country for the last several decades, the proportion of crossbred cattle population remains well below 2 percent. The major challenges and constraints in the AI service delivery system starting from the animal to be inseminated to the quality of semen as well as skill and efficiency of AI technicians should properly be identified and prioritized to improve the system.

3. MATERIALS AND METHODS

3.1. Study Areas and Description

The study was conducted in Amhara, Oromia, Southern Nations Nationalities and Peoples (SNNP) and Tigray Regions. These regions were purposively selected due to their potential for dairy production and significant government and other development partners' efforts in improving the dairy sector in these regions.



Figure 1. Map of Amhara, Oromia, SNNP and Tigray Regions

3.1.1. Amhara Region

According to Ethiopian Demography and Health, Amhara Region is located in the Northwestern part of Ethiopia between 9°20' and 14°20' North latitude and 36° 20' and 40° 20' East longitude (<http://www.ethiodemographyandhealth.org/Amhara.html>). Its land area is estimated at 170,000 square kilometers. Amhara borders the Tigray Region in the North, Afar in the East, Oromia in the South, Benishangul-Gumuz in the Southwest and the

country of Sudan in the west. The region is divided into 11 zones (North Gonder, South Gonder, West Gojjam, East Gojjam, Awi, Wag Hemra, North Wollo, South Wollo, Oromia, North Shewa and Bahir Dar City special zone), and 140 Weredas and 3,429 kebeles (the smallest administrative units).

Amhara region contains much of the highland plateaus above 1,500 meters with rugged formations, gorges, and valleys, as well as millions of settlements in Amhara villages surrounded by subsistence farms and grazing fields. The topographical features represent diversified elevations ranging from 700 meters above sea level (m.a.s.l.) in the eastern edge to over 4,600 m.a.s.l. (the country's peak point at mount Ras Dashen) in the Northwest. Cereals account for more than 80 percent of cultivated land and 85 percent of total crop production. The principal cereal crops cultivated in the Amhara region are teff, barley, wheat, maize, sorghum and finger millet. Pulses and oil crops are the other major categories of field crops. According to the CSA (2018) report Amhara region had 26.7% (16.1 million) of the cattle population in Ethiopia, 35.4% (11.1 million) of sheep, 23.7% (7.8 million) of goats, 31.6% (17.7 million) of poultry and 17.7% (1.2 million) of beehives.

The CSA's total human population estimate for the Amhara region for mid-2008 was 20,136,000 (50% of which were female). Of these 2,408,000 (only 12%) are urban residents.

3.1.2. Oromia region

With 353,690 square kilometers of land area (32% of the country), Oromia represents the largest regional State (Aynalem, 2014a). Its population is estimated at 28,067,000 in mid-July 2008; the largest population size of any region (35.4% of the country's total population). Nearly 4 million are residents of urban areas with an urbanization rate of 13.8% - slightly below the national average. Administratively, Oromia is divided into 17 zones, 245 Weredas, and 36 town administrations with 6500 kebele subdivisions.

The Oromia regional state extends from the western end of the country in western Wellega to the eastern parts of eastern Harrarge from 34°E latitude to 43°E latitude. Its north-south

extent stretches from 4 $\frac{2}{3}$ °North to 10 $\frac{2}{3}$ °North latitude. Topographically and climatically the region is diverse with sharp contrasts. The mid-portion is formed by the Great Rift Valley system that divides the regional state roughly into a western third and eastern two-thirds. Oromia is a region of great physiographic diversity. Its landscape includes high and rugged mountain ranges, plateaus, panoramic gorges, deeply incised river valleys, and rolling plains as well as hills and mountains rising from less than 500 meters above sea level to 4,000 meters.

According to CSA (CSA, 2018) report farmers in the region had an estimated total of 24.4 million cattle (representing 40.5% of Ethiopia's total cattle), 9.4 million sheep (30.0%), 8.6 million goats (26.2%), 19 million poultry of all species (33.9%), and 3.2 million beehives (48.8%).

3.1.3. Southern Nations Nationalities and Peoples (SNNP) region

According to Aynalem (2014b), SNNPR is one of the largest regions in Ethiopia occupying more than 10 percent of the country's land area. The mid-2008 population is estimated at nearly 16 million; almost a fifth of the country's population. With less than one in tenth of its population (8.9%) living in urban areas in 2008, the region is overwhelmingly rural. The region is divided into 13 administrative zones, 133 Woredas and 3,512 Kebeles.

SNNPR boasts all the inhabited environments seen elsewhere in Ethiopia: arable highlands (dega), midlands (woina dega) and lowlands (kolla), and pastoral rangelands (bereha). However, the most prevailing environmental characteristic of the Region is a relatively fertile and humid midland, which contains the densest rural populations of Ethiopia.

The CSA (2018) report indicated that farmers in the region had an estimated total 11.9 million head of cattle (representing 19.7% of Ethiopia's total cattle), 4.6 million sheep (14.8%), 5 million goats (15.1%), 10.5 million poultry of all species (18.7%), and 1.3 million beehives (20.5%).

3.1.4. Tigray region

Located between 36 degrees and 40 degrees east longitude, Tigray forms the northern most reaches of Ethiopia. Its north-south extent spans 12 and a half degrees to 15 degrees north. It is bordered by Eritrea in the north, Sudan to the west, Amhara to the southwest and Afar in the east.

The highlands receive most of their rainfall during the summer months, much of which goes into tributaries of the Nile, 85% of whose water comes from Ethiopia. The soil has been depleted by many centuries of cultivation and water is scarce.

Tigray has an estimated population of 4,565,000 (July 2008) and an average density of 91.2 persons per square kilometers. CSA (2018) estimates indicate that in 2018, farmers in the region had a total of 4.8 million cattle (representing 8.0% of Ethiopia's total cattle), 2.5 million sheep (7.9%), 4.3 million goats (13.1%), 6.2 million poultry of all species (11.0%), and 293,184 beehives (4.5%).

3.2. Study Components

The research was mainly undertaken using a questionnaire survey, key informants' interview and focus group discussions. Semen quality analysis along the AI supply chain was also done to evaluate the quality of semen and identify the major point of quality deterioration along the chain.

The study has the following major parts:

1. An overview of the Ethiopian dairy cattle population and productivity trend
2. Evaluation of AI service input supply system
3. Evaluation of AI delivery system
4. Evaluation of AI technicians' performance and efficiency
5. Evaluation of government led heat synchronization and mass insemination campaigns
6. Adoption of improved dairy cattle husbandry and management practices

3.3. Data Collection Tools

3.3.1. Surveys

To assess, evaluate and understand the AI service delivery system, its seasonality and efficiency, semen and liquid nitrogen supply chain and adoption level of dairy cattle husbandry and management practices, two types of questionnaire surveys were undertaken with AI Technicians and farmers. A cross-sectional design was used for both survey data, which could allow us to collect data at a single point in time and used for descriptive study and the determination of relationships between and among variables (Byerlee and Heisey, 1992).

AI Technicians Survey

AI technicians survey was conducted in July and August 2017 with randomly selected sample AI technicians operating in Amhara, Oromia, SNNP and Tigray regions. A total of 161 AI technicians from the four regions (49 from Amhara, 53 from Oromia, 36 from SNNP and 23 from Tigray regions) were randomly selected and interviewed using a structured questionnaire to collect the required qualitative and quantitative data. AI technicians interviewed on issues related to place and duration of training on AI techniques; experience in AI service delivery; availability of basic AI equipment and access to inputs; transportation system and availability of motorbike and fuel allowance; seasonality of AI service and associated performance; expected number of client farmers; distance traveled for AI and related services delivery; means of communication; breed selection; provision of AI service during off-working hours, weekends and holidays; thawing temperature and time, and price of AI service; other services provided to farmers; synchronization campaigns and its effectiveness; selection of AI technicians for synchronization campaigns; perception on calf sex; frequency of liquid nitrogen top-up and semen quality check practice and quality problem.

Farmers Survey

In July 2018, a survey was conducted with farmers from the four study regions: Amhara, Oromia, SNNP and Tigray regions. Sample farmers were randomly selected from a list of

farmers who received AI from October 2016 to June 2018. The sample size was determined using the following formula as stated in Guilford and Frucher (1973).

$$n = N/(1+Ne^2)$$

Where:

n is the required sample,

N is the population size and

e is the level of precision (10%)

Thus, a total of 419 farmers from the four regions (Amhara = 106, Oromia = 104, SNNP = 105 and Tigray 104) were randomly selected and interviewed on the issues related to dairy farming household characteristics; cattle herd size; breeding practice and years of AI service use; dairy cattle housing and hygiene; feeding and watering; health management practices; record keeping; access to livestock extension system; breed selection; availability and access to AI service; distance traveled to the insemination center; arrival time of AI technicians to inseminate cows/heifers following a call; access to and experience on synchronization campaigns; perception on calf sex and prices of AI and bull services.

3.3.2. Key Informant Interviews - KII

Key Informants Interviews (KIIs) were carried with relevant staff of Regional Bureau of Livestock and Fishery, regional AI centers and National Artificial Insemination Center (NAIC) recently renamed as National Animal Genetic Improvement Institute (NAGII). The key informant interviews were mainly focused on challenges of AI delivery system, equipment and input supply system, national AI service delivery management and coordination (linkage between Regional Artificial Insemination Centers - RAICs & NAIC), liquid nitrogen production situation (installed and current production capacity, major challenges for sustainable liquid nitrogen production and distribution, post-production loss and plant maintenance and repair problems). The responses of these key informants' interviews were used to triangulate the information received from sample respondent AI technicians and farmers.

3.3.3. Focus Group Discussions (FGDs)

Focus Group Discussions (FGDs) were carried out to verify some information collected from sample respondent AI technicians and farmers during individual interviews. The FGDs were mainly conducted with AI technicians, farmers and NAIC and regional AI centers staff in each region and used to prioritize factors that hinder effective AI service delivery in the respective target regions. FGDs were conducted within a group of 5-10 farmers, 5-8 AI technicians and 3-5 regional livestock bureau livestock production experts, and semen lab and LN2 plant staff. A total of 20 FGDs (2 with AI technician groups per region, 2 with farmer groups per region, 1 with regional bureaus livestock production experts and semen and liquid nitrogen production and processing center staff per region) were undertaken in the four regions.

3.3.4. AI Technicians' Field Performance Recording

Data on-field performance of AI technicians in Amhara, Oromia, SNNP and Tigray regions were received from technicians from October 2016 through December 2018 to measure the actual performance of AI technicians using a pre-restructured reporting format. The major components of monthly performance reporting format include dates of AI service, calving, and pregnancy diagnosis and result; straw ID; breed of dam and sire; service repeat; name, gender and address of farmers; and sex of the newborn calf. AI technicians were advised to send their performance report at the end of each month to their respective regional livestock bureau. Then the data were compiled, cleaned and summarized. Data verification was conducted at least for 10% of received data through field observation and phone calls.

3.3.5. Calving Survey

A follow-up calving survey for AI services provided to farmers was conducted in March 2019 in the four regions considered in this study to better understand the performance of AI technicians in terms of conception and calving rates. For this purpose, the list of farmers who received AI service between February and May 2018 was purposely selected and prepared to be used as a sampling frame. This is because farmers can easily remember the outcome of these AI services especially if the cow has calved. Cows/heifers inseminated

between February and May 2018 were expected to give birth between November 2018 and February 2019.

Then, a multi-stage random sampling system was followed to select woredas, kebeles, and farmers from each of the four target regions. Sample farmers were then selected randomly from each woreda and kebele using assigned random numbers. Sample size was estimated at 90% significance level in each region. As suggested by Suresh and Chandrashekara (2012) and Daniel (1999), the following formula was used to determine the sample size for each region since the population size for all region is known.

$$\text{Sample Size} = [z^2 * p(1-p)] / e^2 / 1 + [z^2 * p(1-p)] / e^2 * N]$$

Where:

N = population size

z = z-score

e = margin of error

p = standard of deviation

Table 1. Sample size of farmers used for calving survey

Region	Total number of farmers received AI service	Sample size	Selected Woredas
Amhara	55,317	270	Andabet, Guba Lafto, Mecha, Machakel, Dangila Zuria, Bahir Dar
Oromia	64,762	272	Adama, Girar Jarso, Arsi Negele, Sebeta Hawas, Bako, Kuyu
SNNP	63,432	271	Kachabira, Meskan, Kedida Gamela, Hawassa, Dale, Gumer
Tigray	40,356	270	Adwa, Kilite-Awlaelo, Hawzen, Laelay-Maichew (Axum), Mekele, Saese-Tsaeda-Emba
Total	223,867	1,083	

A total of 1,083 farmers (268 from Amhara (-2 from the expected number), 274 from Oromia (+2 from the expected number), 269 from SNNP (-2 from the expected number) and 272 (+2 from the expected number) from Tigray regions) (Table 1) were interviewed using a checklist which mainly focused on the outcome of AI services provided to client farmers and reported by AI technicians. The interview questions mainly focused on whether the farmers received the reported service or not, and the outcome of AI in terms of pregnancy, calving and sex of the calf.

3.4. Secondary Data

Secondary data on livestock and livestock characteristics from agricultural sample survey reports of the Central Statistical Agency were taken from 2004/05 to 2017/18. Data on total cattle population, indigenous, crossbred and purebred cattle population, dairy and milking cattle population and number of calves born in each year were taken to make trend analysis for the different groups and types of cattle population. The same types of data were taken for Amhara, Oromia, SNNP and Tigray regions to make the same kind of trend analysis across study regions. The analysis is made to evaluate the performance and efficiency of crossbreeding activities at country and regional levels.

Two years (2014/15 and 2015/16) AI technicians' performance data were also collected from both AI technicians' service delivery logbooks or monthly and quarterly reports available at regional bureaus to compare with data received directly from AI technicians on monthly basis. These data were collected using a standard format prepared for this purpose.

3.5. Semen Quality Analysis

3.5.1. Semen Collection, Processing and Cryopreservation

Semen samples are collected from, production, storage, distribution sites and from AI technicians who are considered as end users. At production site semen samples are collected at the time of semen production using standard semen collection procedure. Semen straw samples were randomly taken from the storage point where they were ready for distribution. At storage site, frozen samples are randomly taken from the large semen

straw containers stored in liquid nitrogen. Similar procedure followed to take samples of semen straws from distribution sites. Samples of frozen semen samples were randomly taken from AI technicians from their either 3 or 2 liters mini containers. All semen samples collected from the different segments preserved in liquid nitrogen containers transported and delivered to the NAGII semen quality analysis laboratory for analysis. The sample straws were preserved in the same condition for a maximum of 5 days until analysis was conducted.

3.5.2. *Sample Size*

Semen straws were collected from production, storage, distribution and end-users (AI technicians) for semen quality test. About 34 straws of semen were collected from the production site (NAGII, Bahir Dar Artificial Insemination Center (AIC), Nekemit AIC, Hawassa AIC, and Mekele AIC) (Table 2); which are centers for producing and processing semen. Liquid nitrogen production and processing centers were considered as storage sites and about 89 samples of semen straws were collected from the four regions. Woreda or zone level livestock bureaus were considered as distribution centers and a total of 224 straw samples were taken from this segment. A total of 241 semen straw samples were also collected from AI technicians 2- or 3-liters mobile liquid nitrogen containers.

Table 2. Sampling layout for semen straw samples in Amhara, Oromia, SNNP and Tigray regions

Segment	Amhara	N	Tigray	N	SNNP	N	Oromia	N	Total	N
Production	1	6	1	10	1	8	1	10	4	34
Storage	3	30	1	10	2	20	3	29	9	89
Distribution	5	47	4	40	7	70	7	67	23	224
AI Technicians	6	54	6	59	6	59	8	69	26	241
Overall	12	137	12	119	16	157	19	175	62	588

N = Number of semen straw samples

3.5.3. Laboratory Analysis

As suggested by Pawshe (2017), the semen samples were thawed at 35°C using water bath before analysis for about 1 minute. About 0.25 ml of semen was used for different analysis from each straw. Semen samples were analyzed for their motility and morphology using Computer Assisted Semen Analyzer (CASA) – IVOS II- (that contains a digital camera with internal optics/optical system and an internal computer, its illumination and stage position are controlled by a software) (Figure 2). The semen samples were diluted using bovine semen extender before analysis. The quantitative assessment of sperm cells was performed by counting in a range between 1500 – 4000 cells from each straw and by tracking the total and progressive motile and static cells. The motility (total and progressive) and the morphological assessment was carried out using CASA as per the manufacturers program setting using ordinary slides as availability of leija slide was limited in the country. At the same time five morphometric parameters (distal droplet, proximal droplet, distal midpiece reflex (DMR), bent tail and coiled tail) were used to evaluate the semen and the percentage value of normal and defective cells.

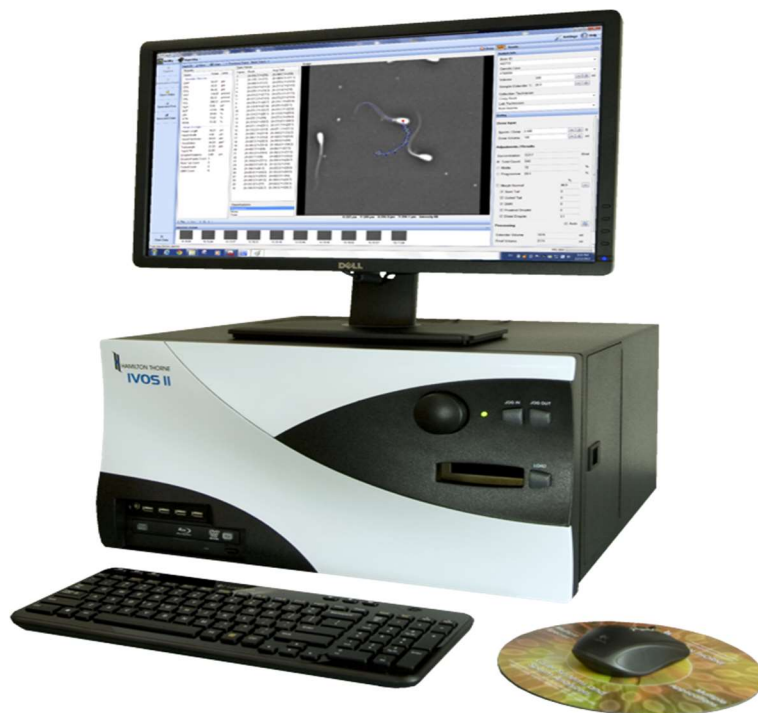


Figure 2. Computer Assisted Semen Analyzer (CASA) used in the analysis of Semen quality

3.6. Data Analysis

Primary data collected from AI technicians and farmers through the survey tools and secondary data collected from AI technician case book and Central Statistics Agency (CSA) of Ethiopia entered into Microsoft Excel (Microsoft Office, 2016 version) and Statistical Package for Social Science (SPSS) version 20 (SPSS, 2011). Semen quality data was entered into Microsoft Excel and transformed using the Statistical Analysis System (SAS) into usable format. For data analysis, both SPSS and Statistical Analysis System (SAS - Version 9) (SAS, 2004) were used based on the type of variable.

For quantitative data, the General Linear Model (GLM) of the SAS was used and means within the same category were separated using the Least Significant Difference (LSD) for those F tests that declared significance ($p < 0.05$). Qualitative data were analyzed systematically either in excel or SPSS and presented in the form of narrations and descriptions.

For quantitative analysis, the following mathematical model was used during data analysis.

$$Y_{ijkl} = \mu + R_i + S_{j(i)} + e_{l(ij)}$$

Where: Y_{ijkl} = the observed value of a dependent variable

μ = overall mean

R_i = the effect of region

$S_{j(i)}$ = the effect of semen supply chain (in the case of semen quality)

$e_{l(ij)}$ = random error

4. RESULTS

The result section of this study has four major chapters. The first chapter highlights key findings based on the secondary data obtained from the Central Statistical Agency (CSA) annual sample survey reports on Livestock Characteristics from 2004/5 to 2017/18. Due emphasis is given to limitations of these data set and country and regional level cattle population and productivity trend and its dynamicity. The second chapter is based on both primary and secondary data and focuses on AI service input supply system and status of AI equipment availability at regional level. AI technicians' access to and sources of major AI inputs, fuel allocation and its criteria, semen and liquid nitrogen production and distribution are major areas highlighted in this chapter. The third chapter evaluates the AI delivery system in the country specifically of the four studied regions (Amhara, Oromia, SNNP and Tigray). AI technicians' and farmers' characteristics, AI service working days, site of insemination services and distance, demand for AI service, thawing practice, prices of insemination service and access to AI technology are major topics highlighted in this chapter. Due emphasis is also given to performance of AI technicians and efficiency of AI delivery system in the country and the results presented in the fourth chapter of this study. The fifth chapter evaluates government led heat synchronization and mass insemination campaigns. The evaluation is based on interview held with AI technicians participated in the campaigns. The last chapter highlights adoption of dairy cattle husbandry and management practices including AI technology.

4.1. An Overview of Ethiopian Dairy Cattle Population and Productivity Trend

4.1.1. The Data Used and Limitations

Secondary data from the Central Statistics Agency (CSA) annual sample survey reports on Livestock Characteristics from 2004/5 to 2017/18 (CSA, 2005 - 2018) is used to analyze the Ethiopian cattle population and milk production dynamics. This is the only available statistical data in the country that can be referenced for academic, research and development purposes. The CSA data have also been used in the formulation, implementation, monitoring, and evaluation of development plans, projects, and programs in the livestock sector. The CSA data is obtained from the survey results undertaken at regional and zonal levels for the sedentary rural areas.

Though the CSA data are the only available comprehensive data of national government source in the country especially on livestock characteristics, there are limitations on the data and its survey reports. The CSA data doesn't include the non-sedentary population of the country especially found in Afar and Somali regions. Moreover, though the meaning of dairy cows and milking cows used in the CSA reports was correct, the data presented in the statistical reports have some kinds of discrepancies. Milking cows should normally be subset of dairy cows, however, the number of milking cows in almost all the survey reports is greater than that of dairy cows.

4.1.2. Trend in Cattle Population

Data obtained from the Ethiopian Central Statistics Agency (CSA, 2005 - 2018) demonstrated that there was a 54% increment in the total number of indigenous cattle populations in the last thirteen years with an annual average increase of 3.7%. The indigenous cattle population increased from about 38.53 million in 2004/5 to about 59.33 million in 2017/18 (Figure 3). Cumulatively, the indigenous cattle population increased by 54 percent from 2004/5 to 2017/18.

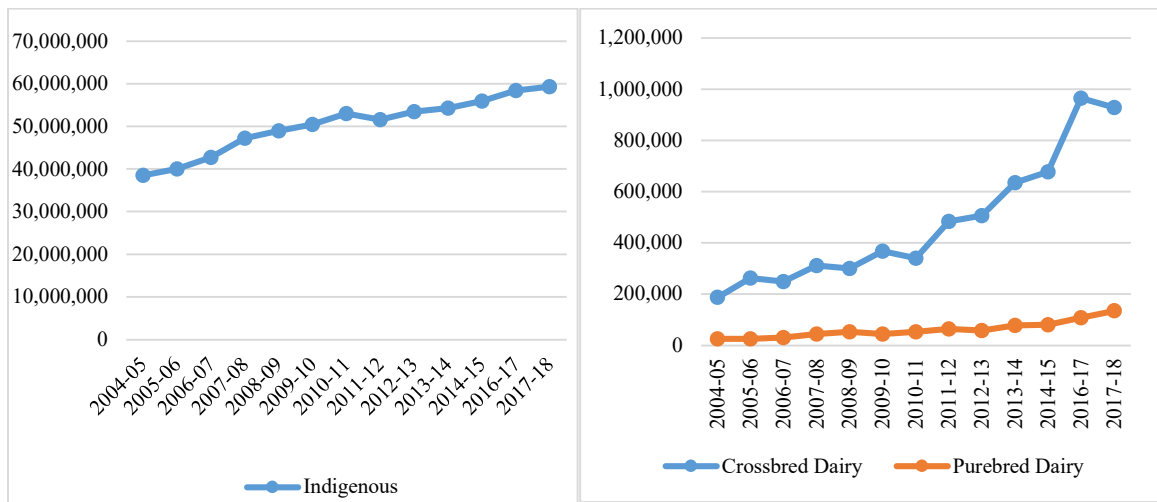


Figure 3. Trend in indigenous (left), cross and exotic breed (right) cattle population in Ethiopia from 2004/5 to 2017/18

However, the crossbred cattle population of the country increased by 395% in the same reference years with an annual average increase of 15.76%. However, the average percentage change in the number of crossbred cattle populations showed significant decrease every other year (Figures 4). The cumulative average percent increase for indigenous cattle population was 31.15% whereas the cumulative average increase in the crossbred cattle population was 110.04% (Figures 5).

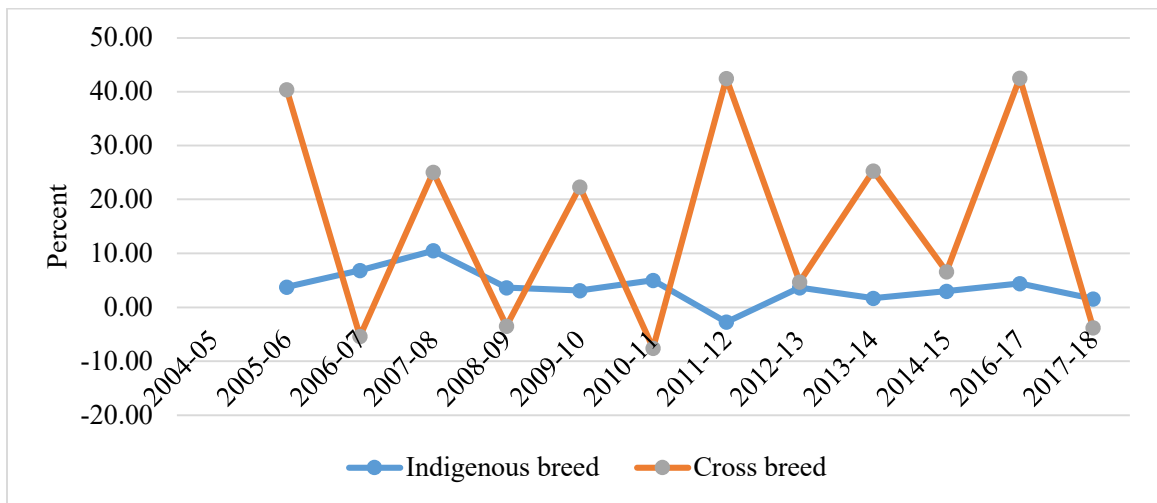


Figure 4. Percentage change (from previous year) in indigenous and crossbred cattle population in Ethiopia from 2004/5 to 2017/18

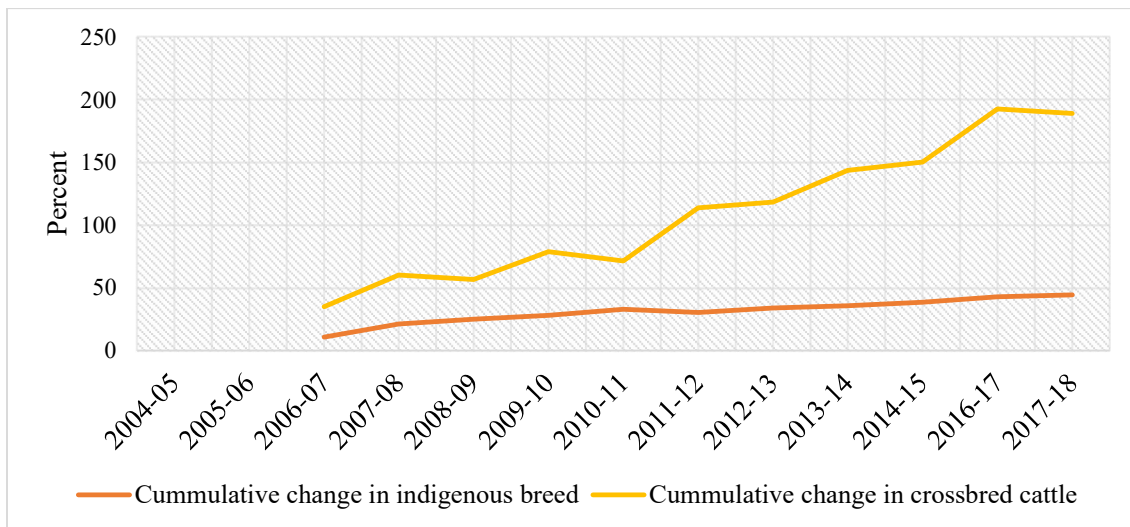


Figure 5. Cummulative percent change in the indigenous and crossbred cattle population in Ethiopia from 2004/5 to 2017/18

Considering the cattle population trend over the past thirteen reference years, the indigenous (3.7% annual increase) and crossbred (15.76% annual increase) cattle population of the country may reach 121.2 million and 5.4 million, respectively by 2029/30. This is 111.87% and 479.03% increase from 2017/18 in indigenous and crossbred cattle population of the country, respectively.

Data extracted from the Ethiopian Central Statistics Agency from 2004/5 to 2017/18 (CSA, 2005 - 2018) demonstrated that proportion of crossbred and exotic cattle population from total population in Ethiopia is less than 2 percent (1.76% in 2017/18) with an average percentage of 1.07% for the last thirteen years and maximum 1.80 percent recorded in 2016/17 (Figure 6).

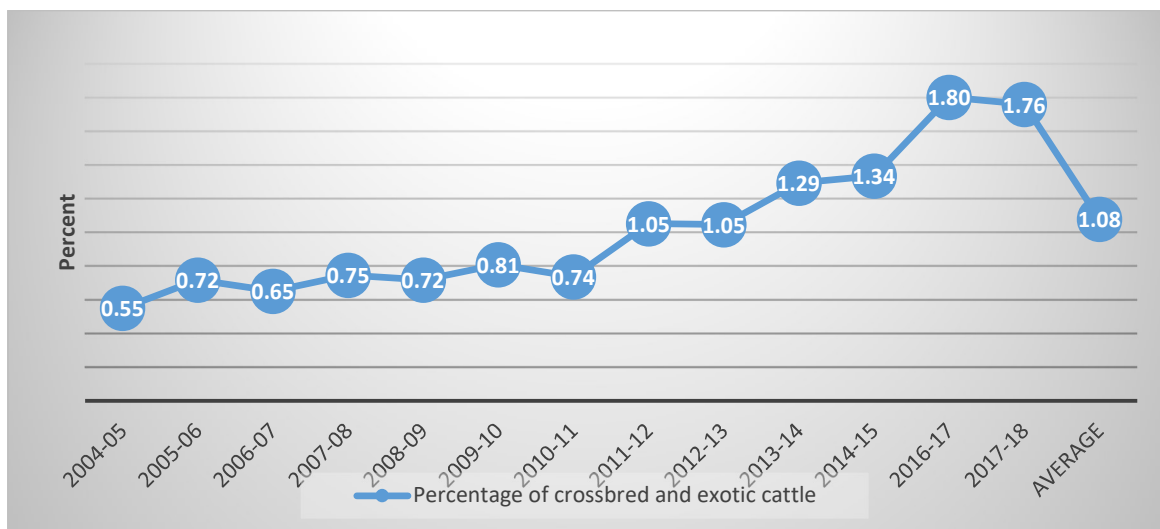


Figure 6. Proportion of cross and exotic cattle population from total cattle population in Ethiopia from 2004/5 to 2017/18

Considering the number of births and total population of cows reported each year from 2004/5 to 2017/18 in the CSA reports on Agricultural Sample Survey on Livestock and Livestock Characteristics (CSA, 2005 - 2018), the average percentage of cows calved is 41.93% with minimum 36.80% and maximum 46.23% reported in 2010/11 and 2005/06, respectively (Figure 5). This means the average calving interval is more than two years. This scenario is more reflected in the indigenous cattle population (Figure 7).

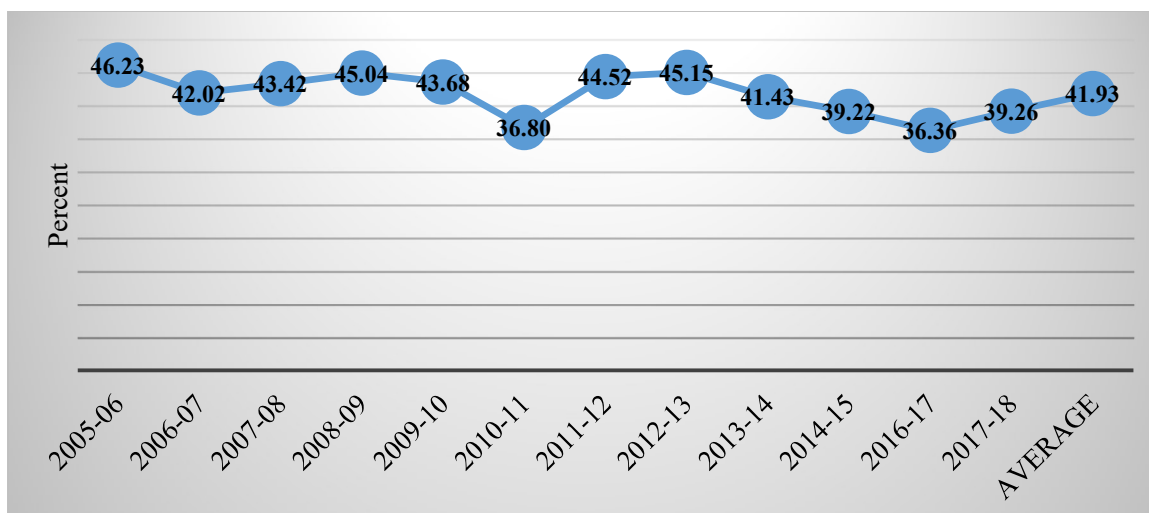


Figure 7. Percentage of cows calved from 2005/6 to 2017/18

4.1.3. Trend in Dairy and Milking Cows

Figure 8 below shows the trend in the number of dairy and milking cows in the country since 2004/05. Milking cows are subset of dairy cows; but in almost all cases of the Ethiopian Central Statistics Agency reports of Agricultural Sample Survey on Livestock and Livestock Characteristics (CSA, 2005 - 2018) dairy cows are considered a subset of milking cows. This is the major limitation of the livestock-related reports of the CSA. In all CSA reports dairy cows are defined as any type of cow used to give milk previously and/or provide milk currently or have never given milk before and pregnant now. The same reports defined milking cows as those cows milked during the year. The graph clearly shows that there was an increasing trend in the number of dairy cows (milking cows in the graph) but there is no significant increase in the total number of milking cows (dairy cow in the graph). Cumulatively, the dairy cows and milking cows in the country increased by 13% and 54%, respectively from 2004/5 to 2017/18.

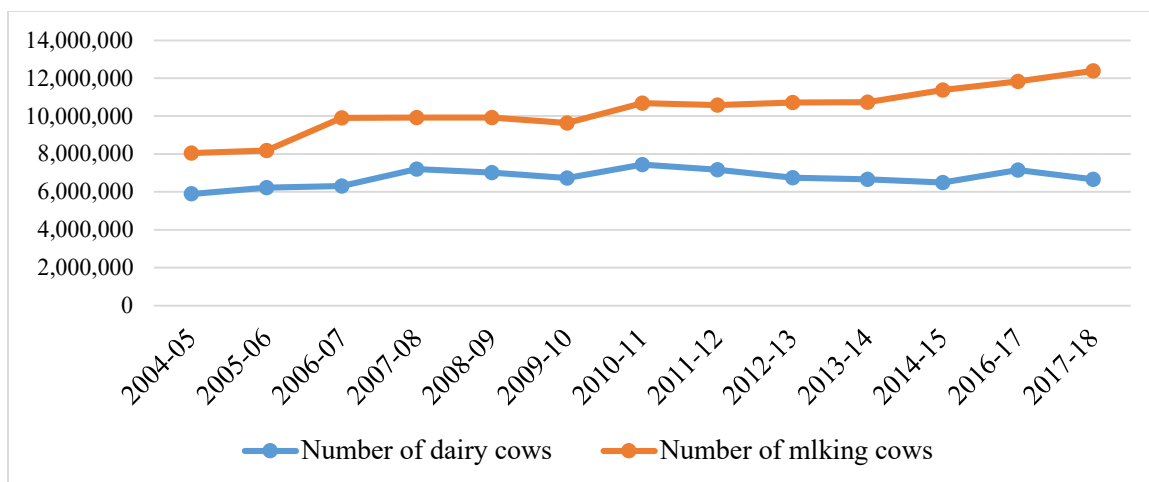


Figure 8. Trend in dairy and milking cow population of Ethiopia from 2004/5 to 2017/18

4.1.4. Trend in Milk Production and Lactation Length

Average milk production per day per cow and lactation length can be considered as good parameters to evaluate the efficiency of crossbreeding programs in the dairy sector. The thirteen years data extracted from CSA, Agricultural Sample Survey on Livestock and Livestock Characteristics (CSA, 2005 - 2018) revealed that there was an increase of only 1 billion liters (0.09 billion liters increase per year) without any change in lactation length (6 months) and an increase of only 0.138 liters/day/cow over the thirteen years period (Figure 9).

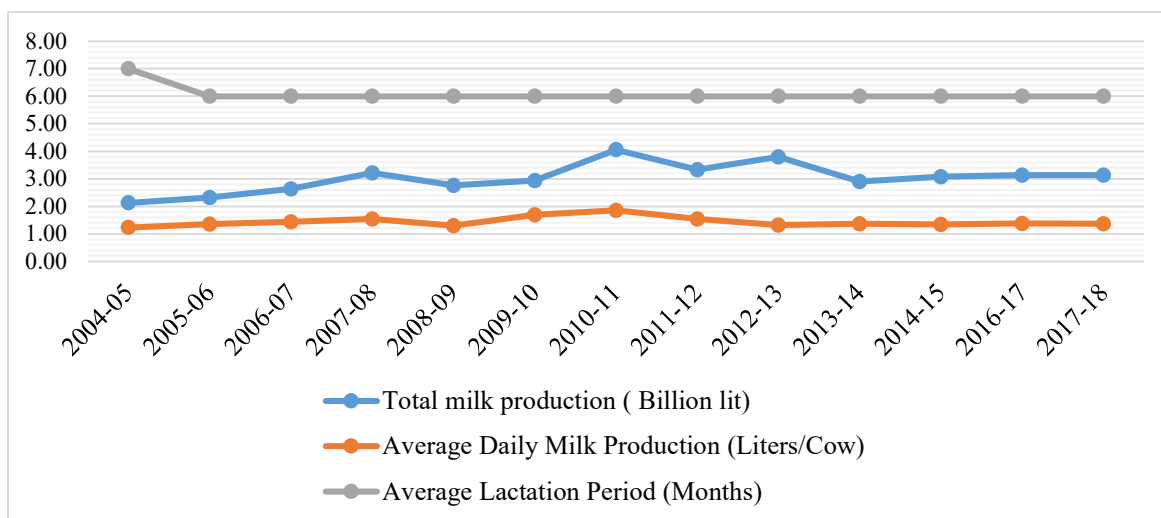


Figure 9. Trend in milk production and lactation length national level, Ethiopia from 2004/5 to 2017/18

4.1.5. Cattle Population Trend in Amhara, Oromia, SNNP and Tigray regions

Trend in Indigenous Cattle Population

From the CSA (2005-2018) reports we can observe that the indigenous cattle population in Amhara region increased on average by 4.25% per year whereas in Oromia by 6.9%, in SNNP by 2.28% and in Tigray by 5.41%. Cumulatively, the indigenous cattle population increased by 63.6% in Amhara, 40.8% in Oromia, 47.5% in SNNP and 74.0% in Tigray regions within 13 years between 2004/5 and 2017/18.

The same set of data (CSA, 2005 - 2018) was used to analyze the trend in the cattle population of Oromia region. However, the 2009/10 data had some discrepancies for the different cattle breed population of the region. The report indicated a population of 12,089,076; 22,923; and 235,904 for exotic, cross and indigenous breeds, respectively (Figure 10). This was very impractical and thus it could be corrected as 12,089,076, for indigenous, 235, 904 for cross and 22,923 for exotic breeds.

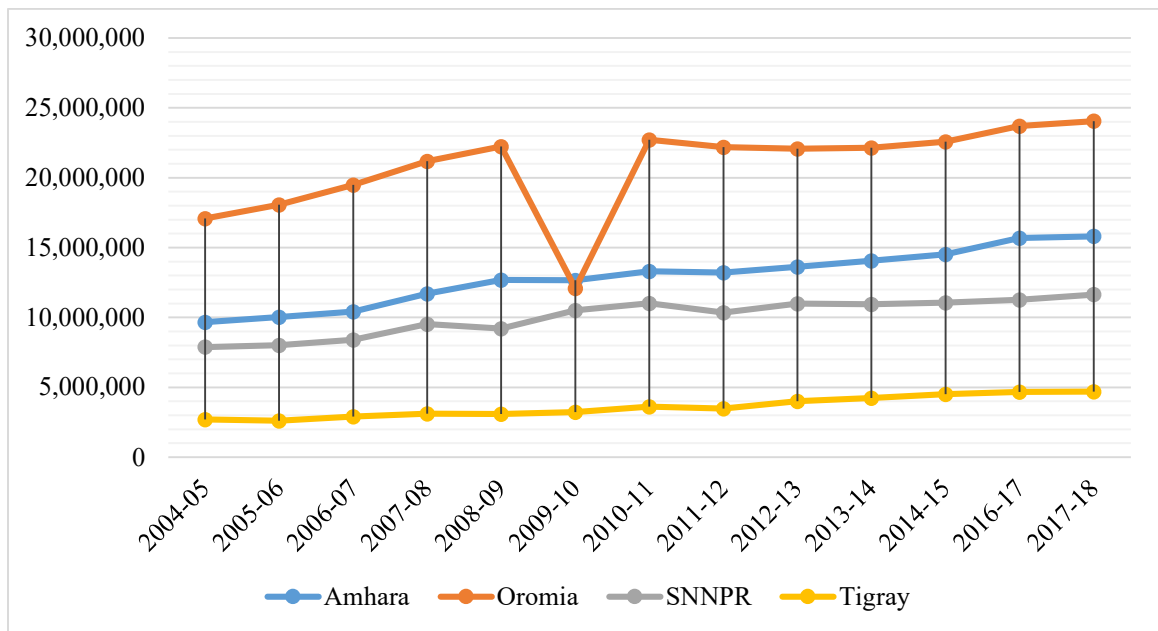


Figure 10. Trend in indigenous cattle population in Amhara, Oromia, SNNP and Tigray regions from 2004/5 to 2017/8

Trend in Cross Breed Cattle Population

According to the CSA data (CSA, 2005 -2018), the crossbreed cattle population of Amhara, Oromia, SNNP and Tigray regions increased on average by 27.2%, 11.1%, 17.4% and 33.1%, respectively in thirteen years since 2004/5. The cumulative increase of crossbred cattle population in Amhara was the biggest (1,151.6%) of all the four regions followed by Tigray (773.9%), SNNP (489.1%) and Oromia (172.8%) regions. A cumulative increase of 268,914 cross breed cattle population recorded in Amhara region whereas in Oromia 196, 260, in SNNP 189,723 and in Tigray 81,740 (Figure 11).

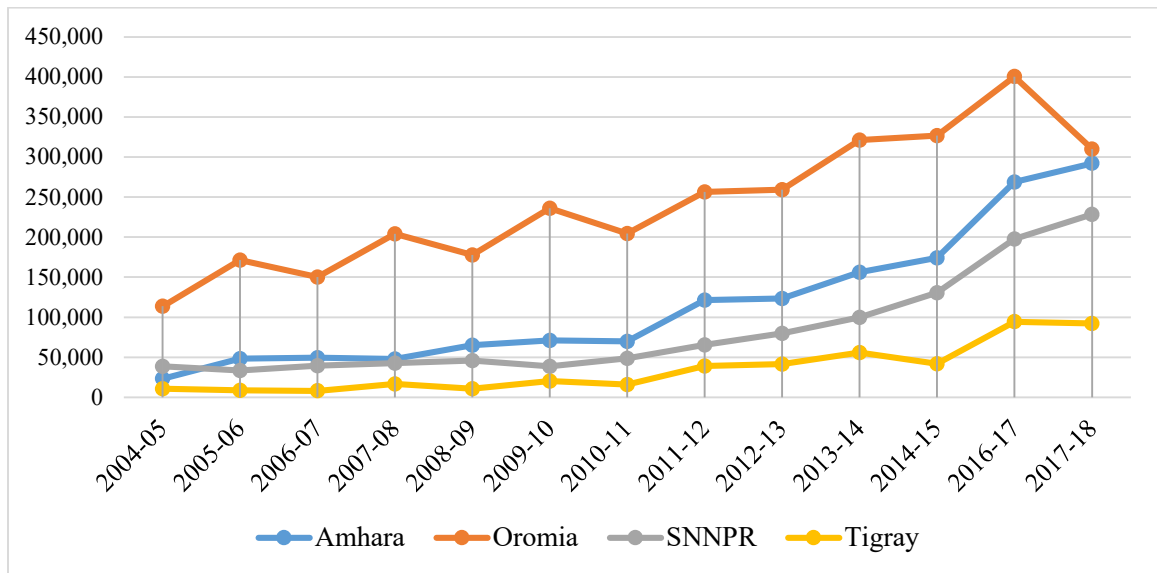


Figure 11. Trend in cross breed cattle population in Amhara, Oromia, SNNP and Tigray regions from 2004/5 to 2017/8

Trend in Exotic Breed Cattle Population

Looking at CSA (CSA, 2005 -2018) reports on exotic breed cattle population, we can observe that data for the reference years are not only inconsistent across regions but also not available for some of the reference years. Thus, the analysis was done using the available data. The exotic breed cattle population increased on average by 18.2% in Amhara, 19.3% in Oromia, 44.0% in SNNP and 31.7% in Tigray region. The total number of exotic cattle in the four regions was less than 100,000 (Figure 12).

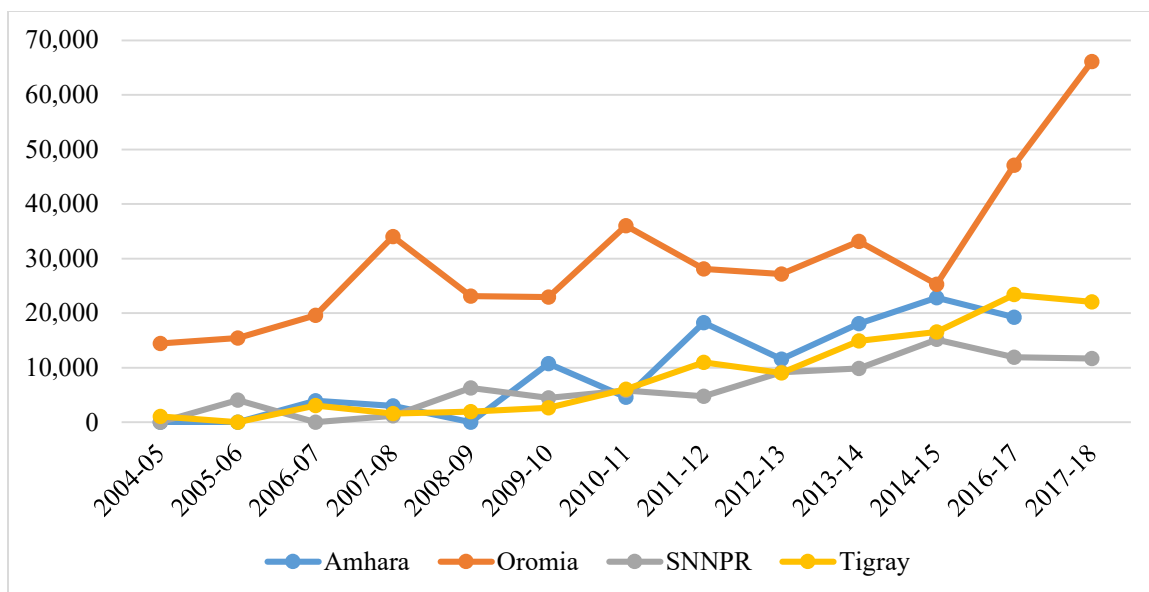


Figure 12. Trend in exotic cattle population in Amhara, Oromia, SNNP and Tigray regions from 2004/5 to 2017/8

Proportion of Cross and Exotic Breed Cattle Population

Figure 13 depicts trends in the proportion of crossbred and exotic breed cattle population from the total cattle population in Amhara, Oromia, SNNP and Tigray regions for thirteen reference years (2004/5 to 2017/18) based on data obtained from CSA (CSA, 2005 -2018). Though not significant, there was an increasing trend in the proportion of cross and exotic breed cattle population during the reference years. The proportion followed a similar trend with the national cross and exotic breed cattle population. The average proportion in the reference years was 0.89% for Amhara, 1.29% for Oromia, 0.84% for SNNP, 1.07% for Tigray regions and 1.03 for the country. In all cases, the proportion of cross and pure breed cattle population was less than 2%.

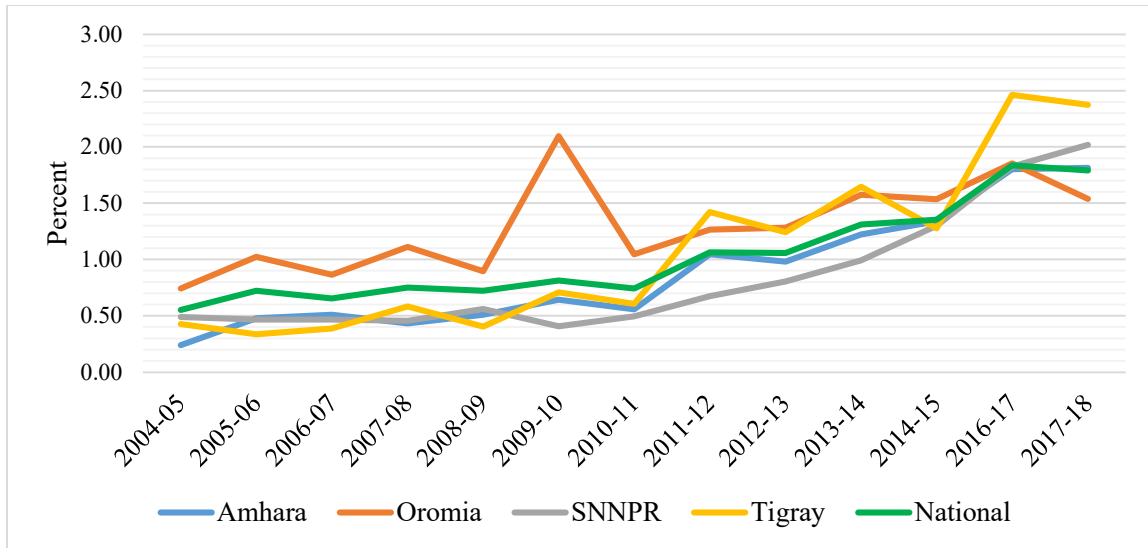


Figure 13. Proportion of cross and exotic cattle population from total cattle population in Amhara, Oromia, SNNPR, Tigray regions and in Ethiopia from 2004/5 to 2017/18

4.2. Evaluation of AI Service Input and Equipment Supply System

For efficient and successful AI service delivery system, sustainable supply of inputs and supplies is required. Apart from having efficient and experienced AI technicians, basic AI equipment and inputs mainly semen and liquid nitrogen should be supplied adequately, sustainability and in good quality.

4.2.1. Access to Semen and Liquid Nitrogen

Both semen and liquid nitrogen (LN₂) are the most important inputs in the AI delivery system. It is impossible to provide AI service in the absence of both or the presence of one without the other. Therefore, due attention should be given to ensure access to both semen and LN₂ to all AI technicians. In April 2018, AI technicians were requested to rate their access to both semen and LN₂ using a 5-point Likert scale (always available when needed, mostly available, sometimes available, rarely available and never available when needed). Those reported with always and mostly available when needed were considered as AI technicians with ready access to semen and LN₂.

About 88 and 75% of AI technicians in the four regions reported ready access to LN₂ and semen (always and mostly available when needed), respectively. All sample respondent AI

technicians in Tigray region reported semen and LN₂ to be readily available. In Amhara region semen was readily available to 90% of sample AI technicians; while the value was 54% in Oromia and 78% in SNNP. LN₂ is readily available when need to 100%, 74% and 89% AI technicians in Amhara, Oromia and SNNP regions, respectively. Availability of both semen and LN₂ was challenging for Oromia and SNNP region AI technicians when compared with that of Tigray and Amhara regions.

In November 2018, similar survey was conducted to understand accessibility of semen and its trend over time as availability of both semen and liquid nitrogen is expected to be changed over time. In Amhara and Tigray regions, availability of semen reduced from 90 to 80% and 100 to 69%, respectively. This was partly associated with lack of semen extender in both regional and NAIC semen laboratories. However, availability was significantly improved in Oromia region from 54 to 71%. Availability remained the same in SNNP region.

In all the four regional states, the source of semen is NAIC and regional semen production centers. Then semen from these sources transported to and stored at the LN₂ production centers. In most cases AI technicians are responsible to collect and transport semen straws using either small (2 or 3 lit) or big (35 lit) containers from the LN₂ production centers. They are expected to top up the containers while transporting the straws. In some cases, other staff members of the woreda bureau might be responsible to transport the semen straws. In such case there is high probability of semen quality deterioration as they are not experienced in transporting the semen straws.

4.2.2. Source of Semen

For the last few decades and even until very recently the only source of semen in the country was the National Artificial Insemination Center (NAIC) thus serving as a sole source to all regions till end of 2016. In 2017, four additional semen production and processing laboratories established in Amhara, Oromia, SNNP and Tigray regions with the support of Agricultural Growth Program phase I (AGP I). However, regional production can't fully satisfy respective regional needs. Therefore, the four regions transported

additional semen straws from NAIC and stored at regional LN₂ plants for regional consumption. About 96% of the AI technicians in Amhara, 70% in Oromia, 89% in SNNP and 100% in Tigray regions were being supplied semen mainly from the nearest LN₂ centers found in their respective regions. Only 4% (in Amhara), 30% (in Oromia) and 11% (in SNNP) AI technicians collected semen straws directly from NAIC semen production and storage center.

4.2.3. Semen Quality Check

About 41% of AI technicians in Amhara, 51% in Oromia, 53% in SNNP and 35% in Tigray regions reported that they regularly check the quality of semen, respectively. Of the total number of AI technicians who checked the quality of semen 80% in Amhara, 83% in Oromia, 37% in SNNP and 50% in Tigray regions reportedly use sample laboratory test; while the difference check by physical method.

4.2.4. Access to Basic AI Equipment

The basic AI equipment include AI gun, sheath, thermo flask, liquid nitrogen container (2 or 3 lit capacity), forceps, cito cutter, thermometer and sheath. However, availability of these basic equipment to the expected quality and quantity was challenging. Except gumboot and overall clothing, the provision of basic AI equipment was better in Tigray region than the other three regions (Figure 14).

Motorbike

Since AI technicians are expected to travel long distances in a diverse topography for AI service delivery, availability of motorbike is of paramount importance. Therefore, motorbike is considered as basic AI equipment in most cases its availability is reportedly better in Tigray region (91.30%) compared with the other three regions (Figure 14). Only 25% of the AI technicians in SNNP region reported that they had motorbike for AI service-related purpose; while the value is about 50% in Amhara and Oromia regions. Allocation of motorbike was found to be highly negatively correlated with gender ($r = -0.296^{**}$) but it was positively correlated with fuel allocation ($r = 0.017$), AI service provision during

regular season ($r=0.042$) and peak season ($r=0.095$), distance travel per day during regular ($r=0.131$) and peak season ($r=-0.495^{**}$).

Liquid Nitrogen Container

Liquid nitrogen container is used to preserve the straws filled with male spermatozoa for breeding purpose. AI technicians are expected to have mobile (2- or 3- liters capacity) LN₂ containers to transport semen straws to the point of service delivery. In this regard, LN₂ container is among basic equipment for AI service. As showed in Figure 14, availability of LN₂ containers was not a challenge as almost all the AI technicians reported that they had either 2- or 3-liters LN₂ containers.

Insemination Gun (AI gun)

AI gun is used to manually deposit the male spermatozoa in the female reproductive organ and is among the major AI equipment. Almost 100% of the AI technicians in the four regions had AI gun (Figure 14). However, replacement was mentioned as the major challenge in the four regions.

Thermo-Flask

Straws filled with semen cells need to be thawed at recommended temperature of 35-37% (Albert and Pamela,1988; Stoja *et al.*, 2016) to make them active from dormant stage where they stored at a temperature of -196^oC in LN₂. Though thermo-flask is basic and used to carry and transport warm water to the site of AI service for thawing purpose, a significant proportion (about 20%) of all sample respondent AI technicians reported that this equipment was lacking (Figure 14).

Forceps

Forceps is used to pick the required straw out of the canister in the LN₂ container. Absence of this basic equipment will lead to selecting and picking semen straw using hand, which may result in extended exposure time of semen straws to ambient temperature. Almost 80% of AI technicians in the four regions reported that they had this basic equipment (Figure 14).

Cito-Cutter

Semen straws must be cut using cito-cutter after thawing but before deposition into the female reproductive tract. About 92% in Amhara, 81% in Oromia, 86% in SNNP and 87% in Tigray regions reported to have cito-cutter (Figure 14).

Thermometer

Thermometer is used to check the temperature of water during thawing of semen straws before deposition. It is also used to measure the rectal temperature of the animal to be inseminated. The proportion of AI technicians reported to have thermometer in Amhara, Oromia, SNNP and Tigray regions was 92%, 72%, 78% and 96%, respectively (Figure 14).

Gumboot and Overall clothing

Gumboot and overall clothing are used to protect AI technicians from waste materials either from the animal or the area of AI service delivery and any kind of danger from the animal to be inseminated. However, only 18%, 47%, 33% and 22% in Amhara, Oromia, SNNP and Tigray regions reported to have Gumboot and overall clothing, respectively (Figure 14).

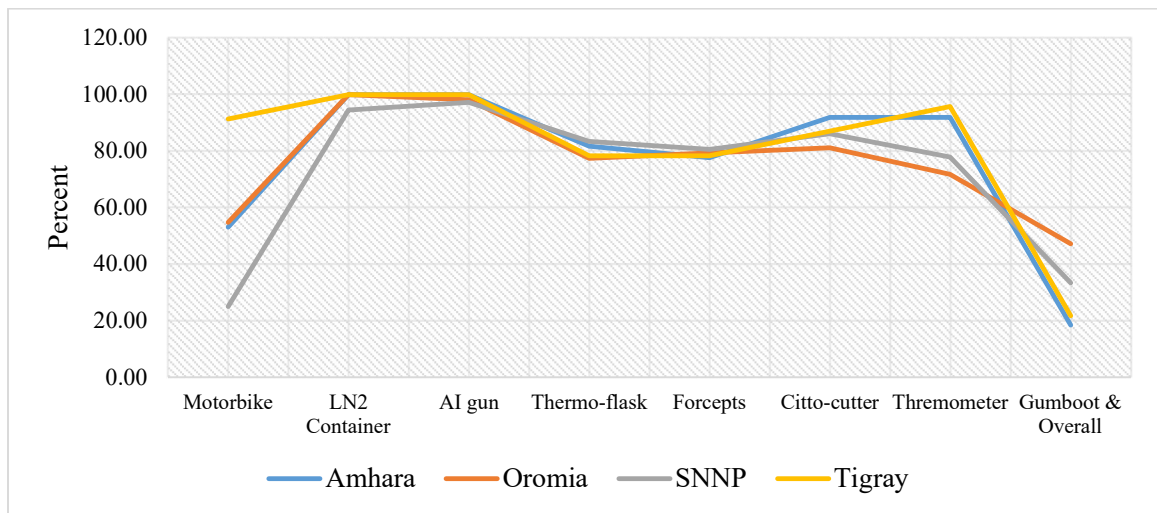


Figure 14. Availability of basic AI equipment in Amhara, Oromia, SNNP and Tigray regions

4.2.5. Fuel Allowance and Criteria

Provision of adequate volume of fuel for motorbike is an essential element in the AI service delivery system. AI technicians are expected to travel long distances with rugged topography and gravel roads to provide AI service and to make follow-up visits to their client farmers. To determine fuel allowance factors such as the distance that AI technicians are expected to travel per day, road condition, topography, and motorbike condition need to be considered. However, only 26 of 49 (53%) of AI technicians in Amhara, 21 of 53 (40%) in Oromia, 9 of 36 (25%) in SNNP and 21 of 23 (91%) in Tigray regions reported to get enough and regular fuel allowance from their respective bureaus.

About 40, 15, 32 and 64 liters of fuel were allocated for AI technician every month in Amhara, Oromia, SNNPR and Tigray regions, respectively. The overall average fuel allocated to AI technicians was 38.9 liters per month. Fuel allocated in Tigray region (64 lit/month/AI technician) is significantly ($p<0.05$) the highest followed by in Amhara (40 liters), Oromia (32 liters) and SNNP (15 liters) regions. The volume of fuel allocated was positively correlated with the number of inseminations during regular ($r=0.010$) and peak ($r=0.029$) seasons but negatively correlated with the number of inseminations during off-season ($r=-0.071$). The volume of fuel allocated was highly positively correlated with distance traveled during regular ($r=0.589^{**}$) and peak ($r=0.567^{**}$) season of AI service.

AI technicians were requested to tally criteria used for fuel allowance. Six criteria were given based on informal interviews and discussion with selected AI technicians and regional bureau staff. The criteria were: number of AI services provided per month, distance traveled per day, number of kebeles assigned to AI technicians, number of client farmers, availability of budget, health condition of AI technicians and fixed (no criteria at all). The most important parameter considered during fuel allocation was distance covered (29.17%) followed by budget availability and available number of AI technicians (Figure 15). Only in Tigray region, a fixed volume of fuel was allocated monthly for AI delivery system.

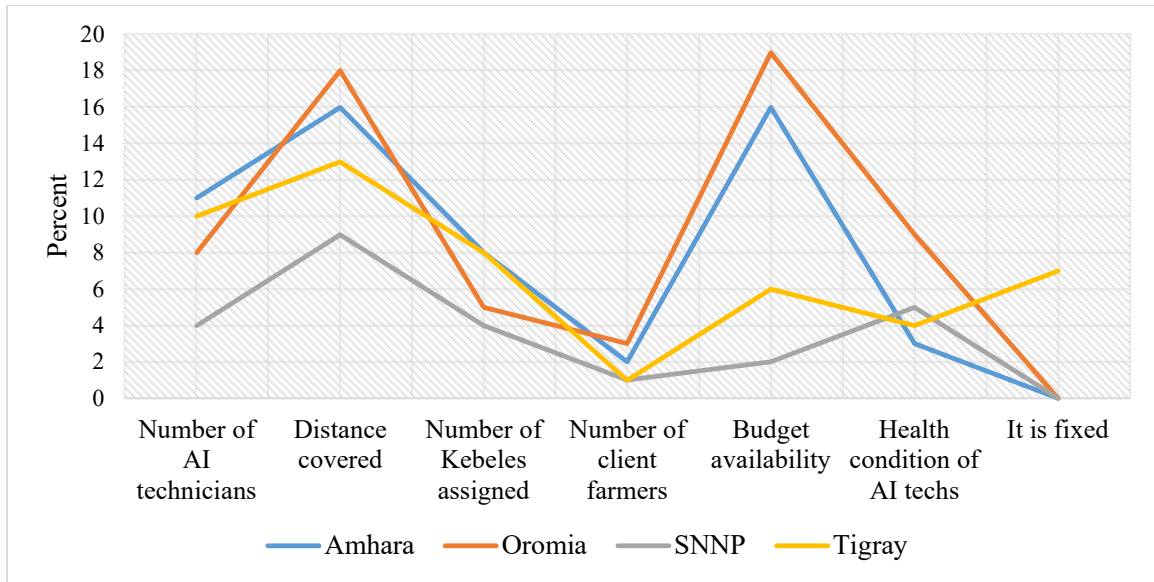


Figure 15. Criteria considered during fuel allocation in Amhara, Oromia, SNNP and Tigray Regions

4.2.6. Semen Production and Supply Chain

Semen Production and Distribution from NAIC

Since its establishment in 1981, the National Artificial Insemination Center (NAIC) has been responsible to coordinate the dairy cattle crossbreeding and breed improvement program of the country. The center was the only responsible government institute for recruiting genetically superior bulls and importing semen of high pedigree records for semen production. Until very recently it was the only center that import, produce, and store semen from bulls of high pedigree records and distribute to different parts of the country. NAIC is the only center with bull stud farm used for bull selection and recruitment for semen production purpose. However, at the end of 2016 four additional semen production and processing laboratories established in Amhara, Oromia, SNNP and Tigray regions with the objective of collection, processing and storage of semen straws to satisfy part of regional demand.

Data received from NAIC revealed that in 2017/18 NAIC handled 58 bulls of various breeds both local and exotic: Holstein Frisian (HF), Jersey, Erob, Borena, Sheko, HF*Borena cross originated from its bull stud farm, the Netherlands, South Africa, and different farms in the country.



Figure 16. Bulls used for Semen production – HF breed (left) and Jersey breed (right)

Data on semen production and distribution since 2009/10 till 2017/18 also received from the center and analyzed. As shown in Figure 17 semen production and distribution were in an increasing trend with average production and distribution of 679,572 and 645,593 straws per year, respectively. Semen production from 2009/10 to 2017/18 increased by 212% and distribution by 263%. On average about 95% of semen straws produced and processed at NAIC distributed to regions.

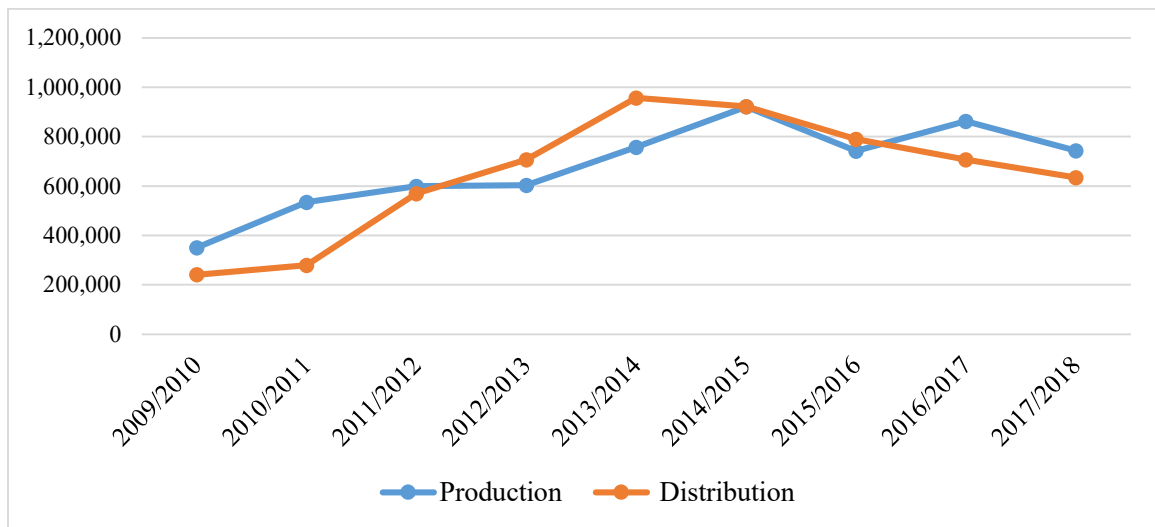


Figure 17. Semen production and distribution from NAIC from 2009/10 to 2017/18

Semen Production in Regional Laboratories

Four regional semen production and processing centers established in end of 2016 with the support of Agricultural Growth Program I (AGP I) in Bahir Dar, Nekemit, Hawassa and

Mekele cities to satisfy part of regional demand. The semen production started in these centers using Holstein Friesian (HF) and Jersey bulls originated from the Netherlands and South Africa. Three bulls from each breed distributed to each of the four production centers, however, few bulls died and culled before starting semen production. The regional semen production centers were producing and processing semen either once or twice per week following their standard procedure. There was no standard semen production and operation procedure during the startup phase, however, Standard Operating Procedure (SOP) for semen production developed through the support of Land O'Lakes – PAID project.

The decision as to which breed should be distributed to the different parts of the regions decided based on agroecology, genetic improvement strategy of the regions and level of dairy commercialization. In most cases Jersey was distributed in mid altitude areas and that of HF in high altitude, urban and dairy commercialization areas. As a strategy, semen produced from specific bull was distributed to specific areas for two consecutive years and then shifted to other areas to control inbreeding problem.

Semen produced in the regions covered about 30 to 35% of regional demand for semen from improved bull (35 to 40% in Tigray region, 35% in Amhara region). The rest was imported from NAIC. Semen imported from NAIC to the four regions was either 100% or 75% HF.

The FGD conducted with regional semen production center staffs revealed that semen produced at regional centers and imported from NAIC had varied preferences. For instance, in Tigray region both types of semen straws had similar preference except in few urban areas where semen produced at regional level preferred more. Both farmers and AI technicians in these areas thought semen imported from NAIC traveled long distance and this results in quality deterioration. In most parts of Amhara region semen produced at NAIC was more preferred than that of regional semen. This was mainly due to end users' (farmers and AI technicians) perception which was mainly related to experience of the semen laboratory in quality semen production and processing.

The major challenges for producing quality semen sustainably in the regional semen production centers were: absence of skilled technicians who have extensive knowledge and skill in semen production and lab equipment maintenance when the lab equipment failed to process; shortage of spare parts for lab equipment, shortage of laboratory supplies and reagents such as semen extender, inconvenient laboratory setup, frequent power cut associated with lack of standby generator and budget shortage.

Though NAIC was responsible to coordinate crossbreeding activity nationally, there was no strong relationship between NAIC and regional semen production and processing centers. The relationship was limited in terms capacity building (training of laboratory technicians) and reporting. However, there was no strong and regular reporting system between the regional semen production centers and that of NAIC. The centers were fully managed and budgeted from their respective regional livestock bureaus.

Data on semen production from regional laboratories and NAIC from September 2017 to October 2018 was also received from semen laboratories and analyzed. Semen production was interrupted in May 2017 at Bahir Dar, Nekemit and Hawassa laboratories and in June 2017 at NAIC semen laboratory due to shortage of semen extender. As shown in Figure 18 and 19 the average monthly semen production from Bahir Dar center was 4,345 straws (min 1,480 and max 9,937), from Nekemit 5,412 straws (min 2,431 and max 7,413), from Mekele 6,333 straws (min 1,471 and max 11,333) and Hawassa 3,716 straws (min 1,288 and 5,296). During the same reference period the average semen production (straws) from NAIC was 59,000 straws (min 23,695 and max 91,593) which was 11 times more than that of the average of the four regional laboratories.

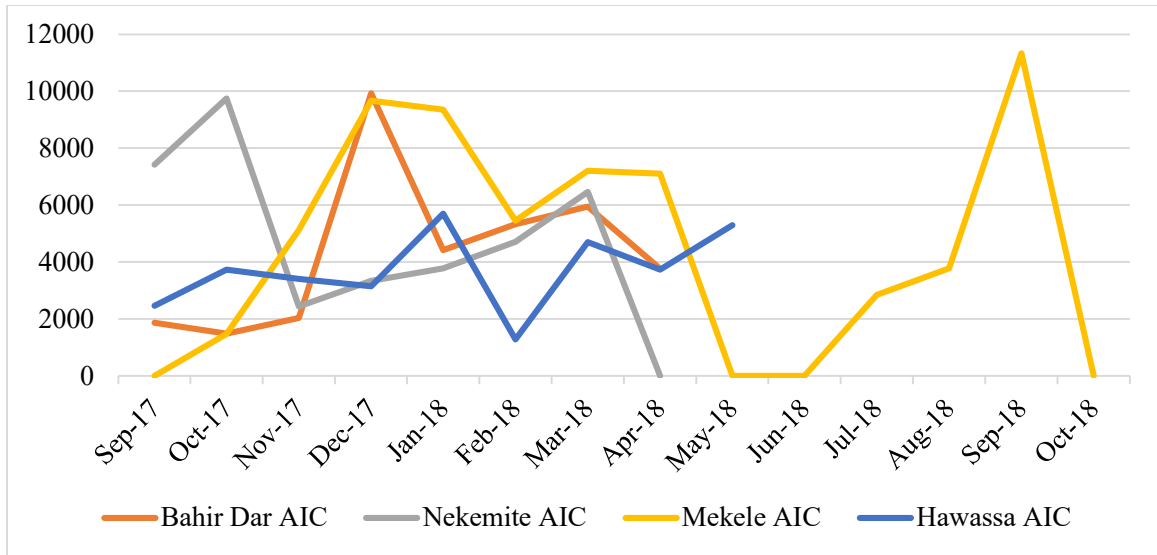


Figure 18. Semen production from regional semen production and processing laboratories from Sep 2017 to Oct 2018.

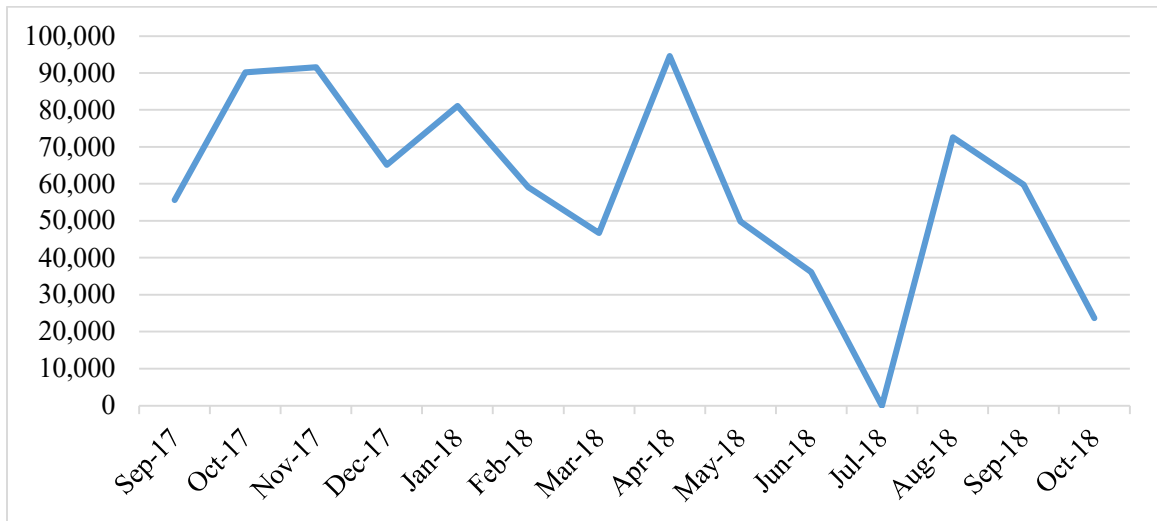


Figure 19. Semen production from NAIC from Sep 2017 to Oct 2018.

Data on semen distribution for nine years as of 2009/10 to 2018/18 also received from NAIC and presented in Table 3 below. A total of 5,352,411 (87.5% of semen produced during these periods) straws distributed to Amhara (825,119 or 15.4%), Oromia (2,034,991 or 38.0%), SNNP (1,728,823 or 32.3%) and Tigray (763,478 or 14.3%) regions.

Table 3. Semen distributed to Amhara, Oromia, SNNP and Tigray regions from NAIC

	Semen distributed to					Total
	Amhara	Oromia	SNNP	Tigray	Total	Production
2009/2010	29,432	73,731	79,532	40,305	223,000	350,492
2010/2011	39,282	81,218	99,703	38,810	259,013	534,171
2011/2012	60,620	115,978	111,236	96,445	384,279	600,000
2012/2013	59,155	272,341	220,127	132,190	683,813	603,763
2013/2014	253,765	293,730	256,572	134,120	938,187	758,243
2014/2015	101,374	443,807	262,399	70,341	877,921	921,932
2015/2016	96,070	294,552	225,331	127,130	743,083	742,421
2016/2017	98,499	233,144	263,156	69,450	664,249	862,201
2017/2018	86,922	226,490	210,767	54,687	578,866	742,929
Total	825,119	2,034,991	1,728,823	763,478	5,352,411	6,116,152
%	15.42	38.02	32.30	14.26	100.00	

4.2.7. *Liquid Nitrogen Production and Supply Chain*

Sustainable supply of liquid nitrogen is an integral part of efficient and effective AI service delivery system and among the most important factors which determine the success of crossbreeding programs. Over the past few decades, Ethiopia has installed about 23 liquid nitrogen plants across the country to meet the national demand (Table 4). Additional liquid nitrogen plants were under the process of installation in some parts of the country during the study period.

Table 4. Liquid nitrogen plants available in the country and status

S.No.	Model	Location	Year installed	Installed capacity (lit/hr)	Current capacity (lit/hr) Dec 2018
1	Jo675 Stirling Compact 1	Hawassa	2013	10	9
2	Jo258 Stirling Compact 1	Wolaita	2000	10	6
3	Jo674 Stirling Compact 1	Mizan	2013	10	8
4	Jo376 Stirling Compact 1	Wolkite	2005	10	6
5	Jo772 Stirling Compact 1	Bahir Dar	2002	10	6.5
6	Jo701 Stirling Compact 1	Debre Markos	2013	10	10
7	Jo556 Stirling Economy	Gondar	2009	5	3
8	Jo567 Stirling Compact 1	Debre Birhan	2010	10	8
9	Jo331 Stirling Compact 1	Dessie	2003	10	6
10	Jo330 Stirling Compact 1	Mekele	2003	10	4.5
11	Jo182 Stirling Compact 1	Mekele	1998	10	8
12	Jo734 Stirling Compact 1	Maychew	2014	10	7
13	Jo735 Stirling Compact 1	Shire	2013	10	7
14	Jo683 Stirling Compact 1	Shashemene	2013	10	8
15	Jo656 Stirling Compact 1	Fithce	2012	10	5
16	Jo770 Stirling Compact 1	Nekemit	2016	10	9
17	Jo332 Stirling Compact 1	Nekemit	2003	10	7
18	Jo773 Stirling Compact 1	Jimma	2016	10	8
19	Jo772 Stirling Compact 1	Hirna	2017	10	9
20	Jo256 Stirling Compact 1	Harar	2000	10	7
21	Jo254 Stirling Compact 1	NAIC	2000	10	7
22	Jo609 Stirling Economy	NAIC	2011	5	3
23	Jo685 Stirling Compact 1	NAIC	2013	10	8

Information collected from AI technicians across the four regions revealed that there was a consistent challenge for reliable access to this input. During the study period, about five liquid nitrogen plants were not functional.



Figure 20. Liquid nitrogen plant in Bahir Dar town, Amhara region

Liquid Nitrogen Distribution

Once produced liquid nitrogen is stored in the 35 lit capacity containers at the production sites (Figure 21). Zone or woreda livestock bureaus were responsible to transport filled liquid nitrogen containers when required. However, liquid nitrogen production centers could sometimes transport the filled containers to woreda bureaus if requested by woreda and zonal bureaus. Such a request could positively be accepted if budget is available and the volume of liquid nitrogen to be transported is justifiable. Since the containers are fragile during transportation AI technicians are recommended to transport themselves to give maximum care and handling during transportation. However, due to various reasons, the zonal or woreda bureaus might not allow AI technicians to travel to the liquid nitrogen centers for this purpose as it has a budget implication. In such circumstances, any other person from the woreda may transport the filled containers to the site of distribution.



Figure 21. Thirty-five liters liquid nitrogen containers used for transportation and storage

Management of Liquid Nitrogen Containers

Frequency of opening the small or mobile liquid nitrogen containers (usually 2 liters capacity), refilling practice and the volume of liquid nitrogen per refilling was among factors considered during the survey undertaken with AI technicians. Very high significant difference ($p < 0.001$) observed in the opening frequency of liquid nitrogen container with an average opening frequency of 6.0 times per day. The highest (8.3) opening time reported in SNNP region whereas the lowest (3.9) in Amhara region. This figure for Oromia and Tigray regions was 6.5 and 6.0, respectively.

AI technicians were also interviewed on the frequency of refilling (top-up) their liquid nitrogen container for the purpose of semen preservation. The overall proportion of AI technicians in the four regions who were refilling their 2 liters liquid nitrogen containers every day was 43%, every two days 28% and every three days 27%. The proportion of AI technicians who were refilling their container every day was 23% in Amhara, 38% in Oromia, 61% in SNNP and 74% in Tigray region. Similarly, about 17% of AI technicians in Amhara region, 43% in Oromia, 32% in SNNP and 13% in Tigray region reported that they refill their small containers every two days. About 56% and 2% of AI technicians in Amhara region, 19% and none in Oromia, 13% and 3% in SNNP and 9% and 4% in Tigray region reported that they refill their container every three days and every five days,

respectively. The proportion of AI technicians who refilled their container every four and five days was insignificant and thus the overall maximum waiting time to refill the 2 liters container was three days. The frequency of opening liquid nitrogen containers per day was positively correlated with the number of inseminations per day during regular ($r=0.566^{**}$), peak season ($r=0.583^{**}$) and off-season ($r=0.732^{**}$) and service per conception ($r=0.004$).

A significant difference ($p < 0.05$) observed in the volume of liquid nitrogen refilled per refilling of the 2 liters container. The average volume of liquid nitrogen-filled per refilling in the four regions was 1.16 liters with maximum volume (1.88 liters) in Amhara region and minimum volume (0.88 liters) in Tigray region. This figure for Oromia and SNNP regions were 1.25 and 1.18, respectively.

4.2.8. Semen Quality along Semen Supply Chain

Quality of semen should be maintained along the AI service supply chain to achieve the desired success in genetic improvement programs. Until very recently NAIC used a microscopic method to evaluate the quality of semen, however, in 2017 NAIC has got Computer Assisted Semen Analyzer (CASA) through the support of Land O'Lakes PAID project. This equipment enables the center to control the semen in a more strict and stringent manner. In March 2018 semen quality assessment conducted for semen straw samples taken from different segments of semen supply chain in the four studied regions and that of NAIC. Semen straw samples taken from semen production, storage, distribution centers and AI technicians who were considered as end users and analyzed using CASA.

Semen Quality at Regional Level

The statistical analysis on post-thaw total motility, progressive motility, normal morphology, and defective morphology showed significance difference ($p < 0.05$) among regions (Table 5). However, the difference in the number of cells was insignificant ($p > 0.05$) among regions. Post thaw total and progressive motility of semen samples taken from Oromia region significantly higher than the other three regions with overall average total and progressive motility percentage of 38% and 28%, respectively.

Table 5. Post-thaw total and progressive motility, normal and defective morphology of sperm of semen taken at various chains (Mean±SE)

Region	N	Sperm cells	Total motility (%)	Progressive motility (%)	Normal morphology (%)	Defective morphology (%)
Amhara	137	2,324±52.1	37.7±1.8 ^b	24.4±1.4 ^c	78.1±0.7 ^{ab}	21.9±0.7 ^{bc}
Oromia	175	2,228±33.0	43.7±1.6 ^a	34.9±1.5 ^a	75.2±0.6 ^c	24.7±0.7 ^a
SNNP	157	2,320±48.9	32.1±1.5 ^c	19.9±1.1 ^d	79.2±0.6 ^a	20.8±0.6 ^c
Tigray	119	2,229±30.5	37.6±1.9 ^b	30.5±1.6 ^b	76.2±0.8 ^{bc}	23.8±0.8 ^{ab}
Overall	588	2,275±21.3	38.0±0.9	27.6±0.7	77.2±0.3	22.8±0.3

Means with different superscripts in the same column are significantly different ($p<0.05$)

The highest percentage of normal morphology (79) recorded for semen samples collected from SNNP region with an overall average percentage of 77 (ranged from 75% to 79%). The highest number of cells (2,324) recorded for semen straws samples from Amhara region with an overall average of 2,275 cells (ranged from 2,228 to 2,324).

Semen Quality along Semen Supply Chain

Significant difference ($p<0.05$) observed along semen supply chains in post-thaw total and progressive motility (Table 6). However, the difference in the number of cells, normal and defective morphology was insignificant ($p>0.05$) for semen samples taken from semen supply chains. Highest percentage of total (48) and progressive (37) motility recorded for semen straws sampled at production site. Total and progressive motility percentages showed a decreasing trend from production to end user (AI technicians in this specific case).

Table 6. Post thaw total motility, progressive motility, normal morphology and sperm number assessed for semen samples taken from various regions of Ethiopia (Mean±SE)

Supply Chain	N	Semen cells	Total motility (%)	Progressive motility (%)	Normal morphology (%)	Defective morphology (%)
Production	34	2328.4±93.7	48.2±3.4 ^a	36.71±3.2 ^a	78.86±1.7	21.1±1.7
Storage	89	2356.5±59.0	38.9±2.2 ^b	26.86±1.9 ^b	76.77±0.9	23.2±0.9
Distribution	224	2253.9±32.7	38.3±1.4 ^b	27.87±1.3 ^b	77.18±0.5	22.8±0.5
AIT	241	2257.4±33.5	35.9±1.3 ^b	26.24±1.1 ^b	77.07±0.5	22.9±0.5
Overall	588	2275.2±21.3	38.0±0.9	27.6±0.7	77.2±0.3	22.8±0.4

Means with different superscripts in the same column are significantly different ($p<0.05$)

At production level the highest (58.2%) total motility recorded for samples taken from Oromia region followed by Tigray region (53.8%) whereas the least (34.9%) was for SNNP region. Similarly, the highest (47.9%) progressive motility at production level recorded for samples taken from Oromia region followed by Tigray region (46.1%) whereas the least was recorded for Amhara region (20.1%). At storage, the highest post-thaw total motility (53.4%) and progressive motility (43.5%) recorded for semen straw sampled from Tigray region. Similarly, the highest (49.4%) and lowest (40.6%) post-thaw progressive motility at distribution point recorded for semen samples taken from Oromia region. AT AI technician level the highest total motility (40%) and progressive motility (29.3%) recorded for semen samples taken from Amhara and Oromia region, respectively.

The normal morphology at the production site ranged from 74.0% in SNNP to 87.5% in Tigray region (75.4% in Amhara and 76.7% in Oromia). At the storage site, it varied from 75.2% in Tigray to 77.9% in SNNP region (76.3 in Amhara and 77.0% in Oromia). At distribution site the value ranged from 73.5% in Tigray to 79.5% in SNNP region (77.6% in Amhara and 76.3% in Oromia). At the level of AI technicians, it varied from 72.5% in Amhara to 80.3% in Oromia region (76.4% in SNNP and 80.1% in Tigray).

Spoilage of Semen Straws

AI technicians were interviewed on the average number of straws available in their container in each month and the number of straws discarded per month due to several reasons. An overall average of 112.8 straws (85.3 in Amhara, 141.5 in Oromia, 121.2 in SNNP and 94.1 in Tigray regions) could be available in the container per month per AI technician. Of which on average 6.6 (6%) straws (5.5 in Amhara, 6.5 in Oromia, 8.3 in SNNP and 6.7 in Tigray regions) discarded per month from each AI technician container. There was no significant difference ($p>0.05$) observed in the number of straws available per month per AI technician among regions; whereas the difference in the number of straws discarded per month per AI technician was significant ($p<0.05$) among regions.

The major reasons for semen spoilage were emptiness of semen straws (mentioned by 47.9% AI technicians in Amhara, 43.4% in Oromia, 38.7% in SNNP and 47.8% in Tigray regions) improper sealing (mentioned by 37.5% AI technicians in Amhara, 39.6% in Oromia, 25.8% in SNNP and 82.6% in Tigray regions), emptiness of liquid nitrogen (mentioned by 37.5% AI technicians in Amhara, 41.5% in Oromia, 41.9% in SNNP and 52.2% in Tigray regions), technical problem of AI technicians (mentioned by 41.7% AI technicians in Amhara, 32.1% in Oromia, 32.3% in SNNP and 30.4% in Tigray regions) and heat shock (mentioned by 41.7% AI technicians in Amhara, 32.1% in Oromia, 35.5% in SNNP and 34.8% in Tigray regions). The overall average proportion of AI technicians who mentioned emptiness of semen straws was 44.5%, improper sealing 42.6%, emptiness of liquid nitrogen 41.9%, technical problem of AI technicians 38.7% and heat shock 36.3%. In Tigray region, improper sealing was the most important reason whereas in Amhara and Oromia emptiness of semen and SNNP emptiness of liquid nitrogen in the container were the most important reason for discarding semen straws.

Exposure Time of Canisters

Significant difference ($p<0.05$) was observed in exposure time of canisters to external or ambient temperature during AI service delivery among the four regions. The overall average exposure time of canister to ambient temperature was 4.1 seconds with the highest

exposure time (5.9 seconds) reported in SNNP region and lowest time (2.7) reported in Amhara region. The result for Oromia and Tigray regions was 4.4 and 3.4, respectively.

4.3. Evaluation of AI Delivery System

4.3.1. Characteristics of AI Technicians

The success of AI service is influenced by factors related to the inseminator, the environment, and the animal to be inseminated. Age, educational status, training and experience of AI technicians are among factors related to AI technicians that can influence the efficiency of insemination services. Thus, it is pertinent to assess these characteristics and correlate them with some AI service performance indicators.

Age of AI Technicians

The average age of AI technicians in Amhara, Oromia, SNNP and Tigray regions was 31.69, 35.43, 35.72 and 37.52 years, respectively with an overall mean age of about 35 years. The age of AI technicians was significantly ($p < 0.05$) lower (31.69 years) in Amhara region than in the other three regions among which no significant difference ($p > 0.05$) existed. Correlation analysis revealed that age was positively correlated with duration of training ($r = 0.387^{**}$), experience of AI technicians ($r = 0.667^{**}$), number of inseminations per day during regular ($r = 0.163^*$), peak ($r = 0.144$) and off ($r = 0.165^*$) seasons.

Educational Status of AI Technicians

The majority (48.45%) of AI technicians were diploma (10th or 12th grade plus two or three years of training) holders whereas 29.19% were first-degree holders (in any discipline) and 19.88% were certified either as AI technician with a period of up to 9 months training or with other kind of short term (less than one year) pieces of training from vocational and technical schools (Table 7). In Tigray and SNNP regions, almost 95% of the AI technicians had a diploma and above levels of education. This figure in Amhara and Oromia regions was 49% and 85%, respectively.

Table 7. Educational status of AI technicians in Amhara, Oromia, SNNP and Tigray regions (2016)

	N	Secondary Education	Certificate	Diploma	Degree and above
Amhara	49	-	25 (51.02)	19 (38.78)	5 (10.20)
Oromia	53	4 (7.55)	4 (7.55)	22 (41.51)	23 (43.40)
SNNP	36	-	2 (5.56)	23 (63.59)	11 (30.56)
Tigray	23	-	1 (4.35)	14 (60.87)	8 (34.78)
Total	161	4 (2.48)	32 (19.88)	78 (48.45)	47 (29.19)

Numbers in parenthesis are percentages

In March 2019, a similar survey was conducted with AI technicians to further investigate and understand the change in their level of education over time. The survey was also aimed at understanding whether AI technicians' diploma or degree level of education is related to livestock science. As shown in Table 8 below there was no significant change in the level of education from 2016 to 2019 except in Amhara region where a significant number of AI technicians transited from certificate to diploma level.

Table 8. Educational status of AI technicians in Amhara, Oromia, SNNP and Tigray regions (2019)

Regions	N	Secondary Education	Certificate	Diploma	Degree and above
Amhara	86	2 (2.33)	28 (32.56)	53 (61.63)	3 (3.49)
Oromia	86	-	8 (9.30)	41 (47.67)	37 (43.02)
SNNP	66	-	17 (25.76)	27 (40.91)	22 (33.33)
Tigray	51	-	1 (1.96)	32 (62.75)	18 (35.29)
Total	289	2	54 (18.69)	153 (52.94)	80 (27.68)

Numbers in parenthesis are percentage

Only 3 (5%) of 56 AI technicians with degree and diploma level of education studied livestock-related science in Amhara region, 37 (47%) of 78 in Oromia region, 22 (45%) of

49 in SNNP region and 19 (38%) of 50 in Tigray region. Overall, 35% of AI technicians (19 of 50) with degree and diploma level had livestock-related educational background.

Regional Distribution of AI Technicians and Proportion of Cattle per AI Technician

Data on the available number of AI technicians in 2016/17 were received from livestock bureaus of the four regions (Amhara, Oromia, SNNP, and Tigray) and summarized in Table 9. There were 241 AI technicians available in Amhara region distributed in 10 zones and 141 woredas. In 2016/17, the number of AI technicians per woreda in this region ranged from 1.0 to 2.0 with an average of 1.62, which stands at the lowest side compared with the other three regions: Oromia (2.93), SNNP (2.51) and Tigray (3.16). The average number of AI technicians per zone in Amhara region was 24.1 (on average 14 woredas per zone). However, the total number of AI technicians in Amhara region increased in 2017/18 to 274 distributed in 144 woredas lifting the average number of AI technicians per woreda to 1.86.

In Oromia region, there were 667 AI technicians distributed in 18 zones and 232 woredas with average number of AI technicians per woreda being about 3 and per zone about 37. The average number of AI technicians available per woreda ranged from 2.27 to 3.67 (mean 2.93) which was higher when compared with Amhara region (1.62) and SNNP region (2.51) in the same reference year. The total number of AI technicians in Oromia region decreased in 2017/18 to 504 with an average number of 2.19 AI technicians per woreda.

The average number of AI technicians available per woreda in SNNP region was 2.51, which was higher when compared with that of Amhara region but lower than that of Oromia region. In this region there were a total of 341 AI technicians distributed in 142 woredas and 15 zones making the average number of AI technicians per zone 23.27, a number lower when compared with Oromia region but comparable with that of Amhara region. The total number of AI technicians in SNNP increased in 2017/18 to 383 of which 28 were female. The average number of AI technicians per woreda in 2017/18 was 2.69.

In Tigray region there were 112 AI technicians distributed in 6 zones and 35 woredas with an average number of 3.16 AI technicians per woreda. The average number of AI

technicians per woreda in this region was the highest when compared with Amhara (1.62), Oromia (2.93) and SNNP (2.51) regions. In 2017/18 the total number of AI technicians increased to 132 with an average number of 3.67 AI technicians per woreda. The average number of available AI technicians per woreda in 2017/18 was the highest when compared to the other three regions (1.86 in Amhara, 2.19 in Oromia and 2.69 in SNNP).

Table 9. Total and average number of AI technicians available in each zone of Amhara region in 2016/17

Regions	Number of Zones	Number of Woredas	Number of AI technicians	Average No. of AI tech/Woreda
Amhara	10	141	241	1.62
Oromia	18	232	667	2.93
SNNP	15	142	341	2.51
Tigray	6	35	112	3.16

Based on the number of dairy and milking animals in 2016/17 (CSA, 2017) and the number of available AI technicians in the same year; the ratio of animals to be inseminated per AI technician per day in Amhara, Oromia, SNNP and Tigray regions was 34, 33, 49 and 21, respectively (Table 10). However, if we consider female cattle population aged 3 to 10 years in 2016/17 (CSA, 2017) and the number of available AI technicians in the same reference year; the ratio was 55, 34, 34 and 38 animals per day for Amhara, Oromia, SNNP and Tigray regions, respectively. In the first situation, the highest (49) and lowest (21) number of animals to be inseminated per AI technician per day was calculated for SNNP and Tigray regions, respectively. In the second situation, the highest (55) number was calculated for Amhara region. If 50% of the female cattle population was to be inseminated (assuming 2 years of calving interval), the ratio of animals to be inseminated (considering dairy and milking cattle population in 2016/17) was 17, 16, 25 and 11 per day per AI technician in Amhara, Oromia, SNNP and Tigray regions, respectively. However, considering the female cattle population aged 3 to 10 years the ratio was 27, 17, 17 and 19

animals per day per AI technician in Amhara, Oromia, SNNP and Tigray regions, respectively.

In most cases, cross and exotic breed cattle are usually bred artificially (AI) where the service is readily available. If we take this (breeding of cross and exotic female cattle population) as another scenario, an AI technician is expected to inseminate 100, 56, 51 and 88 animals per month in Amhara, Oromia, SNNP and Tigray regions, respectively. This ratio was very low (2-5 AI services per day per AI technician) for AI technicians who are served as a fulltime employee in the public system.

Table 10. Number of AI technicians and cattle of breeding age, and animals to AI technician ratio in Amhara, Oromia, SNNP and Tigray regions

Region	Milking and Dairy*	No. of AI technicians	AI Ratio/year	AI ratio/month	AI ratio/day
Amhara	2,990,359	241	12,408	1,034	34
Oromia	7,923,608	667	11,879	990	33
SNNP	6,020,750	341	17,656	1,471	49
Tigray	853,295	112	7,619	635	21
Region	>3 to 10 years female cattle	No. of AI technicians	AI Ratio/year	AI ratio/month	AI ratio/day
Amhara	4,743,829	241	19,684	1,640	55
Oromia	8,149,133	667	12,218	1,018	34
SNNP	4,179,217	341	12,256	1,021	34
Tigray	1,533,742	112	13,694	1,141	38
Region	Cross and exotic	No. of AI technicians	AI Ratio/year	AI ratio/month	AI ratio/day
Amhara	287,993	241	1,195	100	3
Oromia	447,668	232	671	56	2
SNNP	209,541	341	614	51	2
Tigray	117,975	112	1,053	88	3

Milking and Dairy = The sum of Milking and Dairy cows as described in the CSA report

Engagement of Women as AI Technician

Of the total 1,361 AI technicians available in the four regions in 2016/17 only 1.76% (24 of which Amhara = 19, Oromia = 2 and Tigray = 3) were women. The highest proportion (7.9%) of women AI technicians was observed in Amhara region, whereas the proportion of women AI technicians in Oromia and Tigray region was 0.3% and 2.7%, respectively. The total number of AI technicians in 2017/18 decreased to 1,293 of which 93 (7.2%) were women. The engagement of women in the AI service delivery system increased in 2017/18 from 1.8% to 7.2%.

AI Technicians' Training and Experience

The duration of AI technicians' training ranged from 45 days to nine months (Table 11). About 42% of the total AI technicians considered in this study trained for 45 days; while the other 22%, 32%, and 7% of them were trained for a period of three, six and nine months, respectively. In Amhara, the highest (47%) proportion of AI technicians were trained for six months, however, in the remaining three regions, the highest proportion of AI technicians were trained for only 45 days. Only 6% and 17% of AI technicians in Oromia and Tigray regions were trained for nine months. No one was trained for 9 months as AI technician in SNNP region.

Table 11. Duration of AI technicians training in Amhara, Oromia, SNNP and Tigray regions

Region	45 days	Three months	Six months	Nine months	Total
Amhara	4 (8.16)	22 (44.90)	23 (46.94)	-	49
Oromia	36 (67.92)	4 (7.55)	10 (18.87)	3 (5.66)	53
SNNP	19 (52.78)	2 (5.56)	15 (41.67)	-	36
Tigray	8 (34.78)	7 (30.43)	4 (17.39)	4 (17.39)	23
Total	67 (41.61)	35 (21.74)	52 (32.30)	7 (4.35)	161

Numbers in parenthesis are percentage

The National Artificial Insemination Center (NAIC) has been serving as the major AI technicians' training center since its establishment in 1981. Currently, the training is being given regionally by regional Artificial Insemination centers in Amhara, Oromia, SNNP and Tigray regions and Agricultural, Technical, Educational and Vocational Training (ATVET) Institutes. About 12% of Amhara, 34% of Oromia, 19% of SNNP and 96% of Tigray AI technicians were trained at NAIC. On the other hand, 67% of Amhara and 55% of Oromia AI technicians got AI training at regional AI centers. The proportion of AI technicians trained at ATVETs in Amhara, Oromia, SNNPR and Tigray regions was 20%, 11%, 81% and 4%, respectively with the average value being 29%.

One of the major factors for the success of AI service delivery system is the experience of AI technicians. As the experience increases efficiency significantly improves. AI technicians in Amhara, Oromia, SNNP and Tigray regions served as AI technicians for 6.6, 7.8, 9.7 and 10 years, respectively with an overall average experience of 8.2 years. No significant difference ($p>0.05$) was observed in the experience of Amhara and Oromia region AI technicians. Similarly, the experience among Oromia, SNNP and Tigray region AI technicians was not significant ($p>0.05$). The experience of Amhara region AI technicians was significantly lower ($p<0.05$) than SNNP and Tigray region technicians. The maximum (21 years) experience was observed in SNNP region. Experience of AI technicians was positively correlated with the number of inseminations during regular ($r=0.144$), peak ($r=0.159^*$) and off ($r=0.219^{**}$) seasons. However, it was found to be negatively correlated with service per conception ($r=-0.034$).

AI Technicians' Job Satisfaction

AI technicians were interviewed with the intention of understanding whether they are satisfied with their job and the salary they were being paid, if they had plan to change their job and if they were delivering off-hour (especially night-time) services when requested. Accordingly, about 99% of the technicians in the four regions (100%, in Amhara, SNNPR and Tigray regions and 96% in Oromia) reported that they like their job but only 8.75% of the technicians (2% in Amhara, 11% in Oromia, 17% in SNNPR and 4% in Tigray) were satisfied with their monthly salary.

About 33% of the technicians (26% in Amhara, 42% in Oromia, 9% in SNNPR and 65% in Tigray) had plan to change their job due to various reasons with the major ones being the very low monthly salary they earn, and demotivating carrier structure implemented in their respective regions. The highest (65.2%) number of AI technicians planning to change their job was reported in Tigray region. On average, 38% of technicians complained that they were forced to accomplish other assignments given by their respective woredas with the highest (70%) proportion being in the Oromia region. About 59% of technicians in the four regions (51% in Amhara, 70% in Oromia, 63% in SNNPR and 49% in Tigray) reported that they were providing night-time service when needed/requested.

4.3.2. Characteristics of Farmers

The adoption of agricultural technologies is influenced by age, education level and gender of the farmer, household income, farm size, farming experience, frequency of contact with extension or source of information. Therefore, it is pertinent to collect relevant data and evaluate these characteristics as it is believed that they can affect the adoption of AI as a breeding technology.

Gender of Farmers

About 26% and 74% of participated farmers in the interview in the four regions were female and male, respectively, which is also average values for the four regions combined. These figures for Oromia, SNNP and Tigray regions were 14% and 86%, 46% and 54%, and 17% and 83%, respectively.

Age of Farmers

The age of dairy farming household heads was significantly different ($P < 0.0001$) among the four regions with the highest age (45.62 years) recorded in Tigray region and the lowest (40.38 years) in Oromia. The average age of farmers for Amhara and SNNP regions was 47.16 and 45.21, respectively with an overall average age of 45.62 years. No significant difference observed in the age of SNNP and Amhara region dairy farming household heads.

Educational Status of Farmers

About 81%, 58%, 62% and 82% of the household heads attained primary level education or below in Amhara, Oromia, SNNP and Tigray regions, respectively. The proportion of farmers who attained secondary level of education in Amhara, Oromia, SNNP and Tigray regions was 12%, 28%, 23% and 17.5%, respectively with an overall average of 20%. Similarly, about 7%, 14%, 15% and 1% of farmers completed either technical education or above in Amhara, Oromia, SNNP and Tigray regions, respectively with an overall average of 9%.

Family Size

Very high significant difference ($P<0.0001$) observed in the family size among the four regions (Table 12). The average dairy farming household's family size in the four studied regions was 6.18 persons per household with the highest (6.9) and lowest (5.34) in SNNP and Amhara regions, respectively. The average number of male household members in the four regions was 3.21 while the female was 3.05.

Table 12. Family size of dairy farming households in Amhara, Oromia, SNNP and Tigray Regions (Mean±SE)

Region	N	Male	Female	Total
Amhara	103	2.91±0.13 ^b	2.55±0.14 ^b	5.34±0.24 ^b
Oromia	104	3.62±0.22 ^a	3.30±0.19 ^a	6.79±0.35 ^a
SNNP	104	3.39±0.15 ^a	3.51±0.14 ^a	6.90±0.21 ^a
Tigray	101	2.92±0.14 ^b	2.85±0.14 ^b	5.71±0.21 ^b
Total	412	3.21±0.08	3.05±0.08	6.18±0.13

Means with different superscripts in the same column are significantly different ($p<0.05$)

Dairy Households Income

Total household income, income from off-farm activities as well as from livestock related sources in the four regions is summarized in Table 13 below. Very high significant difference ($P<0.0001$) observed in income from off-farm activities among the four regions with a mean income of 2,111.72 ETB per household per month. Total household income,

income from sale of livestock and livestock products was also significantly different ($p<0.05$) among the four regions. The highest income (5,500 ETB) per household per month from livestock sale and livestock products was recorded in Tigray region whereas the least (1,284 ETB) was in Amhara region.

Table 13. Income (Mean ETB \pm SE) from different sources per household per month (July 2018) in Amhara, Oromia, SNNP and Tigray regions

Region	N	Total	Off-farm	Livestock Sale	Livestock Products
Amhara	106	5686.07 \pm 385.75 ^b	2535.55 \pm 264.91	1866.28 \pm 172.80 ^b	1284.23 \pm 169.20 ^b
Oromia	104	6424.30 \pm 404.78 ^{ab}	2303.65 \pm 308.39	2721.90 \pm 233.83 ^a	1398.76 \pm 137.77 ^a
SNNP	105	8019.97 \pm 1160.25 ^a	1778.76 \pm 233.88	2026.63 \pm 232.59 ^b	4214.57 \pm 962.06 ^b
Tigray	104	7324.67 \pm 441.08 ^{ab}	1823.94 \pm 281.93	2725.58 \pm 208.19 ^a	2775.14 \pm 223.08 ^a
Total	419	6860.89 \pm 342.33	2111.72 \pm 137.09	2332.12 \pm 107.87	2417.05 \pm 259.11

Means with different superscripts in the same column are significantly different ($p<0.05$)

Size of Cattle and Other Livestock Species

Very high significant difference ($P<0.0001$) was observed in the number of heifers, and male and female calves owned per household among the four regions (Table 14) with highest number of heifers (1.28) in SNNP, male (1) and female (1) calves in SNNP and Oromia regions, respectively. Significant difference ($p<0.05$) also observed in milking cows, dry cows and total cattle herd size among regions with the highest cattle herd size (7.21) being recorded in the Oromia region.

Table 14. Cattle herd size (Mean±SE) of the dairy farming households in Amhara, Oromia, SNNP and Tigray regions

Region	N	Total cattle	Milking cows	Dry cows	Heifers	Female calves	Male calves
Amhara	105	5.50±0.29 ^b	1.25±0.11 ^{ab}	0.69±0.07 ^b	0.62±0.07 ^b	0.88±0.09 ^{ab}	0.78±0.07 ^b
Oromia	104	7.21±0.51 ^a	1.63±0.13 ^b	1.44±0.15 ^a	1.28±0.13 ^a	0.86±0.11 ^{ab}	1.02±0.10 ^a
SNNP	104	4.88±0.65 ^b	1.73±0.32 ^a	1.00±0.17 ^b	1.06±0.15 ^a	0.99±0.19 ^a	0.52±0.08 ^c
Tigray	103	4.72±0.32 ^b	1.08±0.12 ^b	0.92±0.12 ^b	0.72±0.09 ^b	0.57±0.08 ^b	0.45±0.08 ^c
Total	416	5.58±0.28	1.42±0.10	1.00±0.07	0.91±0.06	0.82±0.06	0.70±0.04

Means with different superscripts in the same column are significantly different ($p<0.05$)

Average chicken number per household was 4.4 with no significant difference ($p>0.05$) observed among the four regions. However, the difference in the average number of sheep and goat was significant ($p<0.05$) among the four regions with an average number of 1.84 and 0.43 per household, respectively. Sample farmers from Tigray region owned the highest number of sheep (3.58) and goat (1.04) per household compared with the other regions. The average number of sheep was 0.95, 1.33 and 1.52 and goats per household in Amhara, Oromia, and SNNP regions was 0.95 and 0.47, 1.33 and 1.33, 1.52 and 0.04 and 3.58 and 1.04, respectively.

Experience of Farmers in Dairying

As understood from sample respondent households, the establishment of dairying was in an increasing trend with most dairy farms being established in the last nine to ten years (2009 – 2018). About 48% of farms in Amhara, 45% in Oromia, 24% in SNNP and 55% in Tigray regions established between 2009 and 2018 (Figure 22).

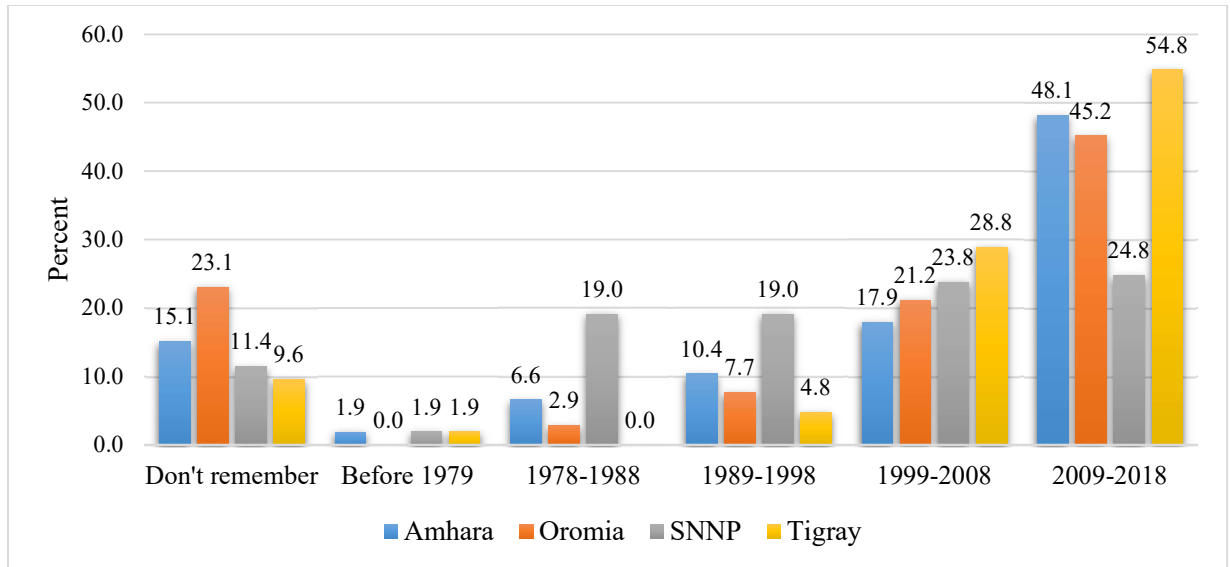


Figure 22. Farmers experience in dairying in Amhara, Oromia, SNNP and Tigray regions

4.3.3. Number of Working Days Per Week

Due to the nature of cows' heat cycle and its time sensitiveness, AI technicians are expected to be on their duty 24 hours per day and 7 days per week. About 100% of the respondent AI technicians in Tigray region reported to work 7 days per week, whereas in Amhara, Oromia and SNNP regions some AI technicians reported a one to two day-off per week that makes average working days 6.71, 6.28 and 6.61 per week, respectively. One day-off per week was reported by 34% of respondent AI technicians in Oromia, 8.16% Amhara, and 15.15% in SNNP regions AI technicians that reported to work 5 days per week make 10.20% in Amhara, 18.87% in Oromia, and 12.12% in SNNP. AI service is very time-sensitive, an animal in heat should be inseminated at the appropriate time for maximum fertilization. To this end, AI technicians always need to be on standby for an eventual call from a needy farmer.

Significant proportion of AI technicians in Oromia region work 5 and 6 days per week. As a result, a significant proportion of animals in heat might miss their heat time without being inseminated. This could, in turn, lead to significant economic loss to farmers, regions and the country in large.

4.3.4. Site of AI Service and Proportion

In most parts of the country AI service is delivered both at the farm gate and at the woreda/kebele crushes where farmers bring their in-heat cows/heifers for the service when AI technicians are unable to travel to farm gate for various reasons (Figure 23). Accordingly, in 96% of the cases, AI service is provided at woreda/kebele sites with regional figures being 97% in Amhara, 94% in Oromia, 92% in SNNP and 100% in Tigray. Overall, 89% (86% in Amhara, 87% in Oromia, 88% in SNNP and 100% in Tigray) of these same sample AI technicians travel to farm gates to provide the service. The provision of AI service at the farm gate was constrained by the availability of motorbike, fuel and time constraint.



Figure 23. AI service delivery at kebele site in Tigray region

According to interviews conducted with AI technicians, in Amhara region about 38% and 62% of the insemination services were provided at the farm gate and woreda/kebele site, respectively (Table 15). Likewise, 49% and 51% of inseminations in Oromia, 46% and 54% of inseminations in SNNP and 67% and 33% of inseminations in Tigray region were provided at farm gate and woreda/kebele site, respectively. In Tigray region, a higher proportion (67%) of AI services were given at the farm gate whereas in Amhara, Oromia and SNNP region higher proportion of inseminations provided at the woreda/kebele crushes. This information can help in the allocation of motorbike and associated budget for fuel, service, and maintenance.

Table 15. Proportion of AI services at the farm gate and woreda/kebele site in Amhara, Oromia, SNNP and Tigray region

Region	N	Proportion of AI Technicians provide AI Service at		Percentage of AI Service at (Mean±SE)	
		Farm Gate	Woreda/Kebele	Farm Gate	Woreda/Kebele
		Amhara	49	97	86	38.2±3.28	61.8±3.28
Oromia	53	94	87	48.5±3.36	51.5±3.36
SNNP	27	92	88	46.0±3.78	54.0±3.78
Tigray	23	100	100	67.3±2.76	32.7±2.76
Overall	152	96	89	48.2±1.80	51.8±1.80

About 56 and 31% of all respondent sample farmers in the four regional states considered in this study reported that they got insemination services only at woreda/kebele crushes and at their farm gate, respectively; while about 13% of them reported to get the service both at woreda/kebele crushes and their farm gate. Among the four regions, the highest (67%) proportion of inseminations performed at woreda/kebele site reported in SNNP region while the lowest (19%) in Tigray region. The highest proportion (67%) of farm gate delivery of AI service was reported from Tigray and the lowest (33%) in SNNP region. About 12% AI technicians in Amhara, 7% in Oromia, 14% in SNNP and 13% in Tigray regions reported that they were able to get the service at both sites depending on the distance of the site, breed of the animal and time.

4.3.5. Traveling Distance for AI Service Delivery

As depicted in Table 16, AI technicians cover an average of 33 km/day during the regular breeding season and 50 km/day during the peak season with no marked difference ($p>0.05$) among regions during the regular season. Significant difference ($p<0.05$) in daily distance covered by AI technicians to deliver service was observed among regions during the peak season with the highest (72.2 km/day) reported in Tigray and the lowest (38.4 km/day) in SNNP region.

Table 16. Distance covered by AI technicians during regular and peak season of the year in Amhara, Oromia, SNNP and Tigray regions (Mean±SE)

Region	N	Distance traveled per day (Km/day)	
		Regular season	Peak season
Amhara	49	35.67±10.16	47.67±6.41 ^b
Oromia	53	29.55±2.00	49.38±2.71 ^b
SNNP	33	29.58±4.36	38.44±4.85 ^b
Tigray	23	42.59±5.45	72.17±7.46 ^a
Total	158	33.35±3.43	49.96±2.74

Means with different superscripts in the same column significantly different ($p < 0.05$).

Distance traveled during the regular season was positively correlated with age of AI technicians ($r=0.017$), experience of AI technicians ($r=0.070$), motorbike availability ($r=0.131$) fuel allocation ($r=0.589^{**}$), number of inseminations per day during regular season ($r=0.049$) and peak season ($r=0.140$). However, it was negatively correlated with gender ($r=-0.163^*$) and education level ($r=-0.029$). Similarly, distance covered during peak season was positively correlated with age of AI technicians ($r=0.215^{**}$), education of AI technicians ($r=0.027$), experience of AI technicians ($r=0.252^{**}$), motorbike availability ($r=0.495^{**}$), fuel allocation ($r=0.567^{**}$) and number of inseminations during regular ($r=0.062$) and peak ($r=0.136$) seasons. However, it was negatively correlated with gender ($r=-0.315^{**}$).

4.3.6. Distance of Insemination Site from farm Gates

In most parts of the country AI service is delivered either at the woreda/kebele center or the farm-gate. If the service is delivered at the woreda or kebele level, farmers are expected to bring their animals to the site of insemination. As understood from sample respondent farmers, it takes less than 30 minutes to reach at the insemination site for about 12% of the cases in Amhara, 21% in Oromia, 14% in SNNP and 13% in Tigray region with an overall value of 15%. About 36% of all the interviewed farmers, however reported the insemination site to be 30 minutes to 1 hour away from their farm gates; while 33% reportedly consume over 1 hour to get to the site of insemination. The remaining 16% of

the sample respondent farmers couldn't tell how long it takes for them to get the insemination site from their farm gates.

4.3.7. Demand for AI Service

Apparent difference ($p < 0.05$) was observed among regions in the number of kebeles assigned per AI technician (Table 17) with the highest being 9.2 in the Oromia region and the lowest (6.1) in Tigray region. Though no significant difference ($p > 0.05$) was observed among regions, the highest number (220.1) of potential farmers that need AI service per kebele was reported in Amhara and the lowest (131.3) in SNNP region. However, the highest (150.6) number of farmers who received insemination service was reported in Tigray region and the lowest (66.1) in SNNP with the difference among regions being significant ($p < 0.05$). Overall, though an average of 8 kebeles each having a total of 199 potential farmers who demand AI service are assigned for each AI technician, only 92 (46%) reportedly receive the service in each kebele.

Table 17. Number of kebeles assigned per AI technician and potential farmers who need AI service in Amhara, Oromia, SNNP and Tigray regions (Mean \pm SE)

Region	N	Number of Kebeles assigned per AI technician	Number of farmers who need AI service per kebele	Number of farmers who received the service per kebele
Amhara	49	8.49 \pm 0.78 ^{ab}	220.12 \pm 60.87	81.55 \pm 9.42 ^b
Oromia	53	9.19 \pm 0.73 ^a	216.64 \pm 19.75	91.55 \pm 11.46 ^b
SNNP	35	8.31 \pm 1.29 ^{ab}	131.26 \pm 22.32	66.11 \pm 13.65 ^b
Tigray	23	6.09 \pm 0.64 ^b	210.00 \pm 25.65	150.61 \pm 16.89 ^a
Total	160	8.34 \pm 0.46	198.50 \pm 20.80	91.73 \pm 6.41

Means with different superscripts in the same column significantly different ($p < 0.05$).

4.3.8. Determining Sire Breed

Choosing the right genetics is among the most important factor in a crossbreeding program that aims to improve milk production and other economically important traits. The result of interviews undertaken with AI technicians revealed that farmers were not involved in determining the sire breed to be used for insemination of their cows/heifers. Only 2% of

all respondent AI technicians reported farmers' participation in choosing sire breeds (none in Amhara and Tigray regions, 3.9% in Oromia and 3.7% in SNNP regions). Farmers alone did not choose or determine the sire breed in Amhara region rather the breed to be used was decided and determined by either by AI technicians (95.9%) or in consultation with farmers (4.1%). Similarly, 90.4% and 3.9% AI technicians in Oromia region; 96.3% and none of the AI technicians in SNNP region and 69.6% and 30.4% of AI technicians in Tigray region reported that the sire breed was chosen by AI technicians alone and in consultation with farmers, respectively with overall proportion of 90.1% and 7.3%. It was only in Tigray region that a significant proportion (30%) of farmers participated in the determination of sire breed which was undertaken in consultation with AI technicians.

Creating proper knowledge among farmers on the effect of sire breed on productive and reproductive traits is vital. Farmers should have basic knowledge on the effect of genetic make-up in bringing the desired result, especially of productivity improvement. Choosing the right sire breed that can suit their local environment is important to get the desired profit through increased productivity.

The proportion of farmers who had basic knowhow about the effect of sire breed on the performance of resultant progenies ranged from 31% in SNNP to 76% in Tigray region (overall mean was 50%). However, only 20% of the sample respondent farmers in Amhara, 31% in Oromia, 11% in SNNP and 27% in Tigray region reported that they participate in the process of selecting the sire breed during AI with an overall average of 22% farmers in the four regions. In more than 60% of cases, the sire breed was decided by AI technicians alone (74% in Amhara, 62% in Oromia, 78% in SNNP and 69% in Tigray region with overall average of 71%).

4.3.9. Thawing Practice

Proper thawing is a very critical aspect for efficient fertilization as well as to limit heat shock and associated quality deterioration. The thawing temperature reported by AI technicians was significantly different ($p < 0.05$) among regions with average thawing temperature of 35.7°C (Table 18). The highest (36.3°C) thawing temperature was reported

in Tigray region and the lowest value (35.3^oC) in SNNP region. Thawing time was significantly different ($p<0.05$) among regions with average thawing time of 28.8 seconds. The highest (34.9 seconds) and lowest (22.8 seconds) thawing time were reported in SNNP and Oromia region, respectively. AI technicians reported that on average it took 6.17 seconds between thawing and insemination and this time was significantly different ($p<0.05$) among regions with longest (10.9 seconds) reported from SNNP and shortest (4.5 seconds) in Amhara region.

Table 18. Thawing temperature, thawing time and time between thawing and insemination in Amhara, Oromia, SNNP and Tigray regions (Mean±SE)

Region	N	Thawing Temperature (°C)	Thawing Time (Sec)	Time between Thawing and Insemination (Sec)
Amhara	49	35.90±0.18 ^{ab}	33.51±1.20 ^a	4.53±0.70 ^b
Oromia	53	35.58±0.18 ^b ^c	22.79±1.65 ^b	4.57±0.60 ^b
SNNP	35	35.31±0.21 ^c	34.94±2.24 ^a	10.88±2.81 ^a
Tigray	23	36.31±0.18 ^a	23.26±2.28 ^b	6.52±1.50 ^b
Total	160	35.72±0.97	28.80±0.98	6.17±0.73

Means with different superscripts in the same column significantly different ($p<0.05$).

4.3.10. Price of AI Service

AI service is predominantly provided by the public sector in many parts of the country including the four surveyed regions. The service is also highly subsidized by the government and farmers are expected to pay only a small amount of money. The price of insemination was significantly different ($p<0.05$) among regions with an average price of 4.50 ETB for about 2.77 repeated inseminations. The highest (5.64 ETB) payment was reported for about 2.5 inseminations in Oromia region and the lowest (2.00 ETB) for about 2.8 inseminations in Tigray. Almost all AI technicians in Tigray region reported the same price of 2.00 ETB for AI service for about 2.83 repeated services. The repeated service reported per a single payment was not significantly different ($p>0.05$) among regions.

According to the interview result undertaken with farmers, very high significant difference ($P<0.0001$) was observed in the price of AI service among the four regions with highest (19.65 ETB) in SNNP and lowest (3.56 ETB) up to 3 consecutive inseminations if the animal doesn't conceive with the 1st and 2nd ones in Oromia regions (Table 19). The average price in the four regions was 11.58 ETB for up to three consecutive inseminations. The regionally set price for AI service as reported from regional bureaus is 4.00 ETB in Amhara, 6.00 ETB in Oromia, 5.00 ETB in SNNP and 2.00 ETB in Tigray region.

Table 19. Price (ETB) of AI in Amhara, Oromia, SNNP and Tigray regions – July 2018

Region	N	Price of AI Mean±SE	Minimum	Maximum	Set Price by Regions
Amhara	90	5.27±0.53 ^b	4.00	50.00	4.00
Oromia	93	3.56±0.22 ^b	-	6.00	6.00
SNNP	98	19.65±3.42 ^a	-	100.00	5.00
Tigray	96	17.03±3.23 ^a	-	100.00	2.00
Total	377	11.58±1.27	-	100.00	

Means with different superscripts in the same column are significantly different ($p<0.05$)

4.3.11. Mean of Transportation and Communication

Since a significant proportion of AI technicians in the four regions didn't have motorbike that can be used for transportation purposes, it is expected that AI technicians could use other modes of transportation. A higher proportion of AI technicians reported to use Taxi (mostly the three-wheel – “Bajaj”) or walk to farmers' house by foot (Table 20). Except in SNNP region, most of the interviewed AI technicians reported that they were using Taxi as major means of transportation in the absence of motorbike or if there is a shortage of fuel.

Table 20. Other mode of transportation in AI service delivery system in Amhara, Oromia, SNNP and Tigray regions

Region	N	Foot	Taxi	Cart	Rental Motorbike	Rental Bicycle
		Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)
Amhara	49	27 (55.10)	37 (75.51)	4 (8.16)	2 (4.08)	2 (4.38)
Oromia	51	23 (45.10)	30 (58.82)	16 (31.37)	5 (9.80)	4 (7.84)
SNNP	36	27 (75.10)	17 (47.22)	6 (16.67)	21 (58.33)	2 (5.56)
Tigray	23	9 (39.13)	16 (69.57)	1 (4.35)	4 (17.39)	-
Total	159	86 (54.09)	100 (62.89)	27 (16.98)	32 (20.13)	8 (5.03)

Freq = Frequency

Figures in parentheses are percentages

About 93.8% of all the sample respondent AI technicians reported their personal mobile phone to be the major means of communication with farmers (in Amhara region 93.8%, Oromia 94.4%, SNNP 91.7% and Tigray 95.7%) for AI related services and information. Insignificant proportion (6.2% overall and 4.1% in Amhara, 5.7% in Oromia, 2.8% in SNNP and 17.4% in Tigray) of AI technicians reported that they communicate with their client farmers through landline. In the absence of both mobile phones and landlines, farmers bring their animals to woreda or kebele sites to breed their animals. This doesn't require calling AI technicians to check their availability. However, physical visit is restricted to working days and hours. About 75% of AI technicians in SNNP region, 55% in Amhara, 45% in Oromia and 43% in SNNP reported that farmers bring their animals physically to the site of insemination.

4.3.12. Access to AI Service

AI service is time-sensitive activity and the cow/heifer in heat should be inseminated at the appropriate time for maximum conception rate. Thus, AI service should be available all times regardless of holidays, weekdays and off-hours. As observed from the current study, AI service is reportedly available from Monday to Sunday for 65% of farmers in the four regions with the highest proportion (81%) in Tigray region and lowest (53%) in SNNP region. Availability of AI service during off-hours, weekends, holidays and evenings was very limited in all the four regions. Only 44% of farmers reported the availability of

insemination service during these times in the four regions (Amhara 45%, Oromia 43%, SNNP 30%, and Tigray 59%).

AI technicians should arrive at the right time when called for AI service to achieve maximum conception rate. As a rule of thumb, a cow/heifer needs to be served in the afternoon if in heat in the morning and vice versa. About 63% of farmers in Amhara, 59% in Oromia, 67% in SNNP and 33% in Tigray and an overall average of 55% farmers did not get AI service at their farm-gate rather they took their animals to insemination sites. The proportion of farmers who got farm-gate AI service was 37% in Amhara, 41% in Oromia, 33% in SNNP and 66% in Tigray region with an overall average of 44%. From those who reported farm-gate insemination service about 26% of farmers in Amhara, 35% in Oromia, 29% in SNNP, and 15% in Tigray region (Overall average of 25%) reported that AI technicians arrived after 1 hour of received a call from farmers. However, from those who got AI service at their farm-gate about 74% of farmers in Amhara, 65% in Oromia, 71% in SNNP and 83% in Tigray regions (average 75%) reported that AI technicians reached to their house within one hour of calling. The proportion of farmers who replied that AI technicians reached within 30 minutes of calling were 5% in Amhara region, 7% in Oromia region, 6% in SNNP region and 18% in Tigray regions (Overall average of 9%).

4.3.13. AI Related Services Provided to Farmers

The provision of additional AI-related services is believed to bring anticipated result in dairy cattle crossbreeding programs. To this effect AI technicians are expected to provide services such as pregnancy diagnosis (PD), calving assistance, veterinary service, hormone assisted estrus synchronization and advisory services. AI technicians were interviewed about services they were providing to farmers apart from artificial insemination. On average 90% of AI technicians were providing pregnancy diagnosis (PD), 58% heat synchronization, 68% calving assistance, 20% veterinary service and 72% advisory services to their client farmers. The highest proportion of AI technicians in Tigray region were providing PD (100%), heat synchronization service (100%), calving assistance (83%) and advisory services (83%) as compared to the other three regions. The highest proportion

(36%) of AI technicians in SNNP region as compared to other regions were providing veterinary service. This figure for Amhara, Oromia and Tigray regions was 6.1%, 20.8% and 21.7%, respectively. About 98% of AI technicians in Amhara, 96.2% in Oromia and 94.4% in SNNP region were providing PD services. Similarly, 45% and 70% of AI technicians in Amhara, 50% and 60% in Oromia and 64% and 67% in SNNP region were providing heat synchronization and calving assistance services, respectively. The proportion of AI technicians who were providing advisory services was 59% in Amhara region, 81% in Oromia and 69% in SNNP region.

Farmers were also interviewed about additional services they received from their AI technicians and the result revealed that only PD and advisory services were highly provided to farmers in the four regions. On average 69% (60% in Amhara, 62% in Oromia, 83% in SNNP and 66% in Tigray regions) and 61% (61% in Amhara, 71% in Oromia, 44% in SNNP and 69% in Tigray regions) farmers in the four regions were getting PD and advisory services, respectively. However, an overall average of only 12% of farmers were getting estrus synchronization service, 22% calving assistance, and 8% veterinary services from AI technicians in the four regions.

4.3.14. Seasonality of AI service

In all studied regions higher number of inseminations reported immediately after the main rainy season and in harvesting season. AI technicians requested to categorize months of a year into regular, peak and off seasons based on the number of inseminations they provided per day. Since there was no regional difference in the categorization, the overall result is presented in Figure 24 below. Months from August to December were categorized as peak season when AI technicians on average provided 6.7 inseminations per day.

January, February, June, and July were categorized as regular season for AI service when AI technicians provided daily average insemination of 3.8. March, April, and May were off-season for AI service when on average only 2.23 inseminations per day were provided.

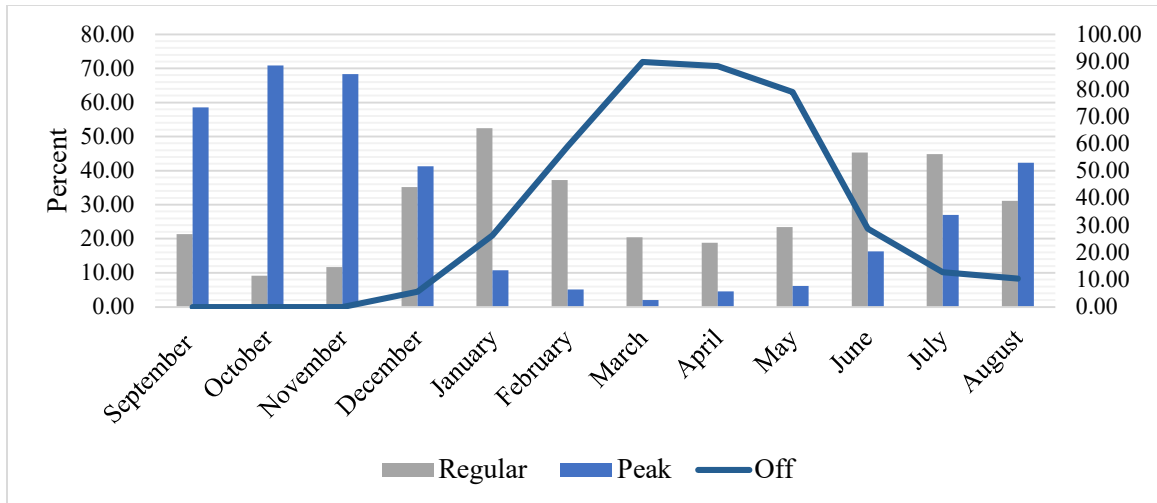


Figure 24. Seasonality of AI service provision in Amhara, Oromia, SNNP and Tigray regions

To support the questionnaire-survey result regarding seasonality of AI service provision, data on the number of AI services provided per individual AI technicians collected on monthly basis from October 2016 through December 2018 and the result is shown in Figure 25 and 26 below. For ease of data management and presentation the months of a year were grouped into quarters following the Ethiopian budget year. July, August and September were classified as Quarter 1, October, November and December as Quarter 2; January, February and March as Quarter 3, and April May and June Quarter 4. The result of data collected on field performance strongly agree with the survey result and revealed the seasonality of AI service delivery system. Peak service was delivered in Quarter 2 (September, October and November) and the service reached its lowest level in Quarter 4 (March, April and May).

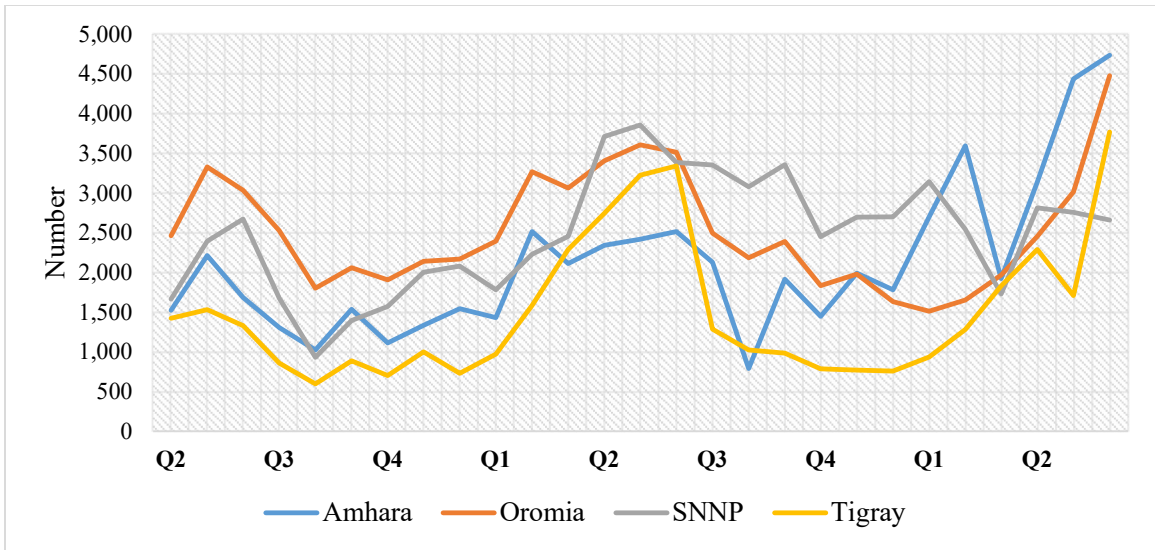


Figure 25. Seasonality of AI service in Amhara, Oromia, SNNP and Tigray regions based on the number of AI services provided from October 2016 to December 2018. Q1 = July August and September; Q2 = October, November and December; Q3 = January, February and March; Q4 = April, May and June

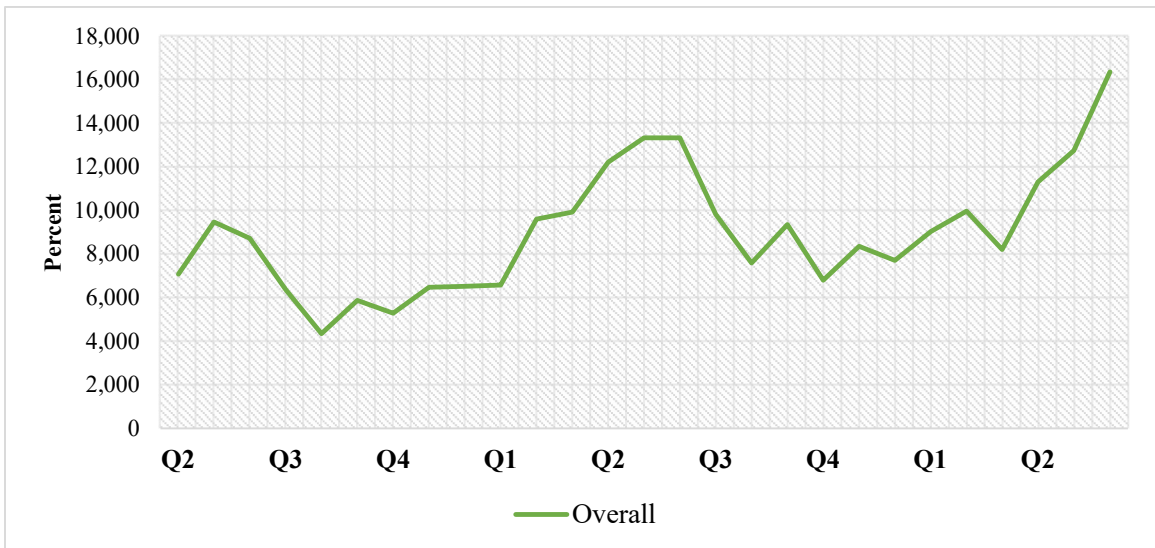


Figure 26. Overall seasonality of AI service based on the number of AI services provided from October 2016 to December 2018. Q1= June, July and August; Q2 = September, October and November; Q3 = December, January and February; Q4 = March, April and May

4.3.15. Preference for AI and Bull Service

It is believed and most research reports revealed that AI service is not reliable in most parts of the country due to various reasons. Thus, it is usual to go for bull service if bull is available in the area. However, bull service was not a preferred breeding method to 91% of farmers in Amhara, 85% in Oromia, 89% in SNNP and 91% in Tigray regions, respectively with an overall average of 89% farmers in the four regions. This proportion of farmers also replied that if AI service is reliable in their area, they didn't want to go for bull service. On average only 11% of farmers in the four regions preferred bull service if it is available in their area (9% in Amhara, 15% in Oromia, 11% in SNNP and 9% in Tigray regions).

4.3.16. Source of Breeding Bull

Due to several reasons especially in the absence of AI service farmers used to go for natural breeding method to mate their female cattle. The proportion of farmers who practiced natural or bull mating in the four surveyed regions was 54% (39% in Amhara, 74% in Oromia, 62% in SNNP and 40% in Tigray regions). Of those who practiced natural mating or bull service about 73% of farmers in Amhara, 70% in Oromia, 88% in SNNP and 60% in Tigray region (on average 74%) were using neighbor's bull. Only 14% of farmers from those who practiced bull mating in the four regions were using their own bull (22% in Amhara, 18% in Oromia, 3% in SNNP and 14% in Tigray regions). Nearly equal proportion (13%) of farmers reported that they use bulls from different institutions (5% in Amhara, 12% in Oromia, 9% in SNNP and 26% in Tigray region).

4.3.17. Price of Bull Service

In most cases, farmers are expected to pay for the bull service if they get the service in their vicinity. The price of bull service was significantly different ($p < 0.0001$) among the four regions. It ranged from free service to 200.00 ETB per service. The lowest (30 ETB) price was recorded in Amhara region, whereas the highest (200.00 ETB) in Tigray region. On average farmers were expected to pay 1.84 ETB in Amhara region, 13.36 ETB in Oromia region, 38.23 in SNNP region ETB and 79.92 ETB in Tigray region for a single bull service.

4.4. Evaluation of AI Technicians Performance and Efficiency

4.4.1. Number of AI Services Provided

AI technicians were interviewed on the number of inseminations they provided per day to their client farmers during regular, peak and off seasons and the result is presented in Table 21. As per the interview result, significant difference ($p<0.05$) observed in the number of AI services provided during regular, peak and off seasons among the four regions. The highest number of AI services per day provided during regular (4.6), peak (7.8) and off (3.4) season reported in SNNP region. Whereas the lowest number of AI services provided per day during regular (2.7), peak (5.2) and off (1.3) seasons reported in Amhara region. In all cases, AI technicians in SNNP region found to provide a higher number of inseminations per day followed by Oromia and Tigray regions.

Table 21. Average number of AI services provided per day per AI tech during regular, peak and off season in Amhara, Oromia, SNNP and Tigray regions (Mean±SE)

Row Labels	N	Number of AI services provided per day per AI tech during		
		Regular Season	Peak Season	Off Season
Amhara	49	2.65±0.30 ^b	5.18±0.50 ^b	1.31±0.16 ^c
Oromia	53	4.42±0.56 ^a	7.47±0.67 ^a	2.51±0.36 ^{ab}
SNNP	36	4.56±0.39 ^a	7.81±0.73 ^a	3.43±0.62 ^a
Tigray	23	3.39±0.41 ^{ab}	6.43±0.84 ^{ab}	1.74±0.23 ^{bc}
Total	161	3.76±0.24	6.70±0.34	2.23±0.20

Means with different superscripts in the same column significantly different ($p<0.05$).

Correlation analysis revealed that the number of inseminations provided per day during regular season was positively correlated with age of AI technicians ($r=0.163^*$), experience of AI technicians ($r=0.144$), motorbike availability ($r=0.042$) and volume of fuel allocated per month ($r=0.010$). However, it was negatively correlated with the education level of AI technicians ($r=-0.119$) and gender of AI technicians ($r=-0.117$). Similarly, the number of inseminations provided during peak season was positively correlated with age ($r=0.144$) and experience ($r=0.159^*$) of AI technicians, motorbike availability ($r=0.095$), fuel allocation ($r=0.029$) and number of inseminations during regular season ($r=0.780^{**}$).

However, it was negatively correlated with gender ($r=-0.130$) and education level ($r=-0.015$).

The actual performance of AI technicians under field level was also assessed from October 2016 through December 2018 especially for the number of AI services they provided to their client farmers. The data was collected using a standard data collection format. Table 22 shows the average number of AI services provided per month per AI technician disaggregated by region, type, and gender. Significant difference ($p<0.05$) observed in the number of inseminations provided on monthly basis per AI technician among the four regions with highest performance recorded in SNNP region (53.2 inseminations per month per AI technician) and lowest in Oromia region (34.5 inseminations per month per AI technician). Similarly, significant difference observed ($p<0.05$) in the number of inseminations provided per month per AI technician between male and female AI technicians. However, the difference between public and private AI technicians was not significant ($p>0.05$).

Table 22. Average number of AI Services Provided Per Month

	Number of AIs/Month/AI tech	N
Region	***	
Amhara	34.87±3.00 ^b	105
Oromia	34.48±2.07 ^b	145
SNNP	53.15±3.64 ^a	69
Tigray	42.42±3.55 ^b	65
Type		
Public	40.27±1.54	341
Private	31.52±4.85	43
Gender	***	
Male	41.80±1.61 ^a	331
Female	23.59±2.88 ^b	53
Overall	39.29±1.48	384

Means with different superscripts in the same column and category significantly different ($p < 0.05$).

4.4.2. Service Per Conception

Service per conception is an important variable to be considered in any of crossbreeding programs, especially of the dairy cattle crossbreeding. One calf should be cropped every year in an efficient crossbreeding program. AI technicians participated in this study were interviewed on their performance regarding service per conception (SPC) based on their available performance data in their case book. The SPC reported by AI technicians was not significantly different among regions ($p > 0.05$) with mean SPC of 2.13. The highest (2.24) SPC reported from SNNP region followed by Amhara region (2.17), Oromia (2.11) and Tigray region (1.95).

Similarly, farmers were interviewed on the number of AI services required for a cow or heifer to be pregnant. About 55% of farmers in Amhara region, 41% in Oromia, 45% in SNNP and 66% in Tigray region responded that at least two inseminations required for a cow/heifer to conceive out of AI service with an overall average of 52% farmers. Only

26% of surveyed farmers in Amhara, 28% in Oromia, 17% in SNNP and 19% in Tigray and overall average of 23% farmers responded that only one insemination is required for a cow or heifer to conceive artificially. A significant proportion of farmers (17% in Amhara, 31% in Oromia, 37% in SNNP and 10% in Tigray regions and overall average of 36%) reported that more two inseminations required for a cow/heifer to conceive.

To support the AI technicians' interview regarding service per conception, in March 2019 a follow-up survey was conducted with 1,083 farmers who received AI service between February and May 2018 in Amhara, Oromia, SNNP and Tigray regions. About 2.6 inseminations were required for a cow to conceive.

4.4.3. Conception and Calving Rates

Under normal conditions, collecting information on conception and calving has various challenges. Time constraint is among the major factors for AI technicians to follow and collect information on the outcome of AI services they provided. To understand and measure the performance of AI service delivery system, a survey was undertaken in March 2019 in the four regions (Amhara, Oromia, SNNP and Tigray) taking statistically representative random sample of farmers from a sampling frame of farmers who received AI service in February, March and May 2018. This was purposefully done as the calves out of these AIs could be at an early age (three months or below) and the chance of getting these calves in the dairy farming household was high. The result of the survey is presented in Table 23 below.

Table 23. Number of cows inseminated, conceived and calved; conception and calving rates in Amhara, Oromia, SNNP and Tigray Regions

Region	Number of			Conception Rate (%)	CR -from Conceived (%)	CR - from Inseminated (%)
	Cows Inseminated	Conceived	Calved			
Amhara	268	173	143	64.6	82.7	53.4
Oromia	274	199	165	72.6	82.9	60.2
SNNP	269	156	129	58.0	82.7	48.0
Tigray	272	142	115	52.2	81.0	42.3
Overall	1,083	670	552	61.9	82.4	51.0

CR= Calving Rate

The results of the calving survey revealed that the overall conception rate was 62% (64.6% in Amhara, 72.6% in Oromia, 58.0% in SNNP and 52.2% in Tigray region) and the calving rate (from conceived) was 82.4% (82.7% in Amhara, 82.9% in Oromia, 82.7% in SNNP and 81.0% in Tigray). The calving rate from the total AIs provided was 51.0% (53.4% in Amhara, 60.2% in Oromia, 48.0% in SNNP and 42.3% in Tigray).

4.4.4. Performance Reports form NAIC

Data received from NAIC on total inseminations and confirmed pregnancies from 2009/10 to 2013/14 revealed that about 38% (minimum 32% and maximum 44%) of the straws distributed to regions used for insemination purpose which resulted in 45% conception rate (from total inseminations) (Figure 27). The service per conception (SPC) during the same reference year was 2.42. No insemination reports available for 62% of the straws distributed to regions.

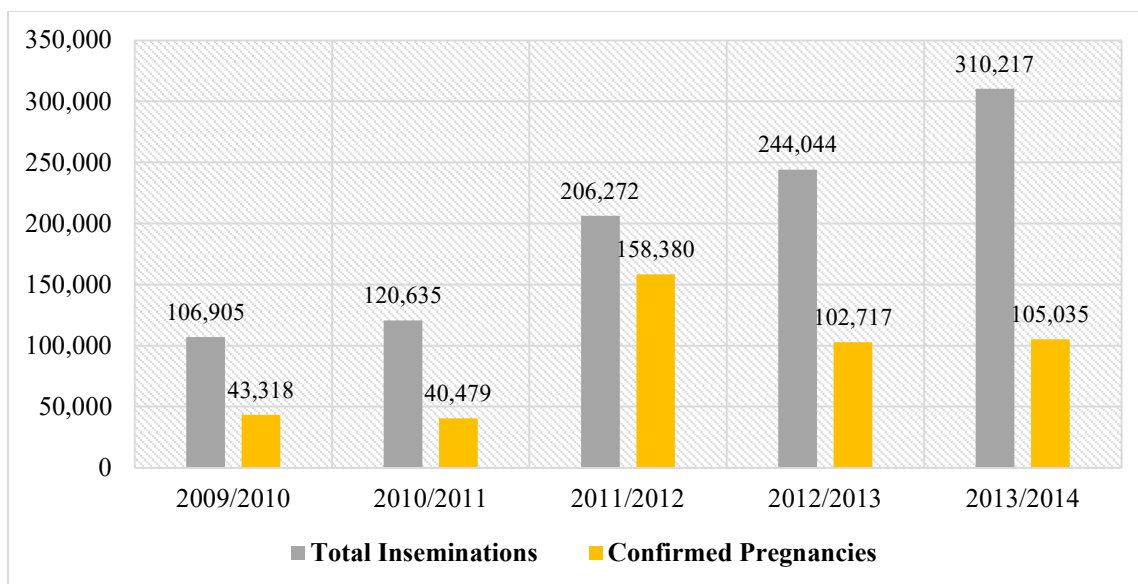


Figure 27. Number of reported inseminations and confirmed pregnancies from 2009/2010 to 2013/14 in Ethiopia

4.5. Evaluation of Government Led Heat Synchronization and Mass Insemination Campaigns

Synchronization campaigns undertaken in many regions of the country almost every year. The report on synchronization campaigns in this study is based entirely on interviews undertaken with AI technicians in the four regions.

On average 89% of interviewed AI technicians responded that they participated in the estrus synchronization campaigns facilitated by regional and/or zonal bureaus. All technicians in Tigray region participated in the campaigns whereas 94% of technicians in Amhara, 87% in Oromia and 80% in SNNP participated in the campaigns. About 71% of AI technicians in the four regions (82% in Amhara, 70% in Oromia, 40% in SNNP and 100% in Tigray region) responded that the campaigns took place at the village level. Insignificant proportion of AI technicians in Amhara (2%), SNNP (46%) and Tigray (9%) reported that the campaigns took place at zonal level crushes with an average of 13%. In Oromia region, none of AI technicians reported zonal level synchronization campaigns. The proportion of AI technicians who reported woreda level synchronization in Amhara region was (47%), in Oromia (47%), in SNNP (51%) and Tigray (26%) with overall average of 45%.

4.5.1. Time of Synchronization Campaigns

The time when synchronization campaigns undertaken is shown in Figure 28 below. In all the four studied regions synchronization campaigns took place starting end of August through December of each year. On average 63% of AI technicians in the four regions reported that synchronization campaigns taking place during these months of the year affect their normal insemination service delivery as they were also responsible to provide insemination services for animals that show heat naturally.

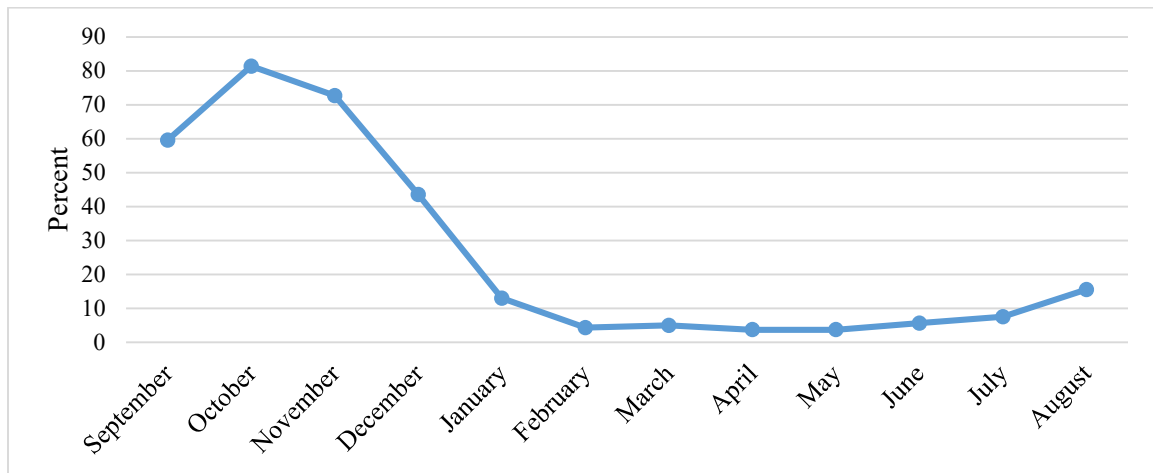


Figure 28. Timing of Synchronization campaigns in Amhara, Oromia, SNNP and Tigray regions

4.5.2. Number of Animals to be Synchronized and Factors Considered

Table 24 presented the number of animals brought and synchronized, showed heat sign, inseminated and conceived in Amhara, Oromia, SNNP and Tigray regions. The data is based on interviews held with AI technicians. Significant difference ($p < 0.05$) observed among regions in the number of animals synchronized per campaign with average animals of 171.7. Of the synchronized animals on average 46% came into heat and 52% conceived from the inseminated animals. The highest number of animals (294.0) synchronized per a given campaign was reported in SNNP region followed by Oromia (154.4) region. Of the synchronized animals the highest proportion of animals (56.6%) showed heat signs and inseminated in SNNP region. Similarly, of the inseminated animals the highest (59%) proportion of animals conceived in Tigray region. Of the total number of animals

synchronized about 31% of animals in Tigray, 30% in SNNP, 20% in Oromia and 19% of animals in Amhara region reported to conceive.

Table 24. Number of animals synchronized, inseminated and conceived in a synchronization campaigns in Amhara, Oromia, SNNP and Tigray regions

Region	N	Number of animals synchronized (Mean±SE)	Number of animals show heat		Number of animals conceived	
			(Mean±SE)	%	(Mean±SE)	%
Amhara	45	142.69±18.76 ^b	51.31±10.07 ^b	35.96	26.80±5.93 ^b	52.53
Oromia	47	154.36±20.03 ^b	60.47±9.67 ^b	39.17	30.37±5.50 ^b	50.22
SNNP	33	294.03±29.09 ^a	166.34±18.41 ^a	56.57	88.03±11.35 ^a	52.92
Tigray	23	77.70±17.38 ^b	41.52±9.35 ^b	53.44	24.65±6.79 ^b	59.37
Total	148	171.69±12.52	79.52±7.32	46.32	41.63±4.28	52.35

Means with different superscripts in the same column significantly different ($p < 0.05$)

Different factors considered to determine the number of animals for synchronization among which farmers' willingness to bring their animals was found to be the most important factor. The factors in their order of importance were (based on the overall proportion of AI technicians who mentioned the factor): farmers willingness to bring their animals (58%), available cattle population (48%), availability of feed in the synchronization site (38%), availability of hormone (34%), availability of AI technicians and other staff (24%), size of synchronization site (19%) and availability of budget (17%). The proportion of AI technicians who mentioned farmers willingness to bring animals for synchronization as factor was 49% in Amhara region was, 47% in Oromia, 65% in SNNP and 87% in Tigray region. Similarly, 53% of AI technicians in Amhara, 36% in Oromia, 44% in SNNP and 70% in Tigray region mentioned available cattle population as factor to fix the number of animals per synchronization site. The proportion of AI technicians who mentioned the availability of staff to undertake the campaigns in Amhara region was 22%, in Oromia region 23%, in SNNP region 32% and in Tigray region 17%. Availability of budget mentioned by 16% AI technicians in Amhara region, 19% AI technicians in Oromia

region, 21% in SNNP region and 9% in Tigray region. Feed and hormone availability were mentioned by 51% and 38% of AI technicians in Amhara region, 26% and 45% technicians in Oromia region, 24% technicians in SNNP region and 57% and 17% technicians in Tigray region, respectively. Factors considered for this purpose were almost similar in the four studied regions.

4.5.3. Selection of AI Technicians for Synchronization Campaigns

AI technicians were requested to list factors to be considered for selection of technicians for synchronization campaigns. The result revealed that 39% of AI technicians in the four regions mentioned their availability, 45% of AI technicians mentioned their experience, and 64% of AI technicians mentioned their performance as the major factors considered during selection of AI technicians for estrus synchronization and mass insemination campaigns. The performance of AI technicians was also listed as a factor by 60% of technicians in Amhara region, 53% in Oromia, 81% in SNNP and 70% in Tigray region. Availability and experience of AI technicians were listed as factors by 38% and 60% AI technicians in Amhara, 49% and 33% in Oromia, 14% and 47% in SNNP and 57% and 39% in Tigray regions. In Oromia and Tigray region availability rather than experience of technicians was highly considered during selection of AI technicians. However, in Amhara and SNNP regions experience of AI technicians weighed more in selecting technicians for synchronization than that of availability. Gender and health condition of AI technicians listed as factors by insignificant proportion of technicians as factor (9% and 6% of AI technicians in Amhara, 0% and 6% in Oromia, 3% and 0% in SNNP and 0% and 9% in Tigray regions).

4.5.4. Selection of Animals for Synchronization

AI technicians were also requested to list factors considered during the selection of animals for hormone induced estrus synchronization and mass insemination campaigns. Among all factors listed by AI technicians body condition was found to be the most important one which was listed by 93.5% of technicians in the four regions (93% in Amhara, 94% in Oromia, 89% in SNNP and 92% in Tigray). Age and health condition of the animals were also equally important in the selection process and mentioned by 78% of AI technicians in

the four regions (74% and 78% in Amhara, 77% and 81% in Oromia, 72% and 61% in SNNP and 88% (both) in Tigray regions). Parity and cyclicity of animals were also listed as factors considered for the selection of animals for mass synchronization campaigns by 64% and 52% of AI technicians in the four regions, respectively. The proportion of AI technicians who listed parity and cyclicity of animals as factors was 54% and 70% in Amhara region, 67% and 33% in Oromia, 75% and 42% in SNNP and 56% and 64% in Tigray region. Similarly, Lactation stage and feed provision capacity of farmers were mentioned as factors by 42% and 39% of AI technicians in the four regions.

4.6. Adoption of Dairy Cattle Husbandry and Management Practices

4.6.1. Experience of Farmers in AI Technology

Farmers were requested on the number of AI services received from their AI technicians in the past twelve months and the result is presented in Figure 29 below. As shown in the figure the majority (63% in Amhara, 69% in Oromia, 53% in SNNP and 60% in Tigray) of farmers received artificial insemination service either once or twice in a year with an average of 62% farmers in the four regions. Only 25% of respondents in the four regions received insemination service thrice or more.

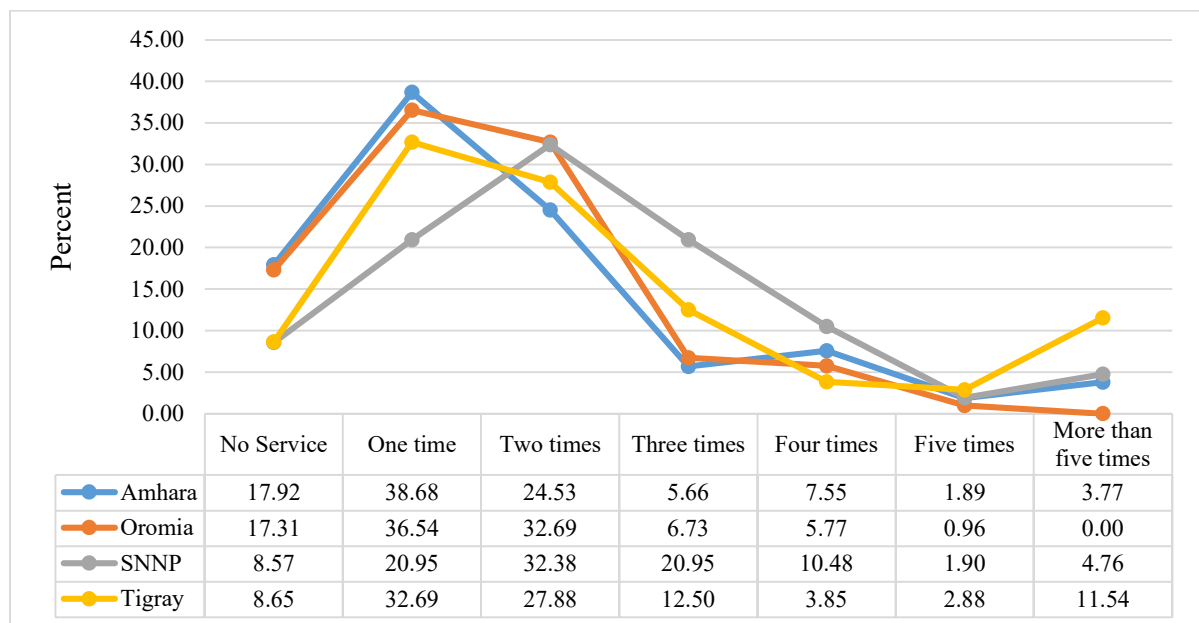


Figure 29. Frequency of AI service received in the last twelve months in Amhara, Oromia, SNNP and Tigray regions

4.6.2. Farmers Satisfaction in AI Service Delivery

Farmers were also interviewed on their experience and perception with their AI technicians and to rate their level of satisfaction regarding insemination services they received. About 9% of farmers in the four regions rated their AI technicians as excellent, 40% as very good, 46% as good and 5% as bad. Similarly, about 8% of farmers in Amhara, 5% in Oromia, 5% in SNNP and 4% in Tigray rated their AI technicians as bad; 57% of farmers in Amhara, 45% in Oromia, 50% in SNNP and 28% in Tigray region rated their AI technicians as good; 32% of farmers in Amhara, 34% in Oromia, 46% in SNNP and 49% in Tigray region rated their AI technicians as very good; and 1% of farmers in Amhara, 17% in Oromia, none in SNNP and 20% in Tigray region rated their AI technicians as excellent.

Almost all farmers were receiving insemination service from public AI technicians and didn't have the opportunity to compare public AI service delivery system with that of a private AI delivery system. Therefore, they rated based on the experience they had with public AI technicians.

4.6.3. Dairy Cattle Husbandry and Management Practices

Housing

Almost 90% and above farmers in the three regions except that of Oromia region (Amhara (95%), SNNP (100%) and Tigray (99%)) kept their cattle in a shed. However, in Oromia region only 74% of farmers had dairy cattle shed. Of those farmers who reported having dairy cattle housing structure in the four regions, about 47% in Amhara, 61% in Oromia, 95% in SNNP and 76% in Tigray regions constructed permanent type of housing. The rest had a semi-permanent type of housing.

Feed Handling and Feeding

About 64% of farmers in Amhara, 38% in Oromia, 33% in SNNP and 14% in Tigray region practiced mainly stall-feeding systems to feed their dairy cattle. Manly grazing system with some stall feeding was found to be the major type of feeding system for 34% farmers in Amhara, 49% in Oromia, 24% in SNNP and 9% in Tigray regions with overall average of 29%. About 17%, of farmers in Amhara, 14% in Oromia and 4% in SNNP region practiced

mainly grazing as a feeding system with an overall average of 9% farmers in the four regions. Similarly, the proportion of farmers who practiced mainly stall feeding with some grazing was 16% in Amhara, 23% in Oromia, 39% in SNNP and 23% in Tigray region with an overall average of 25% farmers.

On average 90% (97% in Amhara, 80% in Oromia, 79% in SNNP and 100% in Tigray) and 74% (64% in Amhara, 65% in Oromia, 77% in SNNP and 91% in Tigray) of farmers in the four regions reported that they practiced feed conservation and dairy cattle supplementation practices, respectively. The proportion of farmers who practiced crop residue treatment in the four regions was insignificant with an overall average of 7%. However, the highest proportion (15%) of farmers who practiced crop residue treatment was in Amhara region. The figures for Oromia, SNNP and Tigray regions were 2%, 9% and 1%, respectively.

Watering

Farmers were interviewed on their water provision system to their dairy cattle and the result revealed that an overall average of 64% of farmers (52% in Amhara, 46% in Oromia, 66% in SNNP and 90% in Tigray) carried water from the watering point to provide to their dairy cattle whereas the rest took the animals to the watering point (48% in Amhara, 52% in Oromia, 34% in SNNP and 10% in Tigray regions). The highest proportion (90%) of dairy farmers in Tigray region carried water to their animals. The proportion of farmers who used either of the two methods were nearly equal in Amhara and Oromia regions.

A significant proportion of farmers (54% on average and 51% in Amhara, 49% in Oromia, 42% in SNNP and 67% in Tigray regions) provided water to their dairy cattle twice per day. About 46% of farmers in Amhara, 45% in Oromia, 36% in SNNP and 20% in Tigray region reported that they provide water once per day. The highest proportion of farmers (67%) who provided water twice per day was found in Tigray region. In the rest three regions nearly equal proportion of farmers were found to provide water either once or twice per day. Only 4% of farmers in Amhara, 15% in Oromia, 13% in SNNP and 13% in Tigray region were providing water to their dairy cattle thrice or more times as required.

Most farmers (43% - 57%) in the four regions were providing 10 – 20 liters of water per day per animal (55% in Amhara, 43% in Oromia, 55% in SNNP and 58% in Tigray regions with overall average of 54%). In Oromia region, about 40% of farmers provided water *ad-lib* to their dairy cattle. However, none of the farmers in SNNP were found to provide water *ad-lib* to their dairy cattle. On average only 11% of farmers in the four regions were providing water *ad-lib* to the dairy cattle. This figure for Amhara and Tigray was 6% and 7%, respectively. About 29% of farmers in Amhara, 15% in Oromia, 4% in SNNP and 5% in Tigray region were providing less than 10 liters of water per day per animal with overall an average of 12% farmers in the four regions. Similarly, about 11% of farmers in Amhara, 2% in Oromia, 41% in SNNP and 29% in Tigray region were providing 20 to 40 liters of water per day per animal with an overall average of 24% farmers.

Health Management Practices

Farmers in the four studied regions were interviewed on the application of improved health management systems especially of deworming, treating animals against parasites and vaccination in the past twelve months. About 75% farmers in Amhara, 67% in Oromia, 82% in SNNP and 52% in Tigray regions (69% of overall average) reported that they deworm their animals regularly using different types of anthelmintic. On the other hand, about 68% of farmers on average in the four regions were found to vaccinate their animals with the highest proportion (98%) in SNNP followed by Tigray (85%), Amhara (52%) and Oromia (38%) regions. Similarly, about 64% of farmers in Amhara, 78% in Oromia, 74% in SNNP and 83% in Tigray region reported the practice of parasitic treatment against external parasites with an overall average of 75% farmers. Farmers in SNNP region seemed to apply better health management practices as compared to the other three regions if we consider these three animal health management practices. The average proportion of farmers who practiced at least one health management practice in Amhara region was 64%, in Oromia, 61%, in SNNP 84% and Tigray 73%.

Record Keeping

From the study conducted in the four regions, it is possible to conclude that record-keeping was not practiced by most dairy farmers. It was only practiced by 12% of the dairy households in the four regions. The least was in Oromia region where only 7% of farmers practiced record keeping. About 19% of farmers in Amhara, 9% in SNNP and 13% in Tigray region were found to keep records related to dairying. The type of record-keeping was not uniform in the four regions and lack consistency.

4.6.4. Application of Improved Husbandry Practices

About 15 dairy husbandry and management practices considered as improved management practices and included in the checklist to assess the level of application of these practices. The improved dairy husbandry and management practices were: AI, housing (permanent type of house), calf pen (separate calf pen), separate milking pen, hygiene (convenient hygiene), feeding system (stall feeding), fodder conservation, supplementation, crop residue treatment, water provision, deworming, parasitic treatment, vaccination, treatment of sick animals and record keeping. Figure 30 showed the proportion of farmers who were practicing at least 4, 8, 12 and all improved dairy husbandry and management practices. About 95%, 58%, 6% and 0.2% of the farmers were found practicing at least 4, 8, 12 and all the management and husbandry practices, respectively.

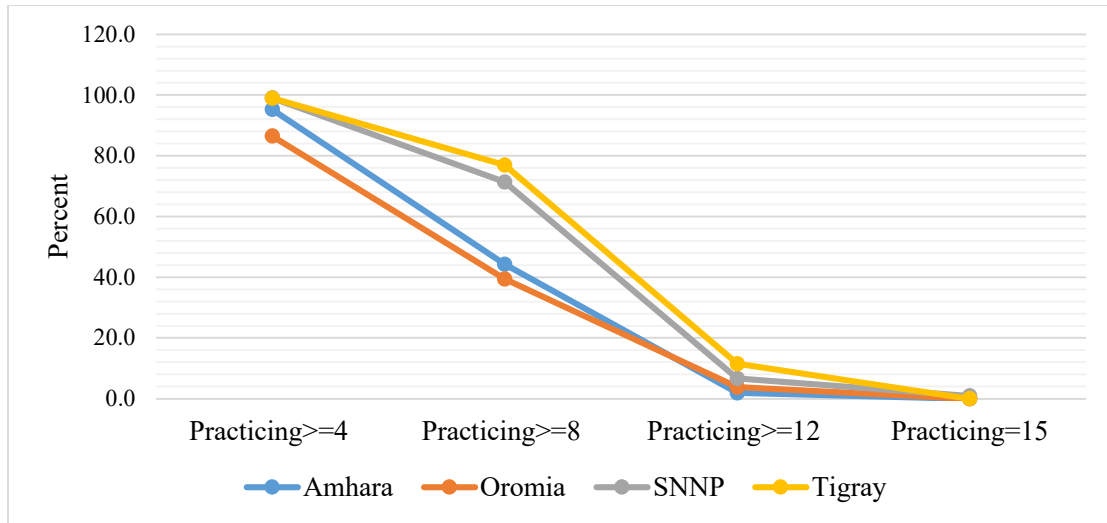


Figure 30. Farmers with improved dairy husbandry and management practices in Amhara, Oromia, SNNP and Tigray regions

4.6.5. Access to Livestock Extension

Better access for livestock extension is among the critical factors for the adoption of livestock production-related technologies to bring the desired impact on productivity parameters. On average 76% of farmers in the four regions (43% in Amhara, 65% in Oromia, 74% in SNNP and 78% in Tigray) had access extension services during the study period.

4.6.6. Dairy Cattle Breeding

On average about 54% of farmers in the four regions reported the use of AI only, 7% bull only and 39% both breeding methods to mate their female cattle. The highest (11%) proportion of farmers who reported bull method as a major breeding technology reported in Amhara region while the lowest (5%) in SNNP region. This figure for Oromia and Tigray regions was 8% and 6%, respectively. The use of AI as a breeding technology was almost similar in Amhara (56% farmers), SNNP (56% farmers) and Tigray (58% farmers) regions. However, the lowest (45%) proportion of farmers who used AI service reported in Oromia region. The proportion of farmers who reported both breeding technologies was significant in almost all the four regions considered in this study (33% in Amhara, 47%, in Oromia, 39% in SNNP and 37% in Tigray).

Farmers were also interviewed on how long they used bull and AI services to breed their dairy cattle and the result is summarized in Table 25. Farmers in the four regions reported that they used bull and AI on average for 9.48 and 5.38 years, respectively. Farmers in Amhara region had the longest experience in bull use while farmers in SNNP had the longest experience in AI use as a breeding method. Significant difference was observed among regions in the experience of bull ($p<0.05$) and AI ($P<0.0001$) use.

Table 25. Years of bull and AI service use in Amhara, Oromia, SNNP and Tigray regions

Region	Bull (Years)		AI (Years)	
	N	Mean±SE	N	Mean±SE
Amhara	42	12.02±1.79 ^a	98	4.09±0.58 ^b
Oromia	55	7.05±0.96 ^b	96	3.93±0.34 ^b
SNNP	54	11.50±1.02 ^a	101	7.35±0.55 ^a
Tigray	42	7.50±0.87 ^b	97	6.05±0.43 ^a
Total	193	9.48±0.60	392	5.38±0.25

Means with different superscripts in the same column are significantly different ($p<0.05$)

On average 45%, 33% and 22% of farmers in the four regions reported that they bred cross, local and both types of cattle by use of AI, respectively. About 75% of farmers in Tigray, 34% in Amhara, 28% in Oromia and 45% in SNNP region used AI for crossbreed cattle. About 49% in Amhara, 46% in Oromia, 26% in SNNP and 13% farmers in Tigray region reported that they used AI for their local cattle breeds. Similarly, 18% of farmers in Amhara, 26% in Oromia, 30% in SNNP and 13% in Tigray region reported the use of both breeding technologies.

4.6.7. Perception on Calf Sex

So far, there were different complaints from the farmers' side regarding the sex of the calf as a result of AI services. Farmers complained that higher proportion of calves out of AI are male. Both farmers and AI technicians participated in this study were interviewed on this complaint to evaluate and understand the significance of this complaint.

AI Technicians' Perception

Since AI technicians are very close to their client farmers and they are the first to receive such complaints, they were requested to rate their level of agreement on this complaint using a five-point Likert scale (strongly disagree to strongly agree). A high proportion of AI technicians (62%) in the four regions disagreed and strongly disagreed on calf sex-related complaints. About 12%, 45% and 18% of AI technicians in Amhara region, 6%, 40% and 6% in Oromia region, 9%, 44% and 26% in SNNP region and 0%, 70% and 13% in Tigray region were indifferent, disagree and strongly disagree, respectively with an overall average of 6%, 47% and 15%.

Similarly, the overall proportion of AI technicians who strongly agree was 9% (none in Amhara and Tigray, 23% in Oromia, 6% in SNNP). The overall average of AI technicians who agree on the complaint was 22% (24% in Amhara, 26% in Oromia, 15% in SNNP and 17% in Tigray region).

Farmers' Perception

To get some evidence on the complaint of farmers regarding calf sex, farmers in the four studied woredas interviewed on their level of agreement on the proportion of male calves out of AI and the result is presented in Figure 31. An overall average of 7% of farmers in the four regions strongly agreed, 15% agreed, 3% indifferent, 60% disagreed and 13% strongly disagreed on calf sex-related complaints.

Thus, based on the interviews undertaken with farmers and AI technicians, the present study disproves farmers' complaint on calf sex. That means, the chance of getting either male or female calf out of AI is equal.

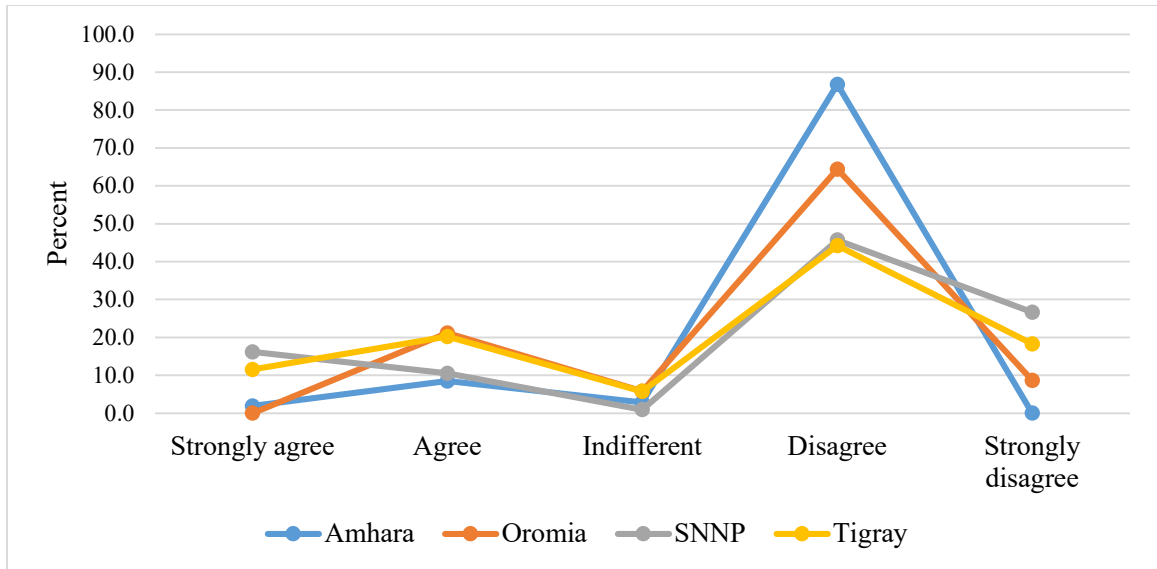


Figure 31. Farmers' perception on calf sex as a result of AI in Amhara, Oromia, SNNP and Tigray regions

5. DISCUSSION

5.1. Evaluation of the Ethiopian Dairy Cattle Population and Productivity Trend

Secondary data from the Central Statistical Agency (CSA) annual sample survey reports on Livestock Characteristics from 2004/5 to 2017/18 (CSA, 2005 - 2018) is used to analyze the Ethiopian cattle population trend. However, the CSA data has its limitations to be used as a reliable data in the livestock sector of the country. For instance, it doesn't include the non-sedentary population of the country found in Afar and Somali regions where huge livestock resources especially of cattle are found. There are also some discrepancies in the data presentation and meaning of dairy and milking cows. Milking cows are a subset of dairy cows, however, in all the CSA survey reports dairy cows are treated as a subset of milking cows. On the other hand, data for 2015/16 (2007 EC) is not available in the CSA data set.

The CSA based data on cattle population is compared with FAOSTAT data (FAO, 2019) from 2004 to 2017 and the two data sets are almost similar with only a difference of 38,340 heads of cattle more in the FAOSTAT data. The difference may be due to lack of 2015/16 data in the CSA database. On the other hand, data extracted from CSA from 2004/5 to 2017/18 (CSA, 2004-2017) revealed that an average annual increase of 3.81% and a cumulative increase of 56% in the total cattle population. This is comparable with FAOSTAT data in the same reference years which reported an average annual increase of 3.88% and a cumulative increase of 57% (FAO, 2019). Though it has its limitations, CSA data is the only data that is available for livestock-related statistics. The average annual increase observed in both sets of data is also equivalent to a few East African countries such as Kenya (3.58%) and Tanzania (3.61%) but lower than Uganda (8.22%). The cumulative increase in the total cattle population in Ethiopia from 2004 to 2017 is also comparable with that of Tanzania (51%) but higher than Kenya (41%) and significantly lower than Uganda (134%) (FAO, 2019).

According to FAOSTAT data, average cattle population data from 2004 to 2017 (FAO, 2019) Ethiopia ranked 6th in the world and 1st in the African continent after Brazil (51.4 billion), India (191.3 billion), USA (93.2 million), China (83.8 million) and Argentina

(53.5 million). This indicates that the country has huge cattle population and can be benefited economically if proper livestock related policies, implementation strategies and infrastructures are in place. However, both the annual increase in the total cattle population and the huge cattle population available in the country can't be evidence for the efficiency of crossbreeding activities undertaken in the country since long. The proportion of crossbred cattle population from the total cattle population available in the country may give a better understanding of the efficiency of crossbreeding activity.

The CSA data (CSA, 2005 – 2018) on the other hand, revealed that the proportion of cross and exotic breed cattle population in Ethiopia could not go beyond 2% (average of 1.08 from 2004/5 to 2017/18) after 5 decades of effort in crossbreeding. This proportion is extremely low as compared to its neighbor country Kenya where there is a vibrant dairy sector in the horn of Africa. According to the KNBS (2009), the proportion of crossbred cattle population in 2009 was 19% whereas in Ethiopia in the same reference year the proportion was 0.81%. UBS (2018) also reported 6.3% of crossbred cattle population in Uganda in 2017 and Feed the Future (2016) and Rwanda Dairy Development (2016) reported 28% and 54% for Rwanda in 2015, respectively. These figures are much higher than Ethiopia's crossbred cattle proportion. However, the crossbred cattle population in Ethiopia is almost equivalent to that of Tanzania (MoLFD, 2015) that reported 2% in 2016/17. All these data show the low performance of the crossbreeding activity that has been implemented in the country for decades. This calls for identification of major challenges and factors hindering the success of crossbreeding programs, design and implement appropriate policies to be benefited from the available huge resource.

Though Ethiopia ranked 1st in the African continent and 6th in the world in total cattle population, the annual milk production is extremely low. This is mainly due to very high proportion (nearly 98%) of indigenous cattle breeds which are characterized by their low milk production potential. With the available total cattle population of 18.3 million heads in 2014 Kenya produced about 4.4 billion liters of milk in 2014 (FAO, 2018). However, in the same reference year, Ethiopia could produce 2.9 billion liters of milk from the total cattle population of 55.0 million heads. This is with 200% more total cattle population but

50% lower milk production than that of Kenya. This can be an evidence that Ethiopia is not benefited from the huge cattle population and the crossbreeding activity. This is also a clear evidence that the crossbreeding activity that has been undertaking in the country for decades is not efficient in terms of increasing the proportion of crossbred cattle population and milk productivity at a national level.

The CSA data from since 2004/5 (CSA, 2005 - 2018) revealed that there was an increase of only 1 billion liters (0.07 billion liters increase per year) without any change in lactation length (6 months) but with milk productivity increase of only 0.138 liters/day/cow over the last thirteen years since 2004/5. With the same lactation length shown in these reference years and with only 0.09 lit/cow/year increase in milk production, it can be concluded that the increase in the annual milk production is neither improvement in productivity nor reproduction parameters but due to the increase in the number of cattle population mainly of indigenous breed. This, in turn, revealed that the crossbreeding program of the country practiced for nearly five decades was not as effective as expected. This can be evidenced in Rwanda where the milking cow population reduced from about 1.4 million in 2015 to about 1.16 million heads in 2018. However, milk production increased from about 710 million kg to over 816 million kg (The New Times, 2018). The mean annual growth rate of milk production reported in the present study is by far less than that of Kenya which is estimated to be more than 4% (Draft National Livestock Policy, 2019).

According to the CSA report (CSA, 2005 – 2018), the average change in the indigenous cattle population in Ethiopia was 3.7% (from the previous year) with a cumulative increase of 31.15% in the last thirteen years (from 2004/5 to 2017/18). In most parts of the country the indigenous cattle are not primarily kept for milk production rather they are kept for social value and draft power (FAO, 2018; Abraham and Abebe, 2018). The low percent change in the number of indigenous cattle populations is an indication for their lower level of reproduction efficiency and the emphasis given to them in terms of breeding to improve their genetic potential. Due to the silent heat behavior and lower productivity of the indigenous cattle, farmers usually allow them to graze with local breed bulls where they can be served naturally (Abraham and Abebe, 2018). Breeding of indigenous cattle breed

is not a priority for most farmers in the country. However, the huge number of indigenous cattle population available in the country can be considered as a potential to improve the overall productivity through crossbreeding programs especially of using AI technology. The higher average change (15.8%) in the percentage of crossbred cattle population during the last thirteen years between 2014/5 and 2017/18 is an evidence that the AI service or crossbreeding activity in the country is implemented mainly on crossbreed cattle population.

Though the meaning for milking and dairy cows was not correct, there was an increasing trend in the number of dairy cows but there was no significant increase in the total number of milking cows. The increasing trend observed in the dairy cows might be due to the increase in the indigenous cattle population. This is also related to the inefficient AI service delivery of the country as breeding of the indigenous cattle is mainly based using bulls of indigenous origin. If the AI service delivery system of the country is efficient, the trend in the number of milking cows would have been in an increasing trend.

The regional comparison in the average increase of both indigenous and crossbred cattle population from 2004/5 to 2017/18 (CSA, 2005 - 2018) revealed that the highest increase reported in Tigray region as compared to the other three regions. The highest average annual increase of 33.1% in the crossbred cattle population could be evidence for the better crossbreeding efficiency implemented in the region. The least (11%) average annual increase in the crossbred cattle population was reported in Oromia region. If we take the huge cattle population found in Oromia region into consideration, it can be concluded that the crossbreeding activity that has been undertaken in the region was the least efficient among the four regions. This doesn't mean that the increase in the crossbred cattle population in the other three regions was satisfactory. This can be evidenced by the proportion of cross and exotic cattle population available in the four regions (Amhara 0.89%, Oromia 1.29%, SNNP 0.84% and Tigray 1.07%) (CSA, 2005 – 2018). More efforts should be in place to change this situation in all the four studied regional states. The crossbreeding programs and implementation strategies need to be revised and amended based on real situation available in the field.

5.2. Evaluation of AI Service Input Supply and Equipment supply System

Availability of basic AI equipment determines the efficiency of AI technicians as well as the success of crossbreeding programs. AI gun, sheath, thermo flask, liquid nitrogen container, forceps, cito cutter, thermometer are among the basic AI equipment than need to be available to make the service delivery system effective. Transportation facilities are also very essential in countries such as Ethiopia where there is poor infrastructure and rugged topography. The present study demonstrates the availability of these basic equipment to the expected quality and quantity was challenging in the studied regions. Tigray region is by far better than the other three regions in availing basic AI equipment to AI technicians. Only half of AI technicians had motorbike in the four regions. Motorbike is required not only for providing insemination service to client farmers, it is also required to undertake a follow-up visits to those who received AI service such as pregnancy check and calving. Camilla (2013) reported about 70% of AI technicians in Uganda use motorbike for transportation and 20% of the technicians use their car.

An AI technician can be responsible to serve on average of eight kebeles in each woreda where there are nearly 200 farmers who potentially need AI service. Moreover, farmers are living in a very dispersed manner and AI technicians can travel on average of 50 kilometers per day during peak season. On top of these, AI is a time-sensitive service and cows/heifers in heat must be inseminated at the right time for maximum conception rate. Therefore, availing motorbike to individual AI technician has paramount importance to get the desired result in dairy cattle crossbreeding that has been implemented in the country since the 1970s.

The result confirms that male AI technicians had better access to motorbike than female AI technicians. Though women AI technicians were very few, they have additional workload in their household especially if they are married. It may not be possible for women AI technicians to walk long distances with their AI equipment especially if they are pregnant. Therefore, the provision of women-friendly motorbikes is vital, and due emphasis should be given for women AI technicians during the procurement and distribution of motorbikes.

The present study also demonstrates a positive correlation between motorbike availability and the number of insemination services provided per AI technician per day during regular season ($r=0.042$) and peak season ($r=0.095$). The data also confirms a positive correlation between motorbike availability and distance traveled per day per AI technician during regular season ($r=0.131$) and peak season ($r=0.495$). Both positive correlations indicate the performance of AI technicians is better when motorbike is provided to AI technicians. The study also demonstrates a positive correlation between motorbike availability and experience of AI technicians ($r=0.339$). This indicates that the experience of AI technicians is considered during motorbike provision.

Availability of LN₂ container and AI gun was not a challenge in the studied regions as almost all of AI technicians had either the 2 liters or 3 liters capacity containers. However, the availability of LN₂ containers without a regular supply of liquid nitrogen can't help AI technicians to provide reliable insemination service to their client farmers. The regular supply of liquid nitrogen was the most critical problem in the studied regions as a result of frequent break down of plants. Sometimes AI technicians might not get liquid nitrogen for a couple of weeks. In such circumstances, the quality of semen used for insemination purposes is questionable. Replacement of AI gun was the major challenge in the four regions. The provision of an additional AI gun is sometimes very important to enable AI technicians to provide the service more regularly and sustainably. Souames et al. (2015) reported about 44% of AI technicians in Algeria had two insemination guns.

The study demonstrates about 20% of AI technicians in the four regions didn't have thermo flask that is used for thawing purpose. However, thawing is the most critical step during the provision of insemination service; and therefore, the availability of thermo flask to transport warm water for thawing purpose is very critical. As indicated in Albert and Pamel (1988) and Stoja et al. (2016) straws filled with semen cells need to be thawed at recommended temperature of 35-37°C to make the sperm cells packed in the straws active from dormant stage where they stored at a temperature of -196°C in LN₂. In the absence of thermo flask, AI technicians usually thaw the straws by holding and rubbing the straws using their palm to use the advantage of their body temperature. However, thawing with

palm is not recommended especially for unskilled and inefficient AI technicians. Since thermos is fragile during movement availing additional nonfragile type of thermos to all AI technicians in this regard is very important. Thus, they can thaw semen straws using standard procedure and this will, in turn, improve semen quality. The proportion of AI technicians who didn't have thermo flask in the studied regions is much better when compared with AI technicians in Algeria where about 68% of them didn't have thermos for thawing semen (Souames et al.,2015).

Nearly 80% of AI technicians in the four regions had a thermometer to check the temperature of water used for thawing and the rectal temperature of the animal to be inseminated. In the absence of a thermometer, AI technicians check the water temperature by their fingers. However, this is not recommended practice as a small variation in the temperature can result in an irreversible effect in the motility of sperm cells packed in the straws. Therefore, allocating budget on an annual basis and procuring enough quantity of thermometers to AI technicians is very important.

5.2.1. Fuel Allowance and Criteria

Only 48% of AI technicians from those who reported to have motorbike in the four regions were getting fuel from their respective woreda regularly. Tigray region is by far better than the other three regions where 91% of AI technicians received fuel allowance regularly from their respective woreda office. The volume of fuel allocated to AI technicians ranged between 15 liters per month per AI technician in Oromia region and 64 liters per month per AI technician in Tigray region with an overall average of 39 liters per month per AI technician. The volume of fuel allocated to AI technicians is still much higher in Tigray region than the other three regions. To bring the anticipated result in the crossbreeding program, allocation of the required volume of fuel is very essential. However, the present data reveals that the regular supply of fuel to AI technicians was a critical challenge in the studied regions except in Tigray region. The volume of fuel allocated was positively correlated with the number of inseminations during regular ($r=0.010$) and peak ($r=0.029$) seasons but negatively correlated with the number of inseminations during off-season ($r=-0.071$). It was also positively correlated with distance traveled per day per AI technician

during regular ($r=0.589$) and peak ($r=0.567$) seasons. More, importantly fuel allocation was negatively correlated with SPC ($r=-0.010$). This means as the volume of fuel increases, the number of insemination services provided, and the distance covered per day increased and thus the efficiency of AI technicians that is explained in terms of SPC also improved.

The study confirms that fuel is allocated without out standard criteria and guidelines. There are significant discrepancies among regions in the criteria considered for fuel allocation. The most important parameter considered during fuel allocation was the distance covered followed by budget availability, available number of AI technicians in the woreda and number of kebeles assigned to each AI technician. Of all these factors, only distance seems relevant parameter that is used for fuel allocation. It was only in Tigray region where there was a fixed volume of fuel allowance per month for AI delivery system. Regional bureaus need to revise the criteria used in the allocation of fuel to bring the desired result in the AI delivery system and to utilize the budget wisely and strategically. The seasonality of AI service delivery, topography, road type, motorbike condition and performance of AI technicians shall be used as criteria in the allocation of fuel.

5.2.2. Semen Production and Supply Chain

NAIC is the only center having its bull stud farm used for bull selection and recruitment intended for semen production. FGD conducted with NAIC staff suggested that there is critical disease problem in the bull stud farm thus significant number of bulls were culled due to the problem. There is no properly designed and implemented progeny testing scheme in the country that help the selection and recruitment of bulls. Therefore, getting the required number of candidate bulls for semen production purpose in the country is very challenging. Though, four additional semen production centers are established in the country, production of semen straws to the required quantity is not still guaranteed due to various problem. Shortage of laboratory inputs such as reagents and supplies, lack of skilled labor, frequent power cut associated with absence of standby generators, lack of regular service and maintenance for laboratory equipment, inconvenient laboratory setup, budget shortage and shortage of breeding bulls used for semen production are among the challenges in the production of semen straws in the country. Both NAIC and regional

semen production centers are used to import breeding bull for semen production centers from abroad. However, importing live animal is not only expensive, adaptation of the breeding bulls to the local environment is questionable. It is understood from the FGDs conducted with regional semen laboratory staff that significant number of imported breeding bull died before they reach to the age of semen production or immediately after they started semen production. In addition to having proper bull selection and recruitment scheme, alternative means of importing geniting materials should be in place. Importation of frozen embryos in this regard can be taken as option.

Five years data received from NAIC on semen production and distribution showed an increasing trend with an average production of and distribution of 679,572 and 645, 593 straws per year, respectively. Based on data received from regional laboratories on semen production (September 2017 to October 2018), the average monthly production from the centers was 4,951 straws per month. During the same reference period the average semen production (straws) from NAIC was 59,000 straws per month which was 11 times more than that of the average of the four regional laboratories. Semen produced in the regional semen production and processing centers fulfilled nearly 35% of regional demand. The rest was imported from NAIC. This report suggests the need for enhancing the regional semen production and processing centers to at least satisfy half of their respective regional demand. Capacity building of the centers to have skilled laboratory technicians; provision of the required inputs and laboratory reagents sustainably and allocation of enough budget should be priority areas for the regional governments.

5.2.3. Liquid Nitrogen Production and Supply Chain

There are about 23 liquid nitrogen plants across the country to satisfy the national demand for liquid nitrogen. The present study demonstrates the presence of a consistent challenge for reliable access to this input. It is very unlikely to get all liquid nitrogen plants functioning at the same time in all the four studied regions. The liquid nitrogen plants installed in the country are of the same model named *StirLin-1 Compact and MNP-10* (production capacity of 10 liters/hour under optimum condition). The installed production capacity of the liquid nitrogen plants available in the country clearly shows how the

machines are old as there are modern plants with a production capacity of 850 lit/hr (https://www.universalboschi.com/?gclid=EAIAIQobChMIrd_4j6b05QIVC7DtCh0rkQ1oEAAAYASAAEgKY1_D_BwE). Though the installed production capacity of most liquid nitrogen plants is 10 liters per hour, the final production capacity depends on the altitude of the place where the plant is installed. Research results revealed that the higher the altitude, the lower the percentage of rated capacity with the highest capacity reached at sea level. Installation at high altitude (>2,300 m) will result in production capacity of below 80%. Plant production efficiency will be above 82% in areas where the altitude is below 2,100 m. some liquid nitrogen plant manufacturers recommend an altitude of below 2000 masl

(https://www.parker.com/Literature/donnick%20hunter%20Industrial%20Division/174004706_EN_NITROGEN_GAS_GENERATORS_PIS.PDF). These reports suggest altitude is the basic parameter while plant establishment. It seems altitude was not considered as a factor when establishing liquid nitrogen plants in the country as they are located at variable altitudes. It seems factors considered during plant establishment in the country were not exactly known and implemented and thus further study shall be conducted to establish the relationship between altitude of liquid nitrogen plants and their production capacity.

The other challenge in the liquid nitrogen plants of *StirLin-1* type is their cryogenerator needs a lot of maintenance attention. The plants require preventive maintenance and service at every 4,000 to 6,000 operating hours. If this is not carried out diligently, production performance reduces significantly whilst power consumption remains the same. This, in turn, leads to significant economic loss. 4,000 to 6,000 working hours means 500 to 750 working days if we assume 8 hours per working day. However, all the liquid nitrogen plants are working more than 8 hours per working day and thus may require preventive maintenance every year or two. The liquid nitrogen production usually interrupted before their service period due to breakdown and/or damage of the different parts of the plant. Due to their old model and frequent preventive maintenance requirement of the current liquid nitrogen plants, the government should look for other alternatives of latest model with better production capacity if there is any plan to establish new plants.

Very high significant difference ($p < 0.001$) observed in the opening frequency of small liquid nitrogen container with an average opening frequency of 6.0 times per day. The study confirms that the frequency of opening of liquid nitrogen containers is positively correlated with the number of inseminations provided per day during regular, peak and offseasons. However, considering the 4.23 average insemination services reported per each AI technician per day, the reported opening frequency of the containers seems very high. Reasons other than insemination service for opening the containers is not exactly identified and future study need to focus on these factors. Identifying these factors will help to minimize post-production loss of liquid nitrogen which is estimated to be significant.

A significant difference ($p < 0.05$) observed in the volume of liquid nitrogen refilled per refilling of the 2 liters container. The average volume of liquid nitrogen that can be filled per refilling in the four regions was 1.16 liters with a maximum volume of 1.88 liters. Based on this average volume of liquid nitrogen required per refilling, 34.8, 17.4 and 11.6 liters of liquid nitrogen need to be available per month per individual AI technician if the frequency of refiling is every day, every two days or every three days, respectively. On average 21.3 liters per month per AI technician of liquid nitrogen required to refill the liquid nitrogen containers in the four regional states. This information helps the regional bureaus to plan, strategize and implement their liquid nitrogen production and distribution plan.

Reliable supply of liquid nitrogen is the most critical problem in developing countries. About 88% and 75% of AI technicians in the studied regions reported ready access to LN₂ and semen. This is extremely better when compared with the report of Camilla (2013) who reported about 60% of AI technicians in Uganda had an unreliable supply of liquid nitrogen. The major problem in the studied areas was both semen and liquid nitrogen was supplied intermittently.

5.2.4. Evaluation of Semen Quality along Semen Supply Chain

Regional Difference

The statistical analysis on post-thaw total motility, progressive motility, normal and defective morphology showed significance difference ($p < 0.05$) among regions. However, the difference in the number of cells assessed was insignificant ($p > 0.05$) among regions. The overall average total and progressive motility percentage of semen samples taken from the four studied regions were 38% and 28%. Similarly, the normal morphology of semen samples taken from these regions was 77%. The overall average number of cells assessed from the semen samples taken from the four regions was 2,275 cells. In the United States the minimum recommended threshold for individual motility in bovine fresh semen is 30% Peter (2002). The same author reported that progressive motility of 70% and higher is considered as very good quality; 50 – 69% good, 30 – 49% fair and less than 30% poor. According to this categorization semen samples taken from the four regions fall under poor category. In contrary to the present findings, higher percentages of semen motility reported by Desalegn et al. (2009) (51.7%), Alemshet and Weldegerima (2018) (52%) and Gebregirogis et al. (2016) (60.5%) for samples taken from NAGII and regional states. Vincent et al. (2012) on the other hand, a different cutoff value to determine the quality of bovine frozen thawed semen in Canada. The cutoff values were 40% for total and 15% for progressive motility. According to these authors, the progressive motility results obtained in the present study was good however the total motility was under the minimum standard set by the authors except in Oromia region where the total motility was higher than 40%.

Semen Quality along the Supply Chain

Significant difference ($p < 0.05$) observed along the semen supply chain in post-thaw total and progressive motility. However, the difference in the number of cells assessed, normal and defective morphology was insignificant ($p > 0.05$) along the semen supply chain. The highest percentage of total (48%) and progressive (37%) motility recorded for semen straws sampled at the production site. Total and progressive motility percentages showed a decreasing trend from production to end-user (AI technicians in this specific case). The progressive motility of semen samples taken from production was 37% and decreased to 26% at the end-user. This clearly shows deterioration of semen quality along the semen

supply chain. This situation is revealed in a study conducted in India where the quality of semen considered good immediately after collection can deteriorates during processing (Sugulle et al., 2006). This would significantly affect the conception rate and leads to great economic loss at farmers level.

Only semen samples taken from the production stage was under fair category according to Peter (2002) and Vencent et al. (2012) categorization. Otherwise, progressive motility of semen samples taken after production was under poor category as per Peter (2002) categorization. However, progressive motility of semen samples taken from the different supply chain was good according to Vincent et al. (2012). Ahmed (2018) on the other hand, indicated the acceptable limit of semen motility at production and after freezing is 70% and 40%, respectively. In general, the motility percentage reported in the present study doesn't satisfactorily meet the minimum requirement as described in Ahmed (2018), Vincent et al. (2012) as well as Peter (2002). The minimum recommended threshold for semen morphology is 70% normal spermatozoa Peter (2002). According to this criterion almost all of semen samples tested for morphology fulfill the minimum criteria (the overall average was 77%). However, the normal morphology of fertile bull semen as reported in Ahmed (2018) is about 90%. This means the fertility of semen along the supply chain is decreasing and might lead to reduced conception rate. A higher percentage (49.6%) of frozen semen motility than the present finding was reported in Harari region of Ethiopia (Belayneh, 2018). This indicates semen quality can be maintained through good semen handling procedures. According to the same author semen production batch and breed does not affect semen motility. This confirms the low percentage of semen motility reported in this study is related to poor handling of semen at various stages.

As per the definition of Peter (2002) semen samples taken from Oromia and Tigray region fall under fair category whereas those taken from Amhara and SNNP region fall under poor category. The present study indicates that the quality of semen used by AI technicians did not meet the minimum quality criteria and the quality was deteriorated along the value chain from production to end-user (AI technicians). This is mainly due to unreliable supply of liquid nitrogen, improper handling of semen straws, lack of knowledge and skill in

handling of semen and significant post-production of liquid nitrogen. Thus, a strategy needs to be designed to improve the handling and transportation of semen to improve the quality thereby to improve the fertilizing efficiency of spermatozoa.

5.3. Evaluation of AI Delivery system

5.3.1. Characteristics of AI Technicians

Gender of AI Technicians

Of the total 1,361 AI technicians available in the four regions in 2016/17 only 1.76% were female. Only in Amhara region, higher proportion (8%) of women AI technicians engaged in the AI service delivery system. The proportion of women increased to 7.2% in 2017/18 through the financial and technical support from Land O'Lakes International Development Fund – Public-Private Partnership for Artificial Insemination Delivery (PAID) project following gender barrier analysis conducted in 2016. Though much efforts made to increase the involvement of women in AI service delivery, the increase shown in 2017/18 was not significant. This demonstrates AI service is predominantly men's job in the studied regions and the country at large. It is beyond the scope of this study to identify factors that hinder women in the AI service delivery system. However, previous research results (published and unpublished) demonstrated that cultural, religious and biological factors play a significant role in hindering women from engaging themselves in AI service delivery system. AI service by women AI technicians is not culturally appreciated as it is dealing with reproductive organs. It is believed in most communities that women lack the required physical fitness to properly perform AI and related services. Extended maternity leave provided to them during pregnancy and after birth prevent women AI technicians from continuously delivering AI service Land O'Lakes (2016, Unpublished). A study conducted by Peter et al. (1992) suggested that female AI technicians had significantly more musculoskeletal disorders due to AI work and thus they have higher probability to be off from their job as it takes longer time to recover from this problem and this biological difference can be an evidence for the low level of women engagement in AI service delivery system apart from the socio-cultural problems. Low level of women engagement in the AI service delivery is reported in the Philippines (Ybañez et al., 2017) where only

8% of AI technicians were female in 2015. According to a report by Galv *med* (2011), nearly all artificial insemination technicians in Africa were men.

Age, Experience and Job Satisfaction of AI Technicians

The result of the present study indicates that the average age of AI technicians in the four regions was 35 years. According to OECD (2019), the working-age population is defined as those aged between 15 and 64. As per this definition, the mean age of AI technicians in the present study falls in the middle of the working-age group. This clearly shows that AI technicians available in the four regions can perform their duties and responsibilities without age-related difficulties. But age is not the only parameter for effective AI service delivery system, gender, experience, health and educational status of AI technicians are among factors that can influence the efficiency of AI service. The mean age of AI technician reported in the present study agrees with other research reports conducted on the characteristics of AI technicians in Philippines (Ybañez et al., 2017), Algeria (Souames et al., 2015) and Sri Lanka (Alexander et al., 1998) where that majority of AI technicians fall between 20 and 40 years of age.

The analysis confirms that age was positively correlated with the experience of AI technicians. This does mean as AI technicians remain in their position for years, they will become more experienced in their position. However, the turnover rate of AI technicians in Ethiopia was high as understood from FGDs conducted with regional bureau staff. The positive correlation between age and experience can be interpreted in terms of efficiency of AI technicians as experienced AI technicians can be efficient in their service delivery. The positive correlation between age and experience in this study agrees with previous research reports that indicated experienced technicians performing better than the non-experienced AI technicians (Senger et al., 1984; Roque, 2011; Souames et al., 2015; Kinyua, 2016; Ybañez et al., 2017). Thus, strategies need to be designed and implemented to motivate and retain AI technicians in their position and further studies should identify factors contributing to the high turn-over rate of AI technicians in the country.

AI technicians in the four studied regions served for an average of 8.2 years. The present study also demonstrates that the experience of AI technicians was positively correlated with the number of inseminations during regular ($r=0.144$) peak ($r=0.159^*$) and off ($r=0.019^{**}$) seasons. The average experience of AI technicians reported in this study seems relatively agrees with the report of Alexander et al. (1998) but lower when compared to research report conducted in Uganda where majority of AI technicians had about 11 to 15 years of experience (Camilla, 2013) in AI service delivery system. However, the positive correlation reported in this study agrees with Souames et al, (2015) where they reported similar relationships in Algeria which was explained by a significantly higher number of AI services performed by experienced AI technicians when compared with the non-experienced AI technicians.

In contrary to the positive relationship between experience and the number of AI services, the present study demonstrates a negative correlation ($r=-0.034$) between experience and service per conception. This might be related to the problem of lack of enough data on the status of AI services provided to client farmers. If follow up visits properly undertaken to check the outcome of AI services provided, the correlation between experience of AI technicians and service per conception would be different from the present result. Therefore, further research is needed to establish a relationship between experience and service per conception.

About one third (33%) of the technicians were not satisfied with their job and thus had plan to change their position due to various reasons most importantly of the minimum salary rate and demotivating carrier structure implemented in their respective regions. Unavailability of the required equipment and inputs especially of motorbike and fuel were among the challenges could demotivate AI technicians to stay in their job. The present data demonstrates the degree of AI technicians' turnover rate. As they become more educated, they will look for a better job with relatively high income. The highest (65%) job dissatisfaction rate was reported in Tigray region. This might be related to their better level of education as compared to other regions. Unlike other studied regions about 95% of the technicians in Tigray region were educated to diploma and above level in livestock

production or other disciplines thus they were in search of other better positions in their office or outside. Higher-level job dissatisfaction than the present finding reported by Zerihun et al. (2013) in Amhara region where 99% of AI technicians were dissatisfied with their job as AI technician.

Educational Status of AI Technicians

The 2016/7 data revealed that about 48% of AI technicians were diploma (10th or 12th grade plus two or three years of training) holders whereas 29% were first-degree holders (in any discipline). A survey conducted with AI technicians in 2019 confirmed that the educational level of AI technicians did not significantly change over time except in Amhara region where a significant number of AI technicians transited from certificate to diploma level. This might be related to the high turnover rate of AI technicians as they may not be remained in their position once upgraded their education. This is further confirmed in the present study that only 35% of AI technicians with degree and diploma level of education (28% from the total) studied livestock-related science. If they don't study livestock-related science, they will look for another job and leave their AI duty. Upgrading the educational level of AI technicians in livestock-related sciences can be considered as one way of keeping them in their AI service delivery position. A higher proportion of AI technicians who attended some level of college studies is reported in the Philippines (Ybañez, 2017).

The education level of AI technicians was negatively correlated with the number of insemination services per day per AI technician during regular season ($r=-0.135$) and peak season ($r=-0.062$) for AI service. This clearly shows experience rather than education can significantly affect the performance of AI technicians. Therefore, maintaining experienced AI technicians in their service delivery position have paramount importance to bring the desired result in the crossbreeding program being implemented in the country.

Duration and Site of AI Training

The present study confirms that the presence of a wide difference in the duration of training in AI technique which was ranged from 45 days to 9 months and most AI technicians (42%) in the four regions trained for 45 days (6 weeks). The wide variability in the training

duration might be related to the absence of standard AI training curriculum at a national level for decades. There was no accredited institute in the country following a uniform module for AI training to produce efficient AI technicians. However, with the support of a Land O'Lakes – PAID project, the existing training curriculum was reviewed, upgraded and distributed nationally to be used as a standard curriculum in the AI technicians' training. The duration of training in this standard curriculum is 45 days. Though there is a wide difference in the duration of AI training, it seems enough when compared with other countries' training duration such as Uganda where the training lasts 2 to 12 weeks (Camilla, 2013). The duration still cannot be considered as a single factor that results in skilled and efficient AI technicians. The relationship between the duration of training and performance of AI technicians is not established in the present study as it is beyond the scope of the study. However, it is vital to establish such relationship which can help to revise the training duration if there is a positive or negative correlation. Accreditation of training institutes will play a significant role in producing skilled AI technicians. Therefore, training institutes need to be accredited by the concerned body.

Apart from the duration of training, due emphasis should be given to the criteria used to select candidate AI technicians for AI training. Previous knowledge on the anatomy and physiology of female cattle reproductive system determines the duration. Competing 12th grade, 10th grade with level I, level II or level III technical education in the ATVETs were the primary criteria used in regional bureaus to select candidate AI technicians. Such candidates might take a longer time to understand the anatomy and physiology of female cattle reproductive system. This knowledge should be taken into consideration while fixing the duration of the AI training. In some parts of the continent and other parts of the world, veterinary background is still considered as criteria while selecting candidate AI technicians. Such candidates might complete the training within a short period (sometimes two to four weeks) as they can easily understand the physiology of the female reproductive system.

Regional AI centers were found to be the major training site for AI technicians in Amhara and Oromia regions. About 96% of AI technicians in Tigray region trained at NAIC. In

SNNP 80% of the AI technicians trained at ATVETs. This clearly shows there is no specific place and standard assigned for AI and related trainings. This is confirmed by visiting the training sites which is conducted during the data collection period. The number of animals to be used for practical AI training purpose was not standardized. The number of animals determined by the availability of both budget and the required type of animals in the market. The training sites did not have similar capacity in terms of AI training facilities and equipment. They were not fully equipped with AI training materials especially of modern facilities. This lack of uniformity might create a significant difference in the performance of AI technicians. Thus, it is required to equip the training sites with all required facilities and inputs including live animals for practical training purposes. Regional training centers are currently equipped with training dummy cows which can significantly minimize the required number of animals for practical purpose. Generally, all the processes and procedures in the AI training need to be standardized across the country.

Ratio between Number of AI Technicians and Animals

In 2016/17 the average number of AI technicians per woreda in Amhara, Oromia, SNNP and Tigray regions was 1.62, 2.93, 2.51 and 3.16, respectively. However, the average number of AI technicians in 2017/18 increased to 1.86, 2.69 and 3.67 in Amhara, SNNP and Tigray regions. However, it is decreased to 2.19 in Oromia region. Factors considered while fixing the number of AI technicians per woreda at regional level were not well identified. Without having reliable data on cattle population at woreda and kebele level, it is not possible to take this factor to fix the number of AI technicians in each woreda. Moreover, the number of kebeles (the lowest administrative point) under each woreda and the number of cattle holders who potentially need the AI service in each kebele are not equal across woredas and regions. Such diversities make fixing the number of AI technicians at woreda level difficult. Therefore, there need to be properly prioritized and weighted factors that can guide fixing the number of AI technicians at each woreda or kebele. It is beyond the scope of the present study to identify factors for the increased or decreased number of AI technicians at Woreda level and thus further study is needed to identify these factors.

If we consider the female cattle population aged 3 to 10 years in 2016/17 (CSA, 2017) and the number of available AI technicians in the same reference year; the overall ratio of animals to be inseminated per AI technician per day was 44 in the four regions. If 50% of the female cattle population to be inseminated (assuming 2 years of calving interval), the overall ratio of animals to be inseminated per AI technician per day (considering female cattle population aged 3 to 10 years in 2016/17) was 20 in the four regions. In both cases, the number of animals to be inseminated was much higher than the actual performance of AI technicians reported to regional offices. The survey result held with AI technicians confirmed that the average number of inseminations performed per AI technician per day during peak season was 6 which was less than 50% of the potential animals to be inseminated in all regions (considering female cattle population aged 3 to 10 years in 2016/17 and two years of calving interval). The actual field performance (39 inseminations per AI technician per month or 1.3 inseminations per AI technician per day) was still much less than the reported survey-based performance (6 inseminations per AI technician per day). In both cases, the performance of AI technicians was very low than the anticipated number of animals to be inseminated. Therefore, it is vital to assess the major challenges and constraints that hinder AI technicians to do more inseminations per day or on every month. Based on the findings, regional specific strategies need to be designed and implemented to improve AI technician's performance that can be explained in terms of the number of services provided per day.

5.3.2. Characteristics of Farmers

Gender and Age of Farmers

The overall proportion of male-headed dairy households (74%) was much higher than that of female-headed dairy households (26%). In most parts of the country, it is a norm that the household is represented by the husband if he is alive, otherwise the household is represented by the wife in the absence of her husband due to various reasons. Though the contribution of women in terms of dairy cattle husbandry and management is significant in a dairy household, their role in the process of household-related decision making in the male-headed households was insignificant.

No significant difference observed in the present study between male and female farmers in terms of the number of years that they use AI technology for breeding purpose. However, gender is thought to be among the major factors which influence technology adoption, especially of agricultural technologies. However, previous research reports showed mixed evidence regarding the role of gender in the process of technology adoption. For instance, Doss and Morris (2001) and Fleming and Yala (2001) didn't see gender difference in the adoption rate of improved maize technology in Ghana and coffee production technology in Papua Guinea, respectively. Bisanda & Mwangi, (1996) on the other hand, observed a strong relationship between gender and technology adoption. Abdallah (2011), on the other hand, reported a negative relationship between AI adoption and gender in Tanzania where women farmers had a better adoption rate.

Significant difference observed in the average age of dairy farming household heads among the four studied regions with an overall average age of 45 years. The average age of farmers reported in this study is not high rather it is in the working-age group. As indicated in Adesiina and Baidu-Forson (1995), Dehninet et al. (2014); McNamara *et al.*, 1991, Peter et al. (2012); and Quddus (2012) age of farmers is among the most important variable which is believed to negatively influence adoption of agricultural technologies. Age is also said to be a primary latent characteristic in the decision-making process for technology adoption. The younger generation is better educated, more flexible and exposed to technology-related information and thus believed to try and adopt agricultural technologies more quickly than older ones. This is mainly because older farmers are conservative and may not want to take risk by trying out a new technology (Audrey, 2014; Peter, 2012). Feder et al. (1985) indicated that as the age of farmers increased farmers will become more reluctant to adopt new technologies. This contradicts findings by Abdallah (2011) and Kaaya et al. (2005) who reported a positive relationship between age and AI technology adoption and Joseph and Ango, (2014) who reported a non-significant relationship between the two variables. The average age of farmers reported in the present study is comparable with other reports such as Quddus (2012) who reported 57% of dairy farmers in Bangladesh belonged to 30-49 years of age and Potdar et al. (2018) who reported an average age of farmers 41 years in India.

Educational Status of Farmers

About 40%, 20% and 9% of dairy household heads attained primary, secondary, technical education or above, respectively. Nearly 30% of farmers were non-educated or illiterate in the four studied regions. This confirms that dairying is being practiced by non-professionals using the traditional way. However, dairying can be used as a source of income to the household in addition to improving household nutrition if proper dairy husbandry and management system is applied. Previous research reports indicated that education level of farmers has significant effect on technology adoption as it creates a favourable mental attitude for the acceptance of new practices especially of information-intensive and management-intensive practices and it can reduce the amount of complexity perceived in a technology thereby increasing a technology's adoption (Abdallah, 2011; Borden et al., 2017; Kaaya et al., 2005; Waller et al., 1998; Caswell et al., 2001; Joseph and Ango, 2014; Pankaj and Nayaran, 2016; Sime et al., 2014). The more educated farmers were more likely to adopt the recommended technology. Quddus, (2012) also reported that secondary and higher educated farmers were nearly 10 times more likely to adopt improved technologies compared to illiterate farmers in Bangladesh. Therefore, the low level of livestock-related technology adoption such as AI technology in the studied regions might be related to the education level of farmers. Strategies need to be designed to improve the technology adoption rate by educating farmers to a certain level.

Family Size

Significant difference ($p < 0.05$) observed in the family size of the dairy farming households among the four regions with an overall average of 6.2 persons per household (ranged between 5.3 and 6.9). The overall average number of male and female household members was 3.21 and 3.05 per household, respectively. Family size has a direct relationship with labor availability required for agricultural activities of the household such as dairying. The average family size reported in the present study is higher than the CSA 1994 census report of 4.8 (CSA, 1999). Mixed relationship observed between family size and AI technology adoption reported in previous studies. Dehninet et al., (2014) observed a positive relationship between the two variables. However, a negative relationship between family size and technology adoption reported in Oromia region, Ethiopia (Sime et al., 2014).

Abdallah (2011) and Joseph and Ango, (2014), on the other hand, did not observe a significant difference between adopters and non-adopters taking family size as factor. The report of Borden et al. (2012) revealed big families (6-7 members) tend to use AI technology and small families (up to three members) preferred to use natural service.

Dairy Household Income

Significant difference ($p < 0.05$) observed in total household income among the four regions during the study period. The overall average total income, income from off-farm activities, income from sale of live animals and livestock products was 6,860, 2,111, 2,332 and 2,417 ETB, respectively. Since household income is related to the income tax issue, farmers might not tell their actual income. Thus, it is expected that the actual average monthly total income might be higher than the reported figure. Since it is beyond the scope of this study, we didn't use different methodological approaches to examine and know the actual household income. Though income is not the only variable of interest to examine factors affecting the adoption level of AI technology, the present study confirms a significant positive correlation (0.195) between total monthly family income and number of years that a dairying household have been used AI technology. It is also confirmed in this study that dairying was among the major source of income for the dairying households in the studied regions. Previous research reports also indicated that household income has a positive relationship with the adoption of agricultural technologies (Watcharaanantapong et al., 2014; Walton et al., 2010). Investing in new and innovative technologies carry higher entry costs and more risk than already established technologies (Diederer et al., 2003). Income in most cases has a relationship with the affordability of inputs and other costs. As indicated in Kaaya et al. (2005) AI cost has a negative relationship with AI technology adoption in Uganda. Dehninet et al. (2014) Peter et al. (2012) and Sime et al. (2014) reported a negative relationship between off-farm income and AI technology adoption and a positive relationship between income from sale of dairying and AI technology adoption. AI is much labor-intensive than the use of bull as AI requires significant time and labor to observe and detect cows in heat and to take the necessary action following the heat. However, this may not be a case in Ethiopia as AI service is highly subsidized by the government.

Access to Extension Service

The present study demonstrates 76% of farmers in the four regions had access to livestock extension services during the study period. Access to livestock extension is an important factor that positively affects the adoption of livestock-related technologies (Abdallah, 2011; Dehinet et al., 2014; Kaaya et al., 2005; Sime et al., 2014) and management practices which can later affect productivity parameters. The result obtained in the present study seems very high as the study focused on those who had at least one kind of extension service. Access, on the other hand, doesn't mean practicing a given technology or management practices. Further research is needed to examine the degree of access and application of extension system by looking at the different types of livestock extension systems. The proportion of farmers who had access to extension system is higher when compared with the report of Dehinet et al. (2014) in Oromia region where only 66% had access to extension service. It is also higher than Bangladesh and Tanzania farmers where only 11% and 20% of farmers reported to have access to extension service (Quddus, 2012; TLMI, 2015). Similarly, the CSA (CSA, 2018) reported that only 9.63% of farmers in the country were engaged in dairy development packages. This is extremely low when it comes to the application of improved dairy-related technologies and management practices.

Experience of Farmers in Dairying

The present study reveals that nearly 43% of the dairy farms in the study regions are established between 2009 and 2018. Moreover, about 78% of dairy farms are established in the last three decades. This clearly shows either a significant proportion of farms are established in the last ten years or dairying may not be kept for a longer period due to various reasons. The increasing demand for milk and milk products especially in urban and peri-urban areas seen in the last two decades can be mentioned as a driving force for the establishment of a significant proportion of dairy farms in the last two to three decades. Future research shall focus on identifying factors that hindering farmers to keep their dairying for a longer period if this problem exists in the country. Land and labor shortage, increasing trend of the price of feed, veterinary and other input might be among important factors in this regard. The experience of farmers reported in the present study agrees with the experience of farmers in some other countries such as Bangladesh where about 66% of

dairy farmers had less than 10 years of experience in dairy farming Quddus (2012). However, Lawrence et al. (2015) reported longer (23 years) dairy farming experience in Kenya. The present study confirms a significant positive correlation ($r=0.362$) between experience in dairying and the number of years that farmers have been using AI technology. This positive correlation agrees with previous research reports where it is indicated that farmers' experience in dairying is interrelated with technology adoption (Abdallah, 2011; Dehninet et al., 2014; Joseph and Ango, 2014; Quddus, 2012). In contrary to the present study a negative correlation reported between experience and adoption of AI technology in Uganda (Kaaya et al., 2005; Masoud and Asghar, 2011; Sime et al., 2014).

Experience of Farmers with AI Technology

Adoption of improved dairy husbandry and management practices are among the most important factors for increased milk productivity (Khanal et al. 2010). However, most farmers are reluctant to adopt improved husbandry and management practices. Thus, the present study confirms the adoption level of these practices was very low in the four studied regions.

Proper breeding strategy and high level of AI adoption, on the other hand, are vital to establish an efficient and profitable dairy sector Quddus (2012). About 62% of farmers in the four regions received artificial insemination service either once or twice in a year with an average AI service number of 2.14. Only 25% of respondents in the four regions received insemination service thrice or more. The study population is those farmers who received AI service at least once. Thus, it is impossible to make comparisons with those who have never used the technology and draw conclusions on the adoption of AI technology. The average number of milking and dry cows reported in the four regions was 1.42 and 1.0, respectively. The number of AI services is directly related to the number of dairy cattle that need the service, availability, and accessibility of the service. Thus, the low number of AI services might be directly related to the small number of dairy cattle that potentially need the service.

Farmers in the four studied regions have been using AI service for an average of 5.4 years. The experience of farmers in AI technology reported in the present study is very similar to

Hammonds (2016) in Bangladesh where farmers had been using for about 5.2 years. With reported 2.14 numbers of inseminations per year and 5.38 years of experience in AI technology, farmers in the four studied regions received an average of 11.5 inseminations since they began using AI technology. This is also very similar to Bangladesh farmers when they performed an average of 10 inseminations since they start using this breeding technology (Hammonds, 2016). AI technology is introduced in the country in the 1960s and 1970s; however, farmers' experience with AI technology is very low considering the time of its introduction. The technology is being provided in the country for about 50 years, but the present study revealed that the technology was being utilized by farmers only for an average of about 5 years. Utilization of AI service for a longer time has paramount importance to establish good dairy herd and improve the genetic make-up of the dairy herd. Reliable and sustainable AI service delivery system in this regard is vital to bring the desired result in AI-based crossbreeding programs. However, farmers' experience with AI technology reported in the present study makes the sustainability and reliability of AI service delivery system in the country questionable. Factors contributed to the low level of experience with AI technology need to be further investigated. Intermittent service delivery system, intermittent input supply system, lack of awareness among farmers, short period of farmers experience for the dairy cattle and low level of livestock extension system can be mentioned as factors that hindering farmers to use AI technology for longer period than reported in this study. Quddus (2012) suggested that lack of basic equipment and negligible AI services, lack of knowledge among farmers about health management and proper feeding of animals are constraints to adopt AI technology and other improved agricultural technologies. Sime et al., (2014), on the other hand, reported a negative relationship between years in AI and adoption of AI technology. This is a different perspective regarding the experience of farmers in AI and its adoption.

The present study clearly shows that farmers do not have extensive experience with AI technology as most farmers received the service only once or twice a year. The number of insemination service alone do not show the efficiency of the service and thus all the services might not be resulted in conception. Therefore, it may be vital to relate insemination services provided to farmers with their satisfaction. Only 9% of farmers in

the four regions rated their AI technicians as excellent, 86% as very good and good. The level of satisfaction was measured without taking the different criteria used to measure satisfaction level. Further study shall be conducted to investigate the level of satisfaction based on clear and measurable criteria. Since private AI service delivery system was not available in most parts of the study areas, farmers rated their satisfaction based on the experience they had with public AI technicians. The present finding agrees with Sisay et al. (2017) who reported 85% of farmers were satisfied with AI service delivery system in West Shewa zone of Ethiopia. Unlike the present finding, Zerihun et al. (2013) reported 69% of farmers in Mecha district of Amhara region were dissatisfied with the overall AI service delivery system and its efficiency. This was mainly due to unreliable and inconsistent AI service. Similarly, 41% of farmers in Jimma district were not satisfied by AI service delivery system (Nuraddis et al., 2014). Yohanis and Tilahu (2018) also reported more than 50% of farmers in Adama Town of Oromia region were not satisfied with the overall AI service delivery system. The same authors mentioned discontinuation of the service during weekends and holidays, shortage of AI technicians, shortage of necessary inputs and long-distance of insemination sites as major reasons for the low satisfaction rate in the AI delivery system. Conception failure is also mentioned as a critical factor for the low satisfaction rate and adoption of AI technology in many parts of the country (Gebregiorgis et al., 2016; Nuraddis et al., 2014; Zerihun et al., 2013; Tessema and Atnaf, 2015; Sisay et al., 2017; Yohanis and Tilahun, 2018).

Adoption of AI technology should be integrated with the adoption of other improved dairy technologies such as improved health management, housing, and feeding. About 66% of farmers in the four studied regions had permanent type of dairy cattle housing. However, the comfort, hygiene, and cleanliness of the dairy cattle houses were questionable. Nearly 62% of farmers were practicing either mainly stall feeding or mainly stall feeding with some grazing type of feeding system. About 68%, 75% and 69% of farmers in the studied regions were practicing deworming, external parasite treatment and vaccination, respectively. Only 12% of farmers in the four regions were keeping records about any aspect of their dairying. On the contrary, nearly 70% of farmers in Uganda keep records of AI (Camilla, 2013). The application of improved management practices seems good in the

studied regions. Further study needs to be conducted to investigate the level of application of each of the management practices and to establish a relationship with productivity and other economically important parameters.

5.3.3. Number of Working Days Per Week

The study reveals that AI technicians in the four regions work for about 6.59 days a week. The result is based on interviews held with AI technicians. There should be other sources of data to confirm the result obtained in this study. However, it was difficult to get reliable data on the number of working days as there was no standard timesheet or attendance available at woreda or kebele offices. If such kind of reliable data is available, the number of working days might be lower than the reported figure. The number of days per week is not the only issue that needs to give due emphasis for efficient service delivery; the number hours that AI technicians stay on their duty is also a determinant factor in effective AI service delivery system. Due to the nature of AI service and its time sensitiveness, AI technicians are expected to be on their duty 24 hours per day and 7 days per week. Otherwise, it will result in significant economic loss as the cows or heifers missed their heat period without being served will show heat sign after 21 days. Future research is needed on this issue using reliable data sources from regional, zonal or woreda bureaus. Unlike the other three regions, 100% of Tigray region AI technicians were on their duty for about 7 days a week.

The result of the interview held with farmers, on the other hand, revealed that nearly 65% of farmers in the four regions were getting insemination service from Monday to Sunday. Unlike the other three regions, a significantly higher proportion of farmers (81%) in Tigray region were getting the service 7 days a week. However, availability of AI service during off hours, weekends, holidays and evenings was very limited in all the four regions with an average of 44% of farmers reported availability of the service during these times. This is extremely low and can significantly affect the result of crossbreeding programs. This result agrees with Yohanis and Tilahu (2018) who reported 50% of AI technicians in Adama town of Oromia region didn't provide insemination service during weekends and holidays.

Regional bureaus should give due emphasis to avail insemination service for 7 days a week including off hours, weekends and holidays. To do this, the current salary and carrier structure need to be revised and a part-time payment system needs to be in place. Other kinds of recognition system that can motivate best performing AI technicians shall be designed and implemented to create a favorable and positive competitive environment among AI technicians.

5.3.4. Demand, Site and Proportion AI service

Significant difference ($p < 0.05$) observed among regions in the number of kebeles assigned per AI technician with an average of 8 kebeles, 199 potential farmers who need the service per kebele but 92 farmers (46%) who were getting the service. Significantly higher proportion of farmers in Tigray region (71%) were getting the service (of the total number of farmers who need the service) as compared to Amhara (36%), Oromia (42%) and SNNP (50%) regions. No significant difference ($p > 0.05$) observed among the four regions in the number of potential farmers who need the insemination service but the difference in the number of farmers who were getting the service was significant ($p < 0.05$). The result of this study demonstrates a huge gap between demand and supply of AI service in the studied regions except that of Tigray region. The number of farmers who need the service and assigned for each technician was about 1,800. This number seems extremely high for an AI technician especially if we consider the availability of basic AI equipment and other necessary input. This calls the need for an additional number of AI technicians in each woreda to address a greater number of farmers and to narrow the gap between demand and actual service provision.

Insemination service is being provided in most parts of the country either at the farm-gate or at woreda/kebele level crashes. The proportion of animals inseminated in both sites depends on the distance of the insemination site, breed of animal and availability of transportation service. However, due to transportation problems and time constraints with AI technicians, farmers usually bring their animals to the site of insemination. About 96% and 89% of AI technicians reported that they were providing AI service at their respective

woreda/kebele sites and the farm-gate, respectively. Unlike the other three regions, all AI technicians in Tigray region were providing farm-gate AI service. This might be related to better availability of transportation facilities especially of motorbikes and the allocation of enough budget for fuel in this region as compared to the other three regions. This situation enabled Tigray region AI technicians to provide a much higher proportion (67%) of AI services at the farm-gate when compared with the other three regions (ranged between 38% in Amhara and 49% in Oromia). The result might suggest that Amhara, Oromia and SNNP regional bureaus shall share the experience of Tigray region in the provision of transportation facilities and allocation of budget to make the AI service delivery system more efficient. Moreover, information on the proportion of insemination services provided at woreda/kebele and farm-gate can help in the allocation of motorbike and associated budget for fuel, service, and maintenance.

In contrary to AI technicians' response, only 31% of farmers in the four studied regions reported that they got insemination service at their farm-gate. Much higher proportion of farmers (67%) in Tigray region reported that they were getting farm-gate service when compared with the other three regions (ranged between 33% in SNNP region and 41% in Oromia). This is also an additional parameter to confirm availability of better AI service delivery system in Tigray region.

The study confirms that it took more than 30 minutes to one hour for 36% of farmers in the four regions and more than one hour for 33% of farmers to reach the site of insemination. Of those who get farm-gate insemination service, about 84% of farmers in the four regions reported that AI technicians arrive within one hour of calling. The time in both cases may not be too long for the insemination service and thus might not affect the conception rate as they lie within the recommended range (4 to 12 hours) between estrus and insemination (Robert and Armando, 2013). Thought the distance in the present study expressed in terms of time, it seems the distance agreed with the report of Zerihun et al. (2013) who reported an average of 28 Km round trip to get the site of insemination. The time of insemination should be measured from the onset of the first heat; however, we didn't consider this issue in the present study. The challenge, in the current service provision system, lies in taking

the animals to the site of insemination, especially of the crossbreds. This required time which can affect the conception rate. A negative correlation established in previous research reports between adoption of AI technology and distance of AI site (Borden et al., 2017; Sime et al., 2014; Sing S.K. et al., 2009; Yohanis and Tilahun, 2018). Therefore, distance need to be considered while establishing insemination sites. Sisay et al. (2017) indicated farmers residing above 30 Kms away from the insemination center cannot get insemination service in West Shewa zone of Ethiopia. Research shall be undertaken to identify the optimum distance of insemination site to improve the adoption and utilization of AI technology.

The provision of insemination service at the farm-gate has additional transportation cost. The cost is covered either by the woreda bureau formally or by farmers informally as they are expected by AI technicians to pay extra payment. On the other hand, farm-gate service avoids additional labor and energy required to take the animals to the site of insemination, save time and avoids any danger while taking the animal to woreda/kebele sites. However, this service type was constrained by the availability of motorbike, fuel and time constraint with AI technicians. It is best if it is possible to provide all insemination services at the farm-gate. If impossible, only local breeds shall be taken to the site of insemination. Therefore, woredas need to develop guidelines on the type of animals inseminated at woreda/kebele sites and the farm-gate. All time-related factors that can affect conception rate should be taken into consideration while establishing insemination sites and allocating AI service-related budget, input, and equipment.

5.3.5. Traveling Distance for AI Service Delivery

The distance reported by AI technicians during peak AI season showed significant difference ($p < 0.05$) among the four regions with an overall average distance of 50 km/day per AI technician and the highest distance reported in Tigray region (72 km/day/AI technician). However, daily mileage during the regular season was not significant ($p > 0.05$) among the four regions. The difference observed during peak and regular season might be related to the difference in cattle population and associated demand for the AI service and geographical size of the four regions. The highest mileage reported in Tigray region might

be related to better transportation facilities, budget allocation, input supply, and higher farm-gate insemination service. The present study demonstrates a positive correlation between distance and number of insemination services both during peak and regular season. The result suggests as better transportation facilities available and enough budget is allocated to AI technicians, they can perform a greater number of insemination services. The negative correlation between distance and SPC suggests better efficiency of AI technicians can be obtained through the provision of proper input, budget, and infrastructure. Future research shall focus on the economics and its profitability of AI service delivery system as it is highly subsidized by the government. The result of such a study may allow the government to revise its strategy, budget and overall efforts that have been devoted to AI delivery system.

5.3.6. Determining Sire Breed

The result of the present study validates an insignificant level of farmers' participation in the process of sire breed selection. Only in Tigray region where a better proportion of farmers seem to participate in the selection process. In more than 80% of inseminations performed in the four regions, AI technicians were responsible for sire breed selection without consulting farmers. This might be due to a lack of knowledge among farmers and different genetics that is available to AI technicians. The study also confirms only half of farmers in the four regions know the effect of sire breed on productivity and related matters. Unlike the present finding Camilla (2013) reported participation of a significant proportion of farmers in sire selection together with their AI technicians in Uganda. Availing different sire breeds that fit the country's crossbreeding program, creating awareness among farmers through training and other means about the benefits of different sire breeds and allow them to participate in the decision-making process will play a significant role in enhancing crossbreeding programs and bringing the desired productivity improvement in the sector. Choosing the right genetics that can suit to the local environment and agroecological conditions is among the most important factor in breeding programs that aimed improved milk production and other economically important traits.

5.3.7. Thawing Practice

The thawing temperature reported by AI technicians was significantly different ($p<0.05$) among regions with average thawing temperature of 35.7°C. Thawing time was also significantly different ($p<0.05$) among regions with an average of 29 seconds. The time between thawing and insemination was also significantly different ($p<0.05$) among regions with an average of 6.17 seconds. The thawing temperature reported in the present study lies within the recommended range and agrees with other similar studies conducted in Algeria where about 80% of AI technicians thawed semen straws between 35°C and 38°C Souames et al. (2015). However, the thawing time reported in the present study seems low when compared with Souames et al. (2015) where they reported 40 seconds of thawing time in Algeria. The thawing temperature, thawing time and interval between thawing and insemination reported in this study is based only on the interview held with AI technicians without undertaking field-level assessment using a standard checklist. Thus, future research in this regard is very essential to investigate and evaluate the thawing practice of AI technicians. The temperature/time combination is an important factor that influences the fertilizing ability of male spermatozoa.

5.3.8. Price of AI Service

The interview held with AI technicians and farmers revealed that the price of insemination was significantly different ($p<0.05$) among regions. However, the repeated services per a single payment until the cow/heifer become pregnant reported by both farmers and AI technicians was not significantly different ($p>0.05$) among regions. AI technicians reported an average price of 4.50 ETB for about 2.77 repeated inseminations. However, farmers reported 11.58 ETB for about 3 consecutive inseminations if the cow/heifer failed to conceive in the first and second inseminations. This is almost a 76% difference between the two prices reported by AI technicians and farmers. It is only in Tigray region, where, all interviewed AI technicians reported a similar price of 2.00 ETB for about 2.83 repeated services. The price of AI service reported by AI technicians and farmers showed significant discrepancies in almost all the four studied regions. The regionally set price for AI service as understood from FGD held with regional bureau staff was 4.00 ETB in Amhara, 6.00 ETB in Oromia, 5.00 ETB in SNNP and 2.00 ETB in Tigray region. The difference

observed in the AI technician and farmer prices might be due to the additional payment that farmers informally pay to their AI technicians to cover service-related costs such as fuel cost. On top of this, the exact price set by the government is not known by all farmers who seek and utilize the service. Lawrence et al. (2015) identified the high cost of AI as a factor that hinders farmers from using AI technology in Kenya. However, in Ethiopia, the price of AI set by the government is extremely low when compared with bull service and thus it may not be the determinant factor in the use of AI technology. Rather, its availability and efficiency are among the most critical factors. Though insemination service is highly subsidized by the government like other Eastern African countries (Feed the Future, 2016), the degree of subsidy is not exactly known and documented. This information will help the government to know how much investment is devoted to the sector and the benefits out of the service in terms of productivity, household nutrition, and livelihood. The information will also help in creating a competitive environment for the private sector engagement in service provision as well as genetics market. Therefore, future research shall focus on such economically important parameters.

5.3.9. AI Related Services Provided to Farmers

The study reveals that an average of 90% AI technicians were providing PD, 58% synchronization, 68% calving assistance, 20% veterinary and 72% advisory services on dairy-related issues. Synchronization service is provided by the government as campaigns in a specific period on an annual basis. However, this service is not provided to individual farmers except in rare cases. Better level of AI-related services is seen in Tigray region than the other three regions. This is justified by more than 80% of AI technicians in the region reported to provide PD, hormone synchronization, calving assistance, and advisory services. Better veterinary service was also provided by AI technicians in the region when compared with the other three regions. The proportion of AI technicians who were providing PD service in the present study is much better than Souames et al. (2015) who reported only 50% of AI technicians in Algeria performed PD in the event of non-return. The proportion of AI technicians who were providing advisory service is lower when compared with the report of Souames et al. (2015) in Algeria where 100% of AI technicians advised their farmers in dairy related matters.

The challenge in the PD service provision is the lack of proper skill and modern equipment which can assist in the diagnosis of pregnancy such as ultrasonography. Due emphasis is not given to PD during AI technicians training in the country. Therefore, enough time should be allocated for AI/ technicians during AI training to enable them to diagnose pregnancies at the recommended stage of pregnancy. Providing veterinary service along with other AI-related services is very essential for the success of breed improvement programs. In this regard, it is advisable to train AI technicians to enable them to provide primary veterinary services and this should be an integral part of the AI technician training curriculum. On the other hand, training of AI technicians with veterinary background would be much helpful to shorten the duration of AI training, increase the efficiency of AI technicians and to provide AI-related services as package to client farmers.

5.4. Evaluation of AI Technicians Performance and Efficiency

5.4.1. Performance of AI Technicians and Seasonality of AI Service

As per the interview result conducted with AI technicians, significant difference ($p<0.05$) observed in the number of AI services provided during regular, peak and off seasons among the four regions. An average of 3.76, 6.70 and 2.23 inseminations provided per day per AI technician during regular, peak and off seasons, respectively (overall average 4.23 inseminations per day per AI technician). In contrary to this survey-based result, much lower field level actual performance is obtained in the four studied regions. Field level actual performance data also showed significant difference ($p<0.05$) in the number of inseminations provided per AI technician per month among regions and between male and female AI technicians with an overall average insemination of 39.3 (nearly 1.5 inseminations per day if the average 6.6 working days per week reported by AI technicians is considered). This is 47% lower than the survey-based performance report (4.23 inseminations/day/AI technician). The study confirms the actual performance of AI technician is significantly very low to bring the desired impact in the multiplication of improved breeds and then to improve productivity. Thus, regional offices need to pay due attention to improve the performance of their AI technicians through availing the necessary inputs, logistics, and infrastructures and establishing a strong monitoring system to follow-up the performance of their AI technicians. Result based career structure, promotion and

recognition system need to be established to motivate AI technicians to perform a greater number of inseminations. The average performance of AI technicians reported in both cases of the present study is higher than Camilla (2013) who reported 11-25 inseminations per month per AI technician in Uganda.

Though private AI technicians were expected to provide a greater number of inseminations per month, the difference between public and private AI technicians was not significant ($p>0.05$). Public AI technicians were providing a higher number of inseminations (40) per month than that of private AI technicians (32). This might be related to the few private AI technicians considered in this study. If the number of private AI technicians considered was high the result might be different. Future research should consider a reasonable number of private AI technicians to make comparisons and draw conclusions that can help the government to revise crossbreeding related policies, guidelines, and strategies.

The study confirms the delivery of AI service is followed a seasonal pattern. On average of 6.7 inseminations are reported per day per AI technician during peak season which is 26.7% more than the number of inseminations provided during regular season (3.8 inseminations/day/AI technician). The peak season lies between August and December when the availability of ample feed resources is secured as these months fall immediately after the long rainy season and fall in the harvesting season for most cereal crops. Green pasture is available for grazing and animals do not expected to be in the negative energy balance during these months of the year. Since feed is available in bulk, estrus synchronization campaigns are also undertaken during this time of the year in all studied regions.

The regular season falls in the months of January, February, June, and July. In January and February green pastures normally dry, however a significant amount of crop residues is available in most parts of the country as these months fall immediately after the harvesting season. June and July are part of the long rainy season and are just immediately after the short rainy season when green feed especially of green pasture is available to a significant extent in the field. Information on seasonality of AI service expressed in the number of AI

services provided per day per AI technician can be used to allocate the required input and logistic for AI service delivery instead of allocating such inputs and logistics regularly throughout the year. AI service delivery system can strategically be planned and implemented based on this information.

5.4.2. Service Per Conception, Conception and Calving Rates

The SPC reported by AI technicians was not significantly different among regions ($p>0.05$) with mean SPC of 2.13. About 2.6 SPC obtained from a follow-up survey conducted with 1,083 farmers who received AI service in a specified period. On the other hand, nearly 2.42 SPC calculated from five years of data received from NAIC. The discrepancy in the three types of reports might be related to a lack of proper and standard reporting system which is mentioned in different sections of this study. This clearly shows the absence of reliable data and structured reporting system to evaluate the exact performance of AI technicians in the studied regions as well as in the country. This calls for the importance of establishing a stringent follow-up reporting system to know the outcome of insemination services provided to farmers. There should be a strong linkage, network and communication among zonal and woreda level breed improvement, animal health and extension offices to undertake the envisaged follow-up reporting system. The SPC in this report is much higher than Desalegn et al. (2009) and Ali et al. (2013) who reported 1.88 and 1.55, respectively. It is also higher than the SPC reported in Kenya (1.9) under a controlled environment (Kinyua, 2016)

About 62% conception rate, 51% (from all received AI) and 82% (from conceived) calving rates are reported in this study. The result is based on a follow-up survey with farmers who received AI services from their AI technicians. The limitation in undertaking such a follow-up survey was improper animal identification, lack of record-keeping, lack of basic farmer related information to properly identify the location of farmers, and infrastructural problem. These challenges suggest the importance of proper animal and farm identification system and record-keeping to successfully undertake a follow-up survey.

The five years data received from NAIC, on the other hand, revealed a 45% conception rate (from total inseminations). The discrepancy between the two conception rates is related to the method of data collection. The second one is based on direct reports obtained and synthesized from regional bureaus and may not reflect the exact performance of the crossbreeding program. To make such a report more reliable, it needs to be supported with a follow-up survey to verify the results received from regional bureaus. All performance-related results reported in this study suggests the importance of proper and structured data collection and reporting system. Due attention should be given to this issue at all levels if the objective of the crossbreeding program is to improve the genetics and productivity of animals. The conception rate reported in this study is higher than Tatek et al. (2011), Ali et al. (2013), Desalegn et al. (2009) and Gebregiorgis et al. (2016) who reported 48.3%, 40.9%, 27% and 56%, respectively. It is also higher than Mwabilwa et al. (2013) who reported a 48% conception rate in Zambia. The calving rate in this report is also higher than Gebregiorgis et al. (2016) who reported 37% in Tigray region, Ethiopia.

This study disproves the complaints about the sex ratio of calves out of AI service. A significant proportion of farmers and AI technicians didn't accept the complaint. The result agrees with Firehiwet et al. (2014) who didn't see a significant difference in the sax ratio of calves out of both natural mating and AI. Thus, such complaint needs to be avoided to increase the adoption rate of AI service among dairy farmers.

5.4.3. Problems Associated with Reporting

AI service is provided at woreda/kebele crashes or at the farm-gate depending on the breed of animal, distance, time, infrastructure and availability of required input and supplies. Under prevailing circumstances, farmers are also expected either to bring their animals for pregnancy diagnosis or call to their AI technicians to examine and report on pregnancy status and then report if the cow is calved. However, a significant proportion of farmers do not bring their animals for pregnancy diagnosis especially if they believe the cow is conceived. They do not also report if the cow is calved due to lack of awareness and cultural taboos. There is no stringent follow-up reporting system after AI service is undertaken due to various reasons and/or challenges. Farmers' willingness, infrastructure, distance,

awareness, and cultural taboos are among factors for lack of follow up reporting. There is also time constraint among AI technicians to revisit their client farmers as they are expected to provide insemination services all the time.

Though evaluation of AI service-related record-keeping such as AI certificate was not part of the present study, gaps were observed in filling the AI certificates properly and documenting the services and follow-up visits in the AI service logbook. Lack of uniformity and standardization was also observed in the AI service logbook. Submission of copies of AI certificates together with summary reports using standard reporting formats was not part of the regional reporting system in all the four regions.

The five years data received from NAIC revealed that no insemination reports available for 62% of the straws distributed to regions. Though the exact reason for this was unknown, it might be related to lack of stringent reporting and coordination system between regional bureaus and NAIC. Further study shall be conducted on the proportion of semen utilized for insemination purposes, unused and discarded due to different reasons. Regular and uniform reporting system should be in place in all regions and NAIC should properly play its coordinating role at the national level. The link between regional bureaus and NAIC should be revised and the responsibilities of all stakeholders need to be properly identified.

5.5. Evaluation of Government led Heat Synchronization and Mass Insemination Campaigns

Significant difference ($p < 0.05$) observed in the number of animals synchronized per campaign/site among regions with an average number of 172 animals. Of the synchronized animals on average 46% came into heat and 52% conceived from the inseminated animals and 24% from the total synchronized animals. Though the difference is not significant, better synchronization efficiency reported in Tigray region where 59% of animals reported to conceive from the inseminated animals or 31% from the total synchronized animals. The present report is based on an interview held with AI technicians and not supported with field-level synchronization campaigns performance data. The field-level data is more reliable than this interview-based report to evaluate the performance of synchronization

campaigns. Even in this interview-based report, the performance of synchronization campaigns is very low when compared with Bainesagn (2015) who reported 61.3% to 73.8% estrus response rate and 40.7% - 72.2% conception rate, Ejigayehu (2018) who reported 72.2% estrus response rate and 30% conception rate, Abiyot and Eyob (2019) 91.9% estrus response rate and 46.2% conception rate, Debir (2016) who reported 87.2% estrus response rate and 42.2% conception rate and Azage et al. (2012) who reported 97.7% estrus response rate.

An overall average of 89% of interviewed AI technicians were participated in the synchronization campaigns in the four regions and nearly 70% of the synchronization campaigns took place at village level synchronization sites which can temporarily be built using local materials and they are undertaking in almost all dairy commercialization areas of the studied regions. An overall average of 63% AI technicians reported that synchronization campaigns took place starting end of August through December of each year. This period lies within the peak season for AI service and related to the availability of ample feed resource during this time. However, animals normally show estrus signs during this period of the year as they are in a positive energy balance. Thus, the timing of synchronization shall be out of this season especially immediately after this season.

Farmers' willingness, available cattle population, availability of feed, availability of hormone, availability of AI technicians and other technical staff, size of synchronization site and availability of budget are among factors in their order of importance considered to fix the number of animals for synchronization. However, the type of hormone and dose used in the campaigns need to be revised. The effect of the current hormonal synchronization protocol on different cattle breeds need to be evaluated and adjusted accordingly. The effect of both availability (39%), experience (45%), performance of AI technicians (64%) were among factors considered during selection of AI technicians for synchronization campaigns.

Body condition, age, health, parity and cyclicity of animals was the most important factor considered during selection of animals for synchronization campaigns. Though, AI

technicians listed these factors as criteria for selection of animals, they may not strictly follow the procedures while undertaking the selection as zonal and regional bureaus pay due attention to the number of animals synchronized but not to the result of the synchronization campaigns. This is mainly due to budget allocation and reporting system is based only on the numbers of animals synchronized. Annette et al. (2015) and Kouamo and Sawadogo (2013) mentioned parity and body condition as a major factor for estrus synchronization. Thus, due emphasis should be given to body condition and parity of the animals during selection. The reporting system shall focus on results instead of numbers to bring the desired result out of such campaigns. Future study shall be conducted by taking field-level data from woreda, zone, and regional offices.

6. CONCLUSION AND RECOMMENDATION

The CSA data is the only available statistical data in the country that can be referenced for academic, research and development purposes. The CSA data have also been used in the formulation, implementation, monitoring, and evaluation of development plans, projects, and programs in the livestock sector. However, the CSA data doesn't include the non-sedentary population of the country especially found in Afar and Somali regions. Moreover, the dairy cows are treated as a subset of milking cows in the CSA reports. Therefore, to be used as a reliable reference regarding the livestock population these issues need to be considered.

With the current trend of indigenous (3.7%) and crossbred (15.76%) cattle population, the country will hold 121.2 million and 5.4 million heads, respectively in 2029/30. There was an increase of only 1 billion liters (0.07 increase per year) without any change in lactation length (6 months) but with an increase of only 0.138 liters/day/cow over the last thirteen years since 2004/5. This clearly shows, the increase in milk production is a result of an increase in the number of indigenous cattle without a significant increase in the crossbred cattle population and associated genetic improvement.

Serious problem is not observed both in the training curriculum and duration of AI technicians training. However, the criteria used to select candidate AI technicians need to be revised again. AI is an art and science and needs background theoretical and if possible practical knowledge on female cattle reproductive anatomy and physiology. Thus, considering candidate AI technicians with this background knowledge will help in producing efficient and competent AI technicians. Though women are said to be passionate and responsible in their job, the engagement of women in AI service delivery is very insignificant due to cultural taboos and biological issues. Much work must be done to increase their engagement as AI technician and special emphasis should be given to them while providing AI equipment, transportation facilities and incentives.

One of the major factors for the success of AI service delivery system is the experience of AI technicians. The turnover rate of AI technicians is high in all studied regions due to

their low monthly income, discouraging career structure and poor recognition and reward system. These factors lead to low level of job satisfaction among AI technicians. Thus, strategies need to be designed and implemented to motivate and retain AI technicians in their position and further studies should identify factors contributing to the high turn-over rate of AI technicians in the country.

Though the study demonstrates high access to livestock extension service system, farmers in the four regions do not have long years of experience in dairying due to various reasons. Unreliable AI service, increasing trend of feed prices, shortage of labor and land are among factors contributing to the short experience of farmers in dairying. Utilization and adoption of AI technology and experience in dairying are interrelated. Therefore, to use and adopt AI technology, farmers are expected to have long years of dairying experience and vice versa. On top of this, emphasis should be given for reliability, quality, availability, and affordability of the service as these factors significantly affect the adoption of the technology.

Availability of basic AI equipment determines the efficiency of AI technicians as well as the success of crossbreeding programs. Limited availability of transportation facilities especially of motorbike and associated fuel allowance is the major challenge for most AI technicians to address a greater number of farmers who need insemination and related services and to make a follow-up visit. Moreover, there are no standard criteria used for fuel allowance that is usually done on monthly basis. Budget availability is the most important determining factor that affects the volume of fuel to be provided to AI technicians. This problem is very severe in all studied regions except in Tigray region. Reliable supply of semen and LN₂ is also a critical problem in the studied regions. There were times when the service is interrupted due to the absence of these basic inputs. Therefore, due emphasis should be given at the regional and national level to provide both semen and LN₂ sustainably.

AI service is very time-sensitive, an animal in heat should be inseminated at the appropriate time for maximum fertilization. To this end, the rule of 7-24 should be applied for

maximum conception rate and associated economic benefit. However, the service is interrupted during weekends, holidays and off-hours in the studied regions. This is associated in most cases with budget shortage to be paid for the extra time service delivery.

Only 46% of those farmers who potentially need the service were getting the insemination service in the studied regions. There is no any kind of standard to be used while assigning AI technicians in each woreda or kebele. The number of farmers who raise cattle, herd size, spatial distribution of farmers and other relevant factors should be considered when determining the number of AI technicians in each kebele or woreda. This can narrow the gap between demand and actual service delivery.

Insemination service is limited at woreda or kebele sites in most studied woredas. Insignificant proportion of services is being delivered at the farm-gate. Woreda/kebele level service is labor-intensive, costly and time-consuming. Therefore, farm-gate service needs to be strengthened especially for crossbred and exotic animals. To make this happen, the provision of transportation facilities to each AI technician is very essential. This will, in turn, boost the demand for AI technology amongst farmers.

Farmers' knowledge on the difference among sire breeds and associated benefit is very limited. On top of this, the availability of straws from different sire breeds and blood level is a critical problem. AI technicians usually use the genetic material that is available in their stock during the service time. Therefore, availing straws from different sire breeds with variable blood level based on the production objective and agroecology is very important. However, such decisions should be supported with field-level research outputs. Thus, collaboration of NAGII, research and higher learning institutes is very essential.

Though the result of this study reveals that AI technicians seem to follow proper thawing practice. However, the availability of proper equipment required for thawing is challenging. And therefore, the thawing practice of AI technicians should be assessed following a standard checklist as this practice significantly determines the outcome of

insemination service. Availing suitable and timesaving thawing equipment in this regard is very essential for maximum conception rate.

The price of AI service in the studied regions is not uniform. Insemination service is said to be highly subsidized by the government, however, the level of subsidy and factors considered while setting the current price are not exactly known. Knowledge among farmers about the price of AI service is variable. It seems farmers are paying extra payment higher than the regionally set price. The reason for extra payment is not known and therefore a strong monitoring and account system should be in place to protect farmers from paying any kind of extra payment.

AI service follows a seasonal pattern in the studied regions. There are high, medium and off seasons based on the demand for AI service. AI service-related logistics, input, and budget allocation should follow the same pattern for better and efficient utilization of available resources. Estrus synchronization campaigns are undertaken during the high season of the insemination service. Efficient AI technicians are mobilized for synchronization campaigns from their respective woredas for a month or longer. Since a significant number of animals are expected to come in heat during this season through their natural cycle, synchronization campaigns shall take place at the end of the peak season. This way it may be possible to address a greater number of animals both through the normal cycle and hormone synchronization. The current study revealed that the performance of synchronization campaigns is not satisfactory and therefore the type of hormones and dose, time and frequency of insemination need to be revised for maximum performance out of such campaigns.

Both secondary and field-level performance data revealed that the performance of the current AI service delivery is very low. However, the government is investing a significant amount of budget to make the system more efficient and productive. This calls for a series of discussion forums both at the regional and national level to identify the problems, make the necessary adjustments and share regional experiences.

The quality of semen at all levels of the supply chain seems poor and this might be among factors contributing to the low performance of AI service delivery in the country. Therefore, stringent quality control system needs to be in place at all levels of the supply chain. Training and awareness creation platforms on proper handling of semen need to be organized for all who participate in the production, storage, distribution and service delivery. Semen of superior quality should be available at all levels especially of end-users for maximum conception rate. Almost all available liquid nitrogen plants in the country are old and getting their spare parts for efficient maintenance and service is very challenging. New models with higher production capacity shall be considered for new installations. Altitude, infrastructure, convenience, and other related factors need to be considered while installing the new plants. Oxygen producing companies need to be consulted and advised to put extra effort, budget and labor that help them to produce and sell liquid nitrogen.

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S.No.	Question	Fill the blank / choose the best answer
	<i>Miazia</i>	h) Regular b) Peak c) Off
	<i>Ginbot</i>	i) Regular b) Peak c) Off
	<i>Sene</i>	j) Regular b) Peak c) Off
	<i>Hamle</i>	k) Regular b) Peak c) Off
	<i>Nehase</i>	l) Regular b) Peak c) Off
23	How many days you work per week?	
24	Where did you perform AI? Indicate the proportion	a) Farm gate % b) Woreda level crash % c) Kebele level crash %
25	How many Kebeles assigned to you for AI service?	..... Kebeles
26	How many farmers are need AI service in each kebele (on average)?	..... farmers
27	For how many farmers you are actually giving service (in each kebele)?	..... farmers
28	How many kilometers in total you can travel per day during regular season?	..... Kms
29	How many kilometers in total you can travel per day during peak season?	..... Kms
30	How many AI technicians available in your woreda including you?	..... AI technicians
31	How do you communicate with farmers?	a) Mobile phone b) Land line c) Farmers come physically
32	Who determine the breed of the straw to be used?	a) Farmer b) AI technician c) Other, specify
33	What is the thawing temperature you use during thawing?	..... °C
34	How long do you thaw at this temperature?	..... seconds
35	How do you check the temperature of water during thawing?	a) Using thermometer b) Using finger c) Other, specify
36	How do you check the thawing time?	a) Stopwatch b) Counting c) Guess
37	How long you take between thawing and insemination?	..... minutes
38	What other services you provide to farmers?	a) Pregnancy diagnosis b) Hormone synchronization c) Calving assistance d) Veterinary/health service e) Advisory service
39	What is the price for AI service	..... birr
40	For how many repeated inseminations?	..... inseminations

S.No.	Question	Fill the blank / choose the best answer
41	Have you ever been participating in hormone synchronization and mass inseminations campaigns in the last two years?	a) Yes b) No
42	Where does the campaign normally undertake?	a) Woreda BoLF b) Research center c) Zone BoLF d) Cooperative e) At village level- Central location f) School g) Local market
43	How many cows (on average) can come for synchronization per campaign?	..... cows
44	How many cows (on average) show heat signs out of hormone synchronized?	..... cows
45	How many cows (on average) conceive out of inseminated in the campaign?	..... cows
46	Is the number of cows that come for synchronization fixed?	a) Yes b) No
47	What parameters considered for deciding the number of cows for synchronization?	a) Number of AI technicians and other staff b) Cattle population c) Budget availability d) Hormone availability e) Availability of feeds f) Farmers willingness to bring animals g) Size of synchronization site
48	When does synchronization campaign take place?	a) Meskerem g) Megabit b) Tikimt h) Miazia c) Hidar i) Ginbot d) Tahisas j) Sene e) Tir k) Hamle f) Yekatit l) Nehasse
49	Why, these months are selected?	a) Feed is available b) Budget is available c) Labor is available d) Farmers are relatively free e) Hormone are available only in these months
50	Does this influence the regular AI service?	a) Yes b) No
51	On what basis AI technicians are selected for the synchronization campaign?	a) Availability b) Years of experience c) Gender d) Performance e) Health condition f) Salary g) Proximity
52	Is there anything considered to select cows/for synchronization?	a) Yes b) No

S.No.	Question	Fill the blank / choose the best answer
53	If yes, what parameters?	a) Parity b) Age c) Body condition d) Lactation stage e) Health condition f) Management level g) Feed provision h) Normal cycling animals
54	Do you like your job?	a) Yes b) No
55	Do you think that you are earning enough as compared to other professions?	a) Yes b) No
56	Do you have any plan to change your job in the near future?	a) Yes b) No
57	Is there any possibility to be forced to do other assignment during regular working hours/days?	a) Yes b) No
58	If the cow should be served during night, do you really give the service?	a) Yes b) No
59	What is your average number of services per conception?	.....
60	Farmers are complaining that most of the calves out of AI are male. Do you agree?	a) Strongly agree b) Agree c) Indifferent d) Disagree e) Strongly disagree
61	Farmers are complaining that most of the calves out of AI are weak and can't stand after calving. Do you agree?	a) Strongly agree b) Agree c) Indifferent d) Disagree e) Strongly disagree
62	Do you think the incentive payment has brought impact on the performance of AI technicians?	a) Yes b) No
63	If yes, what is the average performance before the incentive system?	.....
64	If yes, what is the average performance after the incentive system?	.....
65	If no, why?	a) The value is not attractive b) The payment has long process c) Data collection system is not easy d) I am not interested in the incentive e) I am getting more from other means
66	How many times you open the LN2 container per day for AI service purpose?	.....
67	How long do you expose the canister to ambient T ⁰ to take the straw out from the canister?	..... seconds

Appendix 2. Questionnaire for Farmers

1. General							
1.1	Name						
1.2	Region	a) Amhara b) Oromia c) SNNP d) Tigray					
1.3	Wereda						
1.4	Sex of the household head	a) Male b) Female					
1.5	Age of the household head	..... years				
1.6	Marital status of the household head	a) Married b) Single c) Widowed d) Divorced					
1.7	Educational status of the household head	f) Primary education (Grade 1 to 6) g) Secondary education (Grade 7 to 12) h) Diploma (10 + 3 or 12 + 2) i) Certificate (10/12 + ≤ 6 months) j) Degree and above					
1.8	Family size	<2 years	2-10 years	11-15 years	16-30 years	31-50 years	>50 years
1.9	Male						
1.10	Female						
1.11	Number of livestock owned						
	a) Cattle						
	b) Sheep						
	c) Goat						
	d) Chicken						
1.12	Number of cattle by class						
	a) Milking cows	a) Local.....b) Cross/exotic					
	b) Dry cows	b) Local.....b) Cross/exotic					
	c) Heifers	c) Local.....b) Cross/exotic					
	d) Calves	d) Local.....b) Cross/exotic					
	e) Oxen	e) Local.....b) Cross/exotic					
1.13	When did you start keeping dairy?	.....				
1.14	Why did you start keeping dairy cows?	a) Main economic enterprise b) Supplementary enterprise c) Home milk consumption d) Other, specify					
1.15	Where did you obtain dairy cows?	a) Purchased from neighbors b) Purchased from local market c) Purchased from other area d) Gift from families/relatives e) Obtained through crossbreeding f) Gift from neighbors					
1.16	How many dairy animals did you start with?	.....				
1.17	Total land size owned	..... ha				

1.18	Is the total land size increasing or decreasing for the last 20 years?	a) Increasing b) Decreasing
1.19	Monthly family income from all sources	..... Birr
1.20	Monthly family income from off farm activity	..... Birr
1.21	Income from livestock sales per year	..... Birr
1.22	Income from livestock products sales per year	..... Birr
1.23	Do you have access to credit?	a) Yes b) No
1.24	Do you have saving bank account	a) Yes b) No
1.25	Do you have access to livestock extension service?	a) Yes b) No
1.26	Who is mainly responsible to manage animals?	a) Family member b) Hired person/s
1.27	What breeding technology you use mainly for breeding dairy cows?	a) AI b) Bull c) Both
1.28	If AI go to AI section If Bull go to Bull section If both go to section "Both"	
2. For AI technology users		
2.1	Where did you get AI service?	d) Farm gate e) Woreda level crash f) Kebele level crash
2.2	For how many years you have used AI?	..... years
2.3	For which animals you use AI?	a) Local breeds b) Cross/exotic breeds c) Both
2.4	Who decided the breed of the sire?	a) My self/farmer b) AI technician c) I don't know
2.5	Do you know the importance of the different sire breeds?	a) Yes b) No
2.6	How much do you normally pay for a single AI service?	..... Birr
2.7	Does this amount vary from season to season?	a) Yes b) No
2.8	For how many repeated inseminations you pay once for a single animal?	..... times
2.9	Do you really get the repeated service without payment once paid?	a) Yes b) No
2.10	Do you get official receipts for payment?	a) Yes b) No
2.11	Have you experienced any difficulties in getting the AI service?	a) Yes b) No
2.12	For a cow to conceive, how many times the cow should be inseminated?	a) Once b) Twice c) Three times

		d) More than three times
2.13	Are you satisfied with NAIC semen?	a) Yes b) No
2.14	Do you obliged to pay additional amount than the fixed price?	a) Yes b) No
2.15	Do you obliged/forced to pay for transport if the technician should serve the animal in heat at the farm gate?	a) Yes b) No
2.16	Do you get AI service from Monday to Sunday?	a) Yes b) No
2.17	Do you get AI service during off hours, holidays and evenings?	a) Yes b) No
2.18	What type of AI technicians you use for AI service	a) Public b) Private c) Both
2.19	If you use both, which type you prefer more?	a) Public b) Private
2.20	At what time AI technicians arrive at your home when called?	a) In 30 minutes b) Within one hour c) Within three hours d) Within six hours e) After 6 hours
2.21	How do you communicate with AI technicians?	d) Mobile phone e) Land line f) I go to their office or site
2.22	How far is the Kebele/woreda crush for AI service?	..... km
2.23	How long you should travel to get AI service at Kebeles/woreda crush?	a) Less than 30 minutes b) 30 minutes to 1 hour c) More than 1 hour d) I don't know
2.24	Do AI technicians thaw the semen before insemination?	a) Yes b) No C) I don't know
2.25	For how long AI technicians thaw the semen?	a) seconds b) I don't know
2.26	How do AI technicians check the temperature of water during thawing?	d) Using thermometer e) Using finger f) I don't know
2.27	How long it takes for AI technicians to inseminate a given cow?	..... minutes
2.28	Are you satisfied with AI technicians in their service provision?	a) Yes b) No
2.29	Do you think AI technicians are efficient while service provision?	a) Yes b) No
2.30	If you get bull service easily or if it is available in your village, do you go for AI?	a) Yes b) No
2.31	If yes, why do you choose AI over bull service?	a) AI service is reliable, or it is always available b) AI service is cheap

		<ul style="list-style-type: none"> c) To avoid disease transmission d) To get better breed for better productivity e) There is no bull service in the area f) Calves from AI have better price
2.32	If the cow should be served during night, do you really get the service?	a) Yes b) No
2.33	What other services do you get from AI technicians?	<ul style="list-style-type: none"> f) Pregnancy diagnosis g) Hormone synchronization h) Calving assistance i) Veterinary/health service j) Advisory service
2.34	Have you ever gotten hormone synchronization and mass inseminations service?	a) Yes b) No
2.35	If yes, where do you get the synchronization service?	<ul style="list-style-type: none"> h) Woreda BoLF i) Research center j) Zone BoLF k) Cooperative l) At village level- Central location m) School n) Local market
2.36	If yes, how many cows (on average) you take for synchronization per campaign?	..... cows
2.37	How many cows (on average) show heat signs out of hormone synchronized?	..... cows
2.38	How many cows (on average) conceive out of inseminated in the campaign?	..... cows
2.39	What type of animals you take for synchronization campaign?	<ul style="list-style-type: none"> h) Local cows i) Cross breed/exotic cows j) Local heifers k) Cross breed/exotic heifers
2.40	Farmers are complaining that most of the calves out of AI are male. Do you agree?	<ul style="list-style-type: none"> f) Strongly agree g) Agree h) Indifferent i) Disagree j) Strongly disagree
2.41	Farmers are complaining that most of the calves out of AI are weak and can't stand after calving. Do you agree?	<ul style="list-style-type: none"> f) Strongly agree g) Agree h) Indifferent i) Disagree j) Strongly disagree
2.42	What do you think about the reason for lower conception rate in AI service?	<ul style="list-style-type: none"> a) AI technicians are not efficient b) AI technicians do not arrive on time when called c) It takes long time to reach to Kebele or Woreda level AI service site d) The quality of semen AI technicians use is questionable

		e) AI technicians lack basic AI equipment f) AI technicians are not willing to give the service g) AI technicians are not motivated to give the service
2.43	Did you sell crossbred heifer in the last two years?	a) Yes b) No
2.44	If yes, how many in the last two years?	..... heifers
2.45	What is the average price of crossbred heifer?	a) In calf heifer birr b) Open heifer Birr
2.46	Why did you sale crossbred heifers?	a) Shortage of land b) I had enough number of cows/heifers c) It is profitable d) To buy other more productive animal e) Due to brokers request f) I need the money
2.47	Average milk production per day per animal: from	
	Local breed	..... lit
	Cross/Exoic breed	..... lit
	Total milk produced from all animals – a day before	..... lit
2.48	For home consumption	..... lit
	For sale	..... lit
	For calves	..... lit
	For other purposes	..... lit
2.49	Does your cow’s milk production satisfy you?	a) Yes b) No
3. For Bull users		
3.1	For how many years you have used bulls?	..... years
3.2	Where did you get bull service?	a) Own bull b) Neighbor’s bull c) Cooperative bull d) Other, specify
3.3	If own bull, what is the cost of keeping a bull per month?	..... Birr
If using bull other than own bull		
3.4	How much do you normally pay for a single bull service?	a) Birr
3.5	Does this amount vary from season to season?	a) Yes b) No
3.6	Do you pay another payment if the cow/heifer is not conceived?	a) Yes b) No
3.7	If you pay another payment how much you should pay?	..... Birr
3.8	Do you get official receipts for payment?	a) Yes b) No

3.9	Do you get bull service from Monday to Sunday?	a) Yes b) No
3.10	Do you get bull service during off hours, holidays and evenings?	a) Yes b) No
3.11	Do you get bull service on time whenever needed?	a) Yes b) No
3.12	How far is the bull service site from your home?	..... km
3.13	How long you should travel to get bull service?	a) Less than 30 minutes b) 30 minutes to 1 hour c) More than 1 hour d) I don't know
3.14	On average how many repeated services required for a cow to conceive by bull?	..... services
3.15	Do you think AI can provide you with semen of the best bull you need?	a) Yes b) No
3.16	If you get AI service easily or if it is available in your village, do you go for bull?	a) Yes b) No
3.17	Do you know the problem such as disease transmission when using bull service?	a) Yes b) No
3.18	Do you mind the merit of the bull you use?	a) Yes b) No
3.19	Do you prefer bull than AI service?	a) Yes b) No
3.20	Do you think that if you use AI you can be more profitable than bull service through sale of heifers?	a) Yes b) No
3.21	If yes, why do you choose bull over AI service	a) Bull service is reliable, or it is always available b) Bull service is cheap c) Bull service is efficient d) More chance of getting female calf e) More chance of strong calf f) Calves from bull have better price g) Other, specify
3.22	Farmers are complaining that most of the calves out of AI are male. Do you agree?	a) Strongly agree b) Agree c) Indifferent d) Disagree e) Strongly disagree
3.23	Farmers are complaining that most of the calves out of AI are weak and can't stand after calving. Do you agree?	a) Strongly agree b) Agree c) Indifferent d) Disagree e) Strongly disagree
3.24	Average milk production per day per animal: from	
	Local breed	..... lit
	Cross/Exoic breed	..... lit

3.25	Total milk produced from all animals – a day before	..... lit
	For home consumption	..... lit
	For sale	..... lit
	For calves	..... lit
	For other purposes	..... lit
3.26	Does your cow's milk production satisfy you?	a) Yes b) No
4. For both AI and Bull users		
4.1	For how many years you have used AI?	..... years
4.2	For how many years you have used bulls?	..... years
4.3	Where did you get AI service?	a) Farm gate b) Woreda level crash c) Kebele level crash d) Other, specify.....
4.4	Where did you get bull service?	a) Own bull b) Neighbor's bull c) Cooperative bull
4.4.1	If own bull, what is the cost of keeping a bull per month?	..... Birr
4.5	For which animals you use AI?	a) Local breeds b) Cross/exotic breeds c) Both
4.6	For which animals you use bull?	a) Local breeds b) Cross/exotic breeds c) Both
4.7	How much do you normally pay for a single AI service?	..... Birr
	Does this amount vary from season to season?	a) Yes b) No
	For how many repeated inseminations you pay once for a single animal?	..... times
	Do you get official receipts for payment for AI service?	a) Yes b) No
4.8	How much do you normally pay for a single bull service?	..... Birr
	Does this amount vary from season to season?	a) Yes b) No
	Do you pay another payment if the cow/heifer is not conceived when using bull?	a) Yes b) No
	If you pay another payment how much you should pay?	..... Birr
	Do you get official receipts for payment for bull service?	a) Yes b) No
4.9	Have you experienced any difficulties in getting the AI service?	a) Yes b) No
4.10	Why do you go for bull service?	a) AI service is not always available

		<ul style="list-style-type: none"> b) Technicians are not willing to come to home for service c) When semen is not available d) After repeated service by AI e) To get female calf f) When good bull is available
4.11	Do you get AI service from Monday to Sunday?	a) Yes b) No
4.12	Do you get bull service from Monday to Sunday?	a) Yes b) No
4.13	Do you get AI service during off hours, holidays and evenings?	a) Yes b) No
4.14	Do you get bull service during off hours, holidays and evenings?	a) Yes b) No
4.15	How far is the Kebele/woreda crush for AI service?	..... km
4.16	How far is the bull service site from your home?	..... km
4.17	How long you should travel to get AI service at Kebeles/woreda crush?	<ul style="list-style-type: none"> a) Less than 30 minutes b) 30 minutes to 1 hour c) More than 1 hour d) I don't know
4.18	How long you should travel to get bull service?	<ul style="list-style-type: none"> a) Less than 30 minutes b) 30 minutes to 1 hour c) More than 1 hour d) I don't know
4.19	For a cow to conceive, how many times do you inseminate?	<ul style="list-style-type: none"> a) Once b) Twice c) Three times d) More than three times
4.20	On average how many repeated services required for a cow to conceive by bull?	<ul style="list-style-type: none"> a) Once b) Twice c) Three times d) More than three times
4.21	If you get AI service easily or if it is available in your village, do you go for bull?	a) Yes b) No
4.22	Do you know the problem of disease transmission when using bull service?	a) Yes b) No
4.23	Do you mind the merit of the bull you use?	a) Yes b) No
4.24	Do you prefer AI than Bull service?	a) Yes b) No
4.25	If yes, why do you choose AI over bull service?	<ul style="list-style-type: none"> a) AI service is reliable, or it is always available b) AI service is cheap c) To avoid disease transmission d) To get better breed for better productivity e) There is no bull service in the area f) Calves from AI have better price

		g) Other, specify
4.26	Do you prefer bull than AI service?	a) Yes b) No
	If yes, why do you choose bull over AI service	a) Bull service is reliable, or it is always available b) Bull service is cheap c) Bull service is efficient d) More chance of getting female calf e) More chance of strong calf f) Calves from bull have better price g) Other, specify
4.27	Farmers are complaining that most of the calves out of AI are male. Do you agree?	a) Strongly agree b) Agree c) Indifferent d) Disagree e) Strongly disagree
4.28	Farmers are complaining that most of the calves out of AI are weak and can't stand after calving. Do you agree?	a) Strongly agree b) Agree c) Indifferent d) Disagree e) Strongly disagree
4.29	Do you think that if you use AI you can be more profitable than bull service through sale of heifers?	a) Yes b) No
4.30	Average milk production per day per animal: from	
	Local breed	..... lit
	Cross/Exoic breed	..... lit
4.31	Total milk produced from all animals – a day before	..... lit
	For home consumption	..... lit
	For sale	..... lit
	For calves	..... lit
	For other purposes	..... lit
4.32	Does your cow's milk production satisfy you?	a) Yes b) No

Appendix 3. ANOVA table for semen quality analysis

Number of cells assessed					
Source	df	SS	MS	F	Pr>F
Total	587	156492722			
Region	3	1235923	411974	1.55	0.200
Site	3	816298	272099	1.02	0.382
Error	581	154393998	265738		
<i>R² = 0.01</i>			<i>CV = 22.68</i>		
Total Motility (%)					
Total	587	255306			
Region	3	11223	3741.1	9.08	<0.0001
Site	3	4646	1548.9	3.76	0.0108
Error	581	239385	412.0		
<i>R² = 0.06</i>			<i>CV = 53.46</i>		
Progressive Motility (%)					
Total	587	185825			
Region	3	20984	6994.9	25.16	<0.0001
Site	3	3171	1057.1	3.80	0.0102
Error	581	161508	277.9		
<i>R² = 0.13</i>			<i>CV = 60.49</i>		
Normal Morphology (%)					
Total	587	40835			
Region	3	1565	521.9	7.75	<0.0001
Site	3	140	46.9	0.70	0.5542
Error	581	39155	67.4		
<i>R² = 0.04</i>			<i>CV = 10.64</i>		

Appendix 4. Post thaw total motility, progressive motility, normal morphology and number of cells assessed for semen samples

Region & Value Chain	N	Total Motility (Mean±SE) (%)	Progressive motility (Mean± SE) (%)	Normal Morphology (Mean± SE) (%)	Defective Morphology (Mean± SE) (%)	No of cells assessed (Mean± SE)
Amhara	137	37.7±1.8^b	24.4±1.4^c	78.1±0.7^{ab}	21.9±0.7^{bc}	2,324±52.1^{NS}
Production	6	39.7±8.1	20.1±4.2	76.7±3.4	23.3±3.4	2,564±229.1
Storage	30	35.4±3.7	21.9±2.3	77.0±1.3	23.0±1.3	2,349±99.4
Distribution	47	36.2±3.3	23.1±2.4	76.3±1.3	23.7±1.3	2,290±77.5
AIT	54	40.0±2.8	27.5±2.3	80.3±0.9	19.7±0.9	2312±97.0
Oromia	175	43.7±1.6^a	34.9±1.5^a	75.2±0.6^c	24.7±0.7^a	2,228±33.0^{NS}
Production	10	58.2±4.4	47.9±4.4	75.4±3.3	24.5±3.2	2,034±79.3
Storage	29	40.6±3.2	30.9±2.8	76.3±1.4	23.7±1.41	2,363±107.6
Distribution	67	49.4±2.7	40.6±2.5	77.6±0.9	22.2±1.0	2,214±58.1
AIT	69	37.4±2.6	29.3±2.2	72.5±1.0	27.5±1.0	2,213±39.4
SNNP	157	32.1±1.5^c	19.9±1.1^d	79.2±0.6^a	20.8±0.6^c	2,320±48.9^{NS}
Production	8	34.9±8.7	23.5±6.2	74.0±3.9	26.0±3.9	2,442±311.5
Storage	20	34.6±4.8	20.1±37	77.9±2.4	22.1±2.4	2,343±139.4
Distribution	70	32.4±2.1	19.8±1.5	79.5±0.9	20.5±0.9	2,299±68.1
AIT	59	30.5±2.4	19.3±1.8	80.1±0.9	19.9±0.9	2,321±82.2
Tigray	119	37.6±1.9^b	30.5±1.6^b	76.2±0.8^{bc}	23.8±0.8^{ab}	2,229±30.5^{NS}
Production	10	53.8±4.8	46.1±4.2	87.5±1.3	12.5±1.3	2,391±102.3
Storage	10	53.4±8.2	43.5±7.5	75.2±3.0	24.8±3.0	2,388±143.7
Distribution	40	32.5±3.1	26.3±2.7	73.5±1.2	26.5±1.2	2,199±42.0
AIT	59	35.6±2.4	28.4±2.0	76.4±1.2	23.6±1.2	2,19±45.0
Overall	588	38.0±0.9	27.6±0.7	77.2±0.3	22.8±0.3	2,275±21.3

Means with different superscripts in the same column are significantly different ($p < 0.05$)

NS = Non-Significant

Appendix 5. Correlation among variables

	Gender	Age	Educational Status	Training Duration	Experience	Motorbike Availability	Fuel Volume	AI Regular	AI Peak	AI Off	Distance Regular	Distance Peak	SPC	LN2 Opening
Gender	1													
Age	-.311**	1												
Educational Status	-.191*	-.014	1											
Training Duration	.123	.387**	-.062	1										
Experience	-.219**	.667**	.054	.617**	1									
Motorbike Availability	-.296**	.304**	-.007	.224**	.339**	1								
Fuel Volume	.017	.110	-.077	.343**	.088	.202	1							
AI Regular	-.117	.163*	-.119	-.055	.144	.042	.010	1						
AI Peak	-.130	.144	-.015	-.027	.159*	.095	.029	.780**	1					
AI Off	-.123	.165*	-.103	-.007	.219**	-.018	-.071	.779**	.708**	1				
Distance Regular	-.163*	.017	-.029	.121	.070	.131	.589**	.049	.140	.010	1			
Distance Peak	-.316**	.215**	.027	.242**	.252**	.495**	.567**	.062	.136	.022	.467**	1		
SPC	.112	-.031	-.084	.009	-.034	-.029	-.010	-.012	.032	-.023	-.012	-.035	1	
LN2 Opening	-.164*	.058	-.043	-.159*	.002	-.015	-.165	.566**	.583**	.732**	-.015	.030	.004	1

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed)