Cattle Artificial Insemination Service in Developing Countries: Efficiency, Major Challenges and Economic Loss: A Review

Abstract

This review paper summarizes information on the efficiency, major challenges and economic loss of Artificial Insemination (AI) service in cattle breeding in developing countries.Efficiency of AI can be measured by number of services per conception (NSC), conception rate at first insemination, and calving rate (CR). The optimum recommended NSC for profitable dairy cow ranges from 1-1.7. The NSC varies with animal breeds, production systems and AI breeding methods. The NSC and calving rate vary with conventional AI and fixed time AI breeding methods. Likewise, calving rate (CR) is influenced by poor semen quality, poor semen handling procedure, inadequate insemination skill, poor oestrus detection and wrong time of insemination. Nevertheless, wide use of AI service can cause cattle biodiversity loss. Dairy producers incur additional costs when cows fail to conceive at their first AI services. Moreover, challenges of AI comprised of feed scarcity, animal health, climate change, poor AI infrastructure, poor livestock husbandry practices, weak livestock extension systems and incapability of Artificial Insemination Technicians (AITs)are/were…….. This calls designing suitable interventions to improve the efficiency of AI services. AI service centers should be established as per the recommended number of breedable cows and heifers. AI inputs including AITs should be always available at each AI service center. Sexed semen should be used to enhance replacement heifers, and capacity building should be provided to all concerned bodies. Radio, television and printed medias enhance awareness of community cattle breeders…... Due attention is needed in frequent extension support for the success of the AI.

Keywords: Estrus synchronization, time of insemination, calving rate, production system, conventional AI, Fixed time AI, indigenous cattle, crossbred cattle

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1. Introduction

Dairy farming is vulnerable to global warming and climate change. Likewise, Summer months (dry periods) have adverse effects on fertility outcomes, and heat stress results in dairy fertility declinesworsening in tropical climates (Sammad *et al.*, 2020). Livestock production in developing countries is mostly subsistence oriented and fulfills multiple functions that contribute more for food security (Roessler *et al.*, 2008; Dugumaet *al.*, 2010). Cattle farming provides an important food source for the human population. Beef is rich in animal protein which contains 22 grams of protein, 4.5 grams of fat, and 123 kilocalories of energy (Ahmad *et al.*, 2018). Ethiopia is one of the developing countries and hosted large cattle population, however, the contribution of Ethiopian cattle to income and nutrition has remained very limited (FAO, 2007). The variety of factors which resulted in low cattle productivity comprised of low genetic capacity of indigenous cattle, the poor genetic potential for productive traits, substandard feeding, poor health care, and poor management practices (Duguma*et al*., 2012; Ulfina*et al*., 2013). Artificial insemination (AI)was first practiced in dog and the bitch gave birth to three pups by the pioneer scientist Lazzaro Spallanzani(1780) and known as “Father of modern artificial insemination”.E.I. Ivanoff a pioneer Russian investigator undertook a successful AI in cattle and sheep in 1922.In some countries, however, AI resulted in cattle biodiversity loss where 37% of the cattle population in Turkey were crossbreds and 15% of the population were Holstein cattle (Şen *et al*., 2021).

The profitability of dairy cattle herds fundamentally depends on reproductive efficiency (Melese and Wagaye, 2023).Major source of economic loss in dairy and beef industry is reproductive failure (Perry, 2005). Success of dairy cattle farmingdepends on the key element reproductive management, and the lactation always begins with conception followingcalf birth (Singh *et al*., 2017). Reproductive efficiency has been reported to be the product of successful estrus detection and conception rates. The critical factors in artificial reproductive management are estrus detection and insemination of the cow at the correct time in the estrus cycle (Bekana *et al*. 2005). Zebu cattle (*Bosindicus*) show weak oestrus signs for a shorter duration than *Bos taurus* cows (Garcia, 1988; Dawuda, 1989; Fitzpatrick, 1994). There are usually faulty oestrus detections and also there are cases of silent oestrus in the zebu cattle (Tsadik *et al.*, 2008; Jane *et al*., 2009). Zebu cattle (*Bos indicus*) have short length of estrus behavior with high incidence of estrus occurring during dark hours (Million *et al*., 2006). Estrus detection in Zebu cattle breeds is difficult owing to poor estrus expression (Mukassa-Mugerwa*et al*., 1989). The quality of frozen semen, breeder knowledge in estrus detection, body condition score of beef cattle and the skills of the inseminator influenceAI(BIB,2011; Diwyanto,2012).*Percentage of animals detected in standing estrus and inseminated, inseminator efficiency, fertility level of the herd, and fertility level of the semen are determinants of equation of reproduction* (Perry and Smith, 2015).

The genetic progress and reproductive performance of farm animal genetic resources is accelerated through the application of reproductive technologies (Gizaw *et al*., 2016). Robust methods for dairy cattle breeding include AI and selective bull mating which are globally important to enhance productivity and realize rapid genetic gains (Mwanga *et al*., 2019).AI is one of the most important reproductive techniques ever devised for the genetic improvement of farm animals (Bearden *et al.*, 2004). Globally, only 5% of beef cows are served by AI as opposed to 75% of dairy cows (Vishwanath, 2003). Crossbreeding of indigenous cattle with highly productive exotic cattle have been considered a realistic solution to improve the low productivity of indigenous cattle (Tadesse, 2002). For example, 55.6% of households in Kenya, 30.1% in Rwanda and 16.4% in Uganda owned crossbred of Holstein-Friesian and was the most widely kept exotic breed (EADD, 2011).AI is a reproductive biotechnology that has successfully improved the genetic quality of animals. The implementation of AI in smallholder farmers is much more economical because it can reduce the cost of maintaining breeding males, prevent infectious diseases and facilitates a more accurate recording process (Susilawati, 2013). AI success depends on good animal husbandry and effective disease control measures (Duncanson, 1977). Delivery of AI service in developing countries, for example in Ethiopia followed a seasonal pattern (Melesse *et al*., 2020) which is influenced by the availability of feed where the livestock production system in developing countries is predominantly extensive system(Management Entity, 2021).

Widespread use of AI and the use of high quality semen from genetically superior bulls ensure genetic progress in animals (Dixit *et al*., 2016). Most developed countries generally have AI success rates over 80% (Magyar, 1991) which is higher than the recommendation (75%) of FAO (FAO, 2008).AI is widely practiced in developing countries to enhance cattle genetic quality and productivity. About 50% AI success ratewas reported in Bangladesh and Ethiopia which are low income countries of the globe (Uddin *et al*., 2014; Haque *et al.*, 2015; Ashebir*et al.*, 2016) whilst success rates of less than 50% in Senegal and 70% in Burkina Faso were reported byOuedraogo (2012) cited in the work of (Cabral, 2016).Developing countries should first evaluate the efficiency, major challenges and economic loss of AI service in cattle breeding to identify the gaps in breeding policy and strategy and other technical issues. AI as a reproductive biotechnology and one option of genetic improvement should be promoted and adopted greatly including by the smallholder farmers. However, there is scant summarized information on the efficiency of AI service in cattle breeding in developing countries. Therefore, the objective of this review is to present a synthesized information on the efficiency, major challenges and economic loss of AI service in cattle breeding in developing countries.

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2. Efficiency of Artificial Insemination in cattle breeding in developingcountries

2.1. Number of services per conception (NSC)

Number of services per conception (NSC) as an indicator of reproductive efficiency has been defined as the number of services required for a successful conception (Albero, 1993; HaileMariam*et al*., 1993; Negussie *et al*., 1998; Shiferaw *et al*., 2003). The optimum recommended NSC for profitable dairy cow ranges from 1-1.7 (Evelyn, 2001). However,Toelihere (2005) reported that the normal NSC values range from 1.6-2.0. The lower the value of NSC, the higher the fertility of cows and heifers.

The poor mean NSC of different scholars in different areas and breeds of Ethiopia under conventional AI (CoAI) breeding include Niraj*et al*. (2017) report in Zebu x Holstein Friesian (1.8), Desalegn (2008) report in different genotypes (2.47, 1.91, 1.78 and 1.7), Jemal *et al*. (2016) report in dairy cows and heifers (1.95). Manzi *et al*. (2019) reported a two-time period study in Rwanda in different genotypes (Ankole cows, Ankole x HF, Ankole x Jersey, Ankole x Sahiwal, A x Jersy x Sahiwal and Ankole x Sahiwal x Jersey) kept under extensive system indicated an overall optimum NSC (1.23 for the period 1999-2004 and 1.18 for the period 2014-2017). It was also noted that many authors reported NSC under fixed time AI (FTAI) consisting of Debir *et al*. (2016) report in local cows (1.85), Duro (2022) report in local dairy cow (1.7), Bainesagn (2015) reports in local cows (1.71) and crossbred cows (1.78), Edao, (2022) report in local cows (1.7).

2.2. Conception rate at first insemination (CR^1)

Conception rate at first insemination (CR^1) is a very important index that measures the ability of the cow to conceive after the first service of AI or natural service (Ganchou, *et al*., 2005). In most African countries, poor semen quality, poor semen handling procedure, inadequate insemination skill, poor oestrus detection and wrong time of insemination resulted in low CR^1 (Tegegne *et al*., 1995). Moreover, there is a mutated allele (FXI) in cows, humans and dogs, hence, the mutated allele may lead to repeated breeding syndrome in the cow and cause significant financial losses on dairy farms (Akyuz *et al*., 2012).Müller-Sepúlveda *et al*. (2020) in Chile reported a higher CR^1 (75.6%) in dairy and beef cows. Urzúa*et al*. (2017) in Mexico also reported CR^1 on human chorionic gonadotropin (hCG) five-day post-insemination treated group

(47.5%) and control group (37.4%) of Holstein cows, and overall CR^1 (48.4%) was reported. There were many actions done to improve the CR^1 of dairy cows in different countries of the globe, for example, Hamid and Kamruzzaman (2017) in Bangladesh reported on gonadotropin releasing hormone (GnRH) of one hour before, during or after AI treated group (71.1%) and control group (55.6%) of Holstein Friesian and local crossbred cows. Therefore, GnRH treated dairy cows revealed higher CR^1 than the control group. Potdar *et al*. (2016) reported in India that cows and heifers breed, sire breed, heat stage, AI number and lactation number affected conception rate. Moreover, Patel *et al*. (2017) reported that conception rate due to AI in India is very low.

Conception rate was greatly affected by cattle breeds which were kept under similar production system (Potdar *et al*., 2016). Many authors reported CR^1 under CoAI breeding; Abdula and Bilal (2022) report in local Zebu cows (37.4%), Hamid (2012) report in Zebu cows (24%), Desalegn (2008) report in different genotypes (34.29%, 33.33%, 7.14% and 20.31%), Kindalem (2019) report in indigenous cows (23.36%), Ashebir*et al*. (2016) report in local and crossbred cows (17.64% and 30.12%), Jemal *et al*. (2016) report in dairy cows and heifers (49.3%). Ejigayehu (2018) reports in Boran cows (28.6%) and HF x Boran crossbred cows (31.3%), Tegegn and Zelalem (2017) also reported CR^1(24.69%) under FTAI breeding in Zebu cows.

2.3. Calving rate (CR)

The most appropriate measure of fertility is calving rate (CR) which is defined as the number of calves born per 100 services (Mohamed, 2004). The CR is the inseminators success rate which is the percentage of total number of calves born due to first inseminations divided to total number of first inseminations (Sahin *et al*., 2021). It was noted in CoAI breeding a CR of 22% in indigenous cows (Kindalem, 2019). It was also reported that in FTAI breeding a CR of 10.67% in dairy cows (Dereje, 2018) and CR of 13.58% in Zebu cows (Tegegn and Zelalem, 2017). However, the success rate of AI (CR) in intensively managed dairy cows in Turkey was very high (41.36%) and the animals were bred by CoAI(Sahin*et al*., 2021).

Table 1Efficiency of Artificial Insemination on CoAI in developing countries (Please split your tables and cascade as sub topic)

Country	Cattle breed/type	Production system	NSC (mean)	CR^1 (%)	CR (%)	Author(s)

Bangladesh	Crossbred	Not specified	-	95.6	-	Bahar *et al*., 2024
Bangladesh	Local	Not specified	-	96.2	-	Bahar *et al*., 2024
Algeria	Brown Swiss	Not specified	-	73.2	-	Mouffok *et al*., 2019
Algeria	Montbeliard	Not specified	-	67.8	-	Mouffok *et al*., 2019
Algeria	Holstein	Not specified	-	63.7	-	Mouffok *et al*., 2019
Algeria	Pie Rouge	Not specified	-	59.6	-	Mouffok *et al*., 2019
Algeria	Fleckvieh	Not specified	-	53.0	-	Mouffok *et al*., 2019
Algeria	Overall	Not specified	1.3	64.0	-	Mouffok *et al*., 2019
Ethiopia	Simada cows	Extensive system	1.1	-	-	Getie*et al*., 2015
Ethiopia	HF	Intensive system	2.1	-	-	Alewya, 2014
Ethiopia	F_1 HF x Boran cows	Intensive system	2.1	-	-	Yohannes *et al*., 2017
Kenya	Dairy cows	Extensive system	1.9	39.0	-	Kinyua, 2016
Zambia	Friesian x Zebu cross (65%)	Extensive (69%) and intensive (8%)	1.8	48.0	-	Mwambilwa*et al*., 2013
India	Dangi heifers and cows	Semi-intensive	-	49.2	-	Potdar *et al*., 2016
India	HF crossbred	Semi-intensive	-	41.4	-	Potdar *et al*., 2016
India	Jersey crossbred	Semi-intensive	-	43.6	-	Potdar *et al*., 2016
India	Khillar	Semi-intensive	-	46.9	-	Potdar *et al*., 2016
India	ND cattle	Semi-intensive	-	45.9	-	Potdar *et al*., 2016
Rwanda	Ankole cows	Extensive system	-	71.0	-	Manzi *et al*., 2019

Rwanda	Ankole x HF	Extensive system	-	78.0	-	Manzi *et al.*, 2019
Rwanda	Ankole x Jersey	Extensive system	-	73.0	-	Manzi *et al.*, 2019
Rwanda	Ankole x Sahiwal	Extensive system	-	67.0	-	Manzi *et al.*, 2019
Rwanda	A x Jersy x Sahiwal	Extensive system	-	75.0	-	Manzi *et al.*, 2019
Rwanda	Ankole x Sahiwal x Jersey	Extensive system	-	71.0	-	Manzi *et al.*, 2019
Bangladesh	50% HF × 50% Local	Not specified	1.3	-	-	Azad *et al*., 2023
Bangladesh	62.5% HF × 37.5 Local	Not specified	1.3	-	-	Azad *et al*., 2023
Bangladesh	75% HF × 25% Local	Not specified	1.4	-	-	Azad *et al*., 2023
Bangladesh	>75% HF × <25% Local	Not specified	1.4	-	-	Azad *et al*., 2023
Manokwari Regency	Beef cattle	Not specified	1.8	-	47.1	Haryanto *et al*., 2019
Indonesia	Beef cattle	Intensive system	1.63	65.15	-	Azizah *et al*., 2022
Bhutan	Dairy cows	Not specified	1.8	-	-	Wangchuk *et al.*, 2022
Ethiopia	Dairy cows	Not specified	2.6	62.0	51.0	Melesse *et al.*, 2020
Bangladesh	Local cows	Not specified	1.4	73.0	-	Razi *et al.*, 2010
Bangladesh	Sahiwal X local cross	Not specified	1.5	65.0	-	Razi *et al.*, 2010
Bangladesh	Friesian cross X local	Not specified	1.8	60.0	-	Razi *et al.*, 2010
Uganda	Dairy breed	Intensive system	1.7	-	-	Mugisha *et al.*, 2014
Uganda	Nondairy breed	Intensive system	1.3	-	-	Mugisha *et al.*, 2014
Ethiopia	Local dairy cows	Extensive and intensive systems	-	72.9	-	Yeshitila*et al.*, 2019

Ethiopia	Local and crossbred cows	Extensive system	1.95	49.3	-	Jemal *et al*., 2016
Ethiopia	Local and crossbred cows	Extensive and intensive system	-	47.8	-	Woldu *et al.*, 2011
Ethiopia	Crossbred dairy cows	Extensive and intensive systems	-	75.5	-	Yeshitila*et al*., 2019
Ethiopia	Local dairy cows	Extensive and intensive systems	-	53.5	-	Muhammed *et al*., 2021
Ethiopia	Crossbred cows	Extensive and intensive systems	-	69.1	-	Muhammed *et al*., 2021
Ethiopia	Local Zebu cows	Extensive system	-	48.9	-	Abdula and Bilal, 2022
Ethiopia	Local Zebu cows	Extensive system	-	37.4	-	Abdula and Bilal, 2022
Ethiopia	Zebu x Holstein-Friesian	Farmer's management system	1.8	-	-	Niraj *et al*. 2017
Ethiopia	HF x Zebu, Jersey x Zebu cows	Intensive system	-	62.5	-	Abdula and Bilal, 2022
Ethiopia	HF x Zebu, Jersey x Zebu cows	Intensive system	-	41.5	-	Abdula and Bilal, 2022
Ethiopia	Local cows	Mixed crop-livestock production	1.14	-	-	Tadesse *et al*., 2022
Ethiopia	Crossbred cows	Mixed crop-livestock production	1.15	-	-	Tadesse *et al*., 2022
Ethiopia	Local and crossbred cows	Mixed crop-livestock production	-	51.03	-	Tadesse *et al*., 2022
Ethiopia	Indigenous cattle	Mixed crop-livestock production system		23.36	22	Kindalem, 2019
Ethiopia	82.3% crossbred dairy cows	Not specified	-	64.8	-	Belete *et al*. (2018)
Ethiopia	Fogera x Holstein Friesian	Not specified	1.56	-	-	Sena *et al*. 2014
Ethiopia	>80% crossbred cows and <20% local cows	Not specified	-	**17.64**	-	Ashebir*et al*., 2016
Ethiopia	>80% crossbred cows and <20% local cows	Not specified	-	**30.1**	-	Ashebir*et al*., 2016

Ethiopia	>80% crossbred cows and <20% local cows	Not specified	-	**48.5**	-	Ashebir*et al.*, 2016
Ethiopia	HF x Zebu crossbred	Urban and Peri-urban	1.7	64.6	54.8	Alemshet*et al.* (2017)
Tanzania	Ayrshire crossbred and Friesian crossbred	Smallholder farms	2.6	43.6	-	Mwaipopo and Mbaga, 2022
Tanzania	Ayrshire crossbred	Smallholder farms	1.1	22.5	-	Mwaipopo and Mbaga, 2022
Tanzania	Friesian crossbred	Smallholder farms	1.8	77.5	-	Mwaipopo and Mbaga, 2022
Tanzania	Ayrshire, Friesian, Boran, F_1Ayrshire	Large farms	1.4	72.5	-	Mwaipopo and Mbaga, 2022
Tanzania	Ayrshire	Large farms	1.6	61.6	-	Mwaipopo and Mbaga, 2022
Tanzania	Friesian	Large farms	1.5		-	Mwaipopo and Mbaga, 2022
Tanzania	Boran	Large farms	1.2	81.4	-	Mwaipopo and Mbaga, 2022
Tanzania	F1 Ayrshire x Boran cross	Large farms	1.2	90.3	-	Mwaipopo and Mbaga, 2022
Tanzania	F1 Friesian	Large farms	1.4	69.7	-	Mwaipopo and Mbaga, 2022
Bangladesh	Friesian crossbred	Not specified	1.6	57.1	-	Khan *et al*, 2015
Bangladesh	Sahiwal crossbred	Not specified	1.8	52.6	-	Khan *et al*, 2015
Bangladesh	Local (Zebu) cows	Not specified	2.3	63.8	-	Khan *et al*, 2015
Bangladesh	Not specified	Not specified	1.8	56.0	-	Hoque *et al*., 2003
Bangladesh	HF (0.5) X Local (0.5) cows	Intensive system	2.5	63.9	-	Bilkis *et al*., 2016
Bangladesh	HF (0.75) X Local (0.25) cows	Intensive system	1.9	66.4	-	Bilkis *et al*., 2016
Bangladesh	HF (0.5) X Sahiwal (0.5) cows	Intensive system	1.8	63.4	-	Bilkis *et al*., 2016

Bangladesh	HF (0.5) X Sahiwal (0.25) X Local (0.25) cows	Intensive system	1.6	61.6	-	Bilkis *et al*., 2016
Ethiopia	Begait, Arado and HF crossbred cows	Extensive system	4.8	20.4	20.5	Mekonnen & Berhe, 2023
Canada	Holstein heifers	Intensive system	-	76.0	-	Ambrose *et al*., 2010
Bangladesh	Local cows	Not specified	-	73.9	-	Howlader *et al*., 2019
Bangladesh	Friesian X local cows	Not specified	-	70.0	-	Howlader *et al*., 2019
Ethiopia	Crossbred dairy cows	Not specified	1.5	-	-	Tafari, 2016
Ethiopia	Dairy cows	Intensive (64.8%) and extensive (35.2%)	1.4	40.9	-	Lemma and Yilma, 2015
Pohuwato Regency	Beef cattle	Not specified	1.4	66.7	-	Mukhtar *et al*., 2019
Ethiopia	HF	Intensive system	1.9	-	-	Wondossen*et al*., 2018
Ethiopia	Local dairy cows	Not specified	1.7	-	-	Abera and Ulfina, 2022
Ethiopia	Crossbred dairy cows	Not specified	1.7	-	-	Abera and Ulfina, 2022
Ethiopia	Local cows	Extensive system	2.2	-	-	Mohammed and Getachew. 2021
Ethiopia	F1	Extensive system	2.0	-	-	Mohammed and Getachew. 2021
Ethiopia	F2	Extensive system	1.6	-	-	Mohammed and Getachew. 2021
India	Local cows	Extensive system	-	49.1	-	Bansal *et al*., 2019
India	HF X Local crossbreds	Extensive system	-	49.6	-	Bansal *et al*., 2019
India	Jersey X local crossbreds	Extensive system	-	51.9	-	Bansal *et al*., 2019
India	Non-descript cows	Extensive system	-	51.0	-	Bansal *et al*., 2019

AI= Artificial Insemination, CoAI=Conventional AI, FTAI=Fixed Time AI, NSC=Number of Services per Conception, CR^1=Conception Rate at first insemination, CR=Calving Rate, Holstein Friesian (HF)

Table 2Efficiency of Artificial Insemination on FTAI in developing countries

Country	Cattle breed/type	Production system	NSC (mean)	CR[1] (%)	CR (%)	Author(s)
Kenya 2016	Dairy cattle	Not specified	-	33.6	-	Mwai*et al*., 2020
Kenya 2017	Dairy cattle	Not specified	-	43.3	-	Mwai*et al*., 2020
Kenya 2018	Dairy cattle	Not specified	-	43.8	-	Mwai*et al*., 2020
Kenya 2019	Dairy cattle	Not specified	-	59.9	-	Mwai*et al*., 2020
Ethiopia	Local cows	Extensive system	1.85	54	-	Debir *et al*., 2016
Ethiopia	Crossbred cows	Extensive system	1.44	69.6	-	Debir *et al*., 2016
Ethiopia	Dairy cattle	Extensive system	-	34.61	10.67	Dereje, 2018
Ethiopia	Boran cows	Intensive system	-	28.6	-	Ejigayehu, 2018
Ethiopia	HF x Boran crossbred cows	Intensive system	-	31.3	-	Ejigayehu, 2018
Ethiopia	Local cows	Not specified	1.7	59.5	-	Edao, 2022
Ethiopia	Crossbred cows	Not specified	1.5	65.0	-	Edao, 2022
Ethiopia	Local cows	Not specified	-	40.8	-	Haile *et al*., 2023
Ethiopia	Crossbred cows	Not specified	-	64.8	-	Haile *et al*., 2023
Ethiopia	Boran cows	Semi-intensive	-	70.6	-	Alebachew, 2018
Ethiopia	Zebu x Holstein cross	Semi-intensive	-	50	-	Alebachew, 2018
Ethiopia	Local cows	Extensive system	2.2	45.7	-	Desalegn and Eskindir, 2023
Ethiopia	Crossbred cows	Extensive system	1.4	70.5	-	Desalegn and Eskindir, 2023
Ethiopia	Local cows	Extensive system	2.4	42.3	-	Desalegn and Eskindir, 2023

Ethiopia	Crossbred cows	Extensive system	1.7	60.2	-	Desalegn and Eskindir, 2023
Ethiopia	Dairy cows	Mixed crop-livestock	1.8	-	-	Hamza, 2023
Sudan	Friesian X Kenana	Intensive system	-	40.0	-	Abdelwahid H.H.*et al*., 2019
Nigeria	Bunaji Cows	Intensive system	-	12.5	-	Azubuike *et al*., 2019
Nigeria	Bunaji Cows	Intensive system	-	0	-	Azubuike *et al*., 2019
Canada	Holstein heifers	Intensive system	-	72.0	-	Ambrose *et al*., 2010
Canada	Beef cows (Ranch)	Extensive system (winter)	-	97.5	92.5	Lardner *et al*., 2015
Bangladesh	Indigenous heifers	Mixed farming system	1.4	50.3	-	Shankar *et al*., 2017
Bangladesh	Indigenous cows	Mixed farming system	1.3	76.9	-	Shankar *et al*., 2017
Malaysia	Brangus cows	Intensive system	-	18.0	-	Malik *et al*., 2012
Ethiopia	Local and HF crossbred cows	Not specified	2.4	20.5	-	Sharew*et al*., 2021

AI = Artificial Insemination, CoAI= Conventional AI, FTAI = Fixed Time AI, NSC = Number of Services per Conception, CR^1 = Conception Rate at first insemination, CR = Calving Rate

3. Major challenges and economic loss of AI in cattle breeding in developing countries

The main objective of AI is to improve the genetic quality by utilizing the semen of superior beef cattle (Susilawati, 2011). On the contrary, AI can result in livestock biodiversity loss due to wide use of single genotype in different areas for a long period of time (Rege *et al*., 2006). Persistent drought, outbreak of livestock diseases and parasites, climate change, inadequate extension service, high transportation costs, shortage of qualified ranch managers, inadequate transport, inadequate staff accommodation, lack of maintenance of fire breaks and perimeter fence at the AI centers, and trekking cows over very long distances to the AI centers were the major challenges of AI service in Botswana (Moreki *et al*., 2019). Increased days open and decreased conception rates from year to year resulted in declining reproductive performance of dairy cows

(Aynalem *et al*., 2011). A number of technical, financial, infrastructural, managerial and heat detection hindered the success rate of AI in Ethiopia (Shiferaw *et al*., 2003; Nuraddis*et al*., 2014). Most artificial insemination technicians (AITs) in Ethiopia did not master the semen thawing process properly which led to some unsuccessful inseminations. The AITs were trained to thaw the semen to 32^{o}C-35^{o}C for a minimum of 40 seconds by immersing the straw in warm water. All of the interviewed AITs confirmed that the thawing level was quite a useful technique to them to follow (Ndambi *et al*. 2017).

Reproductive management tools such as estrus synchronization (ES) involves induction of estrous in a group of females to breed relatively in around the same time (Schafer *et al*., 2007; Rick, 2013). ES and artificial insemination (AI) are influential technologies for cattle producers in terms of genetic improvement, reproductive management and performance (Jinks *et al*., 2013). Pregnancy rate (PR) is the product of heat detection rate and conception rate (CR) which is the opportunity for a cow to become pregnant during the first 21 days of the breeding season (Ferguson and Galligan, 1993). Failure of cows to become pregnant and the need for repeated AI services are usually causes of economic losses of the cattle farmers (Stevenson *et al*., 1990). A study revealed that a dairy farmer spent an additional cost per cow per day an average of 473.70 ETB in cows that did not conceive by first AI, whereas cows that failed to conceive at their first AI but conceived by second and third service spent extra costs of 21,665.30 ETB for reproductive treatment and other management (Tadesse *et al.*, 2022). Moreover, Muhammed *et al*. (2021) reported that a dairy farmer spent an additional cost per cow per day an average of 440.00 ETB in cows that did not conceive by first AIservicedue tonutrition, milk loss, and labor until conception.

AI was rejected by some farmers of different parts of Ethiopia due to the birth of dominant number of male calves as compared to females. For example, Kindalem (2019) reported 77.27% of male calf births in JanamoraWereda of North Gondar, Ethiopia. Similarly, Merga and Tariku (2015) found report 50% of male calf births in and around of Gondar, Ethiopia. Furthermore, there were no proper recording of AI service in different developing countries including Ethiopia (11.3%), Kenya (72.5%), Uganda (76.0%) and Tanzania (87.5%)which hinder quick genetic improvement (Mwanga *et al*., 2019).There was poor AI service record keeping in Ethiopia as compared to Kenya, Uganda and Tanzania.

Comment [u7]: contradictive ideas

*Table 3**Major AI challenges of cattle breeding kept under different management options in Ethiopia**(Please split your tables and cascade as sub topic)***

Challenges	**Prevalence (%)**	**Cattle breed/type**	**Production system**	**Author(s)**
Repeat breeding	20.2	Dairy cows	Intensive and semi-intensive	Regassa and Ashebir, 2016
Inadequate support of concerned bodies	39.6	Dairy cows	Not specified	Tekalign and Amaru, 2019
Unskilled AITs	21.1	Dairy cows	Not specified	Tekalign and Amaru, 2019
Lack of awareness about AI	39.3	Dairy cows	Not specified	Tekalign and Amaru, 2019
Unskilled AITs	14.6	Local and HF crossbred	Not specified	Share*wet al.*, 2021
Heat detection problems	13.4	Local and HF crossbred	Not specified	Share*wet al.*, 2021
Long distance travel to AI service center	11.6	Local and HF crossbred	Not specified	Share*wet al.*, 2021
Long distance travel to AI service center	25.5	Local and crossbred	Extensive (5.5%), semi-intensive (74.5%) and intensive (20.0%)	Haben *et al.*, 2020
Lack of awareness about AI	20.0	Local and crossbred	Extensive (5.5%), semi-intensive (74.5%) and intensive (20.0%)	Haben *et al.*, 2020
Time of insemination	28.2	Local and crossbred	Extensive (5.5%), semi-intensive (74.5%) and intensive (20.0%)	Haben *et al.*, 2020
Heat detection problems	26.4	Local and crossbred	Extensive (5.5%), semi-intensive (74.5%) and intensive (20.0%)	Haben *et al.*, 2020
Unskilled AITs	21.8	Local and crossbred	Extensive (5.5%), semi-intensive (74.5%) and intensive (20.0%)	Haben *et al.*, 2020

Management problems	14.5	Local and crossbred	Extensive (5.5%), semi-intensive (74.5%) and intensive (20.0%)	Haben *et al.*, 2020
Time of insemination	20.2	82.3% crossbred dairy cows	Not specified	Belete *et al.* (2018)
Management problems	20	82.3% crossbred dairy cows	Not specified	Belete *et al.* (2018)
Hygiene problems	17.5	82.3% crossbred dairy cows	Not specified	Belete *et al.* (2018)
Heat detection problems	12.2	82.3% crossbred dairy cows	Not specified	Belete *et al.* (2018)
No regular and consistent AI service	98.7	Dairy cattle	Mixed crop-livestock production	Ephrem (2019)
No mobile AI service	94.5	Dairy cattle	Mixed crop-livestock production	Ephrem (2019)
No AI service on weekends	93	Dairy cattle	Mixed crop-livestock production	Ephrem (2019)
Shortage of AI inputs	71.1	Dairy cattle	Mixed crop-livestock production	Ephrem (2019)
Inadequacy of AITs	91.7	Dairy cattle	Mixed crop-livestock production	Ephrem (2019)
No private AI service	100	Dairy cattle	Mixed crop-livestock production	Ephrem (2019)
Lack of training for awareness creation	91.9	Dairy cattle	Mixed crop-livestock production	Ephrem (2019)
Late insemination by farmers	33.3	Dairy cattle	Mixed crop-livestock production	Ephrem (2019)
Lack of awareness about AI	22.2	Dairy cattle	Intensive (9.6% AI failure), Extensive (52.0% AI failure) and Semi-intensive (38.4%)	Mohammed *et al.* (2015)
Time of insemination	21.6	Dairy cattle	Intensive (9.6% AI failure), Extensive (52.0% AI failure) and Semi-intensive (38.4%)	Mohammed *et al.* (2015)

Lack of AIT	18	Dairy cattle	Intensive (9.6% AI failure), Extensive (52.0% AI failure) and Semi-intensive (38.4%)	Mohammed *et al.* (2015)
Management problem	8.4	Dairy cattle	Intensive (9.6% AI failure), Extensive (52.0% AI failure) and Semi-intensive (38.4%)	Mohammed *et al.* (2015)
Heat detection problems	8.7	Dairy cattle	Intensive (9.6% AI failure), Extensive (52.0% AI failure) and Semi-intensive (38.4%)	Mohammed *et al.* (2015)
No AI service on weekends and holiday	46.0	Dairy cattle (local and cross)	Not specified	Zerihun *et al.* (2013)
Shortage of AITs	41.0	Dairy cattle (local and cross)	Not specified	Zerihun *et al.* (2013)
Shortage of AI inputs	34.0	Dairy cattle (local and cross)	Not specified	Zerihun *et al.* (2013)
Long distance travel to AI service center	46.2	Dairy cattle (local and cross)	Not specified	Zerihun *et al.* (2013)
Unskilled AITs	33.4	Dairy cattle (local and cross)	Not specified	Zerihun *et al.* (2013)
No AI service on weekends and holiday	32.2	Dairy cattle	Not specified	Alazar *et al.* (2015)
Shortage of AITs	44.8	Dairy cattle	Not specified	Alazar *et al.* (2015)
Shortage of AI inputs	25.0	Dairy cattle	Not specified	Alazar *et al.* (2015)
No AI service on weekends and holiday	51.2	Dairy cattle	Extensive system	Riyad *et al.* (2017)
Shortage of AITs	18.2	Dairy cattle	Extensive system	Riyad *et al.* (2017)

Shortage of AI inputs	30.6	Dairy cattle	Extensive system	Riyad *et al.* (2017)
No AI service on weekends and holiday	55.3	Local zebu and HF x Zebu crossbred	Mixed crop-livestock system	Gizaw and Dima, 2016
Long distance travel to AI service center	42.9	Local zebu and HF x Zebu crossbred	Mixed crop-livestock system	Gizaw and Dima, 2016
Long distance travel to AI service center	57.1	Local zebu and HF x Zebu crossbred	Mixed crop-livestock system	Gizaw and Dima, 2016
Shortage of AITs	46.3	Local zebu and HF x Zebu crossbred	Mixed crop-livestock system	Gizaw and Dima, 2016
Shortage of AITs	53.7	Local zebu and HF x Zebu crossbred	Mixed crop-livestock system	Gizaw and Dima, 2016
High charge of AI service	62.9	Local zebu and HF x Zebu crossbred	Mixed crop-livestock system	Gizaw and Dima, 2016
High charge of AI service	37.9	Local zebu and HF x Zebu crossbred	Mixed crop-livestock system	Gizaw and Dima, 2016
Shortage of AI inputs	77.1	Local zebu and HF x Zebu crossbred	Mixed crop-livestock system	Gizaw and Dima, 2016
Shortage of AI inputs	22.9	Local zebu and HF x Zebu crossbred	Mixed crop-livestock system	Gizaw and Dima, 2016
Repeat breeding	79.7	Local zebu and HF x Zebu	Mixed crop-livestock system	Gizaw and Dima, 2016

		crossbred		
Repeat breeding	69.5	Local zebu and HF x Zebu crossbred	Mixed crop-livestock system	Gizaw and Dima, 2016
Feed shortage	93.3	Dairy cows	Urban dairy farming	Engidawork, 2018
Heat detection problem	81.7	Dairy cows	Urban dairy farming	Engidawork, 2018
High charge of AI service	71.7	Dairy cows	Urban dairy farming	Engidawork, 2018
Long distance travel to AI service center	21.7	Dairy cows	Urban dairy farming	Engidawork, 2018
Husbandry problem	13.3	Dairy cows	Urban dairy farming	Engidawork, 2018
No AI service on weekends and holiday	24.6	Dairy cows	Mixed crop-livestock system	Nuraddis*et al.* (2014)
Shortage of AITs	27.0	Dairy cows	Mixed crop-livestock system	Nuraddis*et al.* (2014)
Shortage of AI inputs	7.4	Dairy cows	Mixed crop-livestock system	Nuraddis*et al.* (2014)
No regular provision of AI	90.4	Dairy cows	Not specified	Bainesagn, 2015
No AI service on weekends and holiday	94.9	Dairy cows	Not specified	Bainesagn, 2015
AI service interruption	53.0	Dairy cows	Extensive and semi intensive production systems	Yohanis and Tilahun, 2018
No AI service on weekends and holiday	18.8	Dairy cows	Extensive and semi intensive production systems	Yohanis and Tilahun, 2018
Long distance travel to AI service center	12.2	Dairy cows	Extensive and semi intensive production systems	Yohanis and Tilahun, 2018
Shortage of AI inputs	29.8	Dairy cows	Extensive and semi intensive production systems	Yohanis and Tilahun, 2018
Inadequacy of AITs	10.5	Dairy cows	Extensive and semi intensive production systems	Yohanis and Tilahun, 2018

Heat detection problem	8.8	Dairy cows	Extensive and semi intensive production systems	Yohanis and Tilahun, 2018
Inadequate support of concerned bodies	19.3	Dairy cows	Extensive and semi intensive production systems	Yohanis and Tilahun, 2018
Heat detection problem	28.0	>80% crossbred cows and <20% local cows	Not specified	Ashebir*et al*., 2016
Lack of awareness	18.0	>80% crossbred cows and <20% local cows	Not specified	Ashebir*et al*., 2016
Lack of infrastructures	16.0	>80% crossbred cows and <20% local cows	Not specified	Ashebir*et al*., 2016
Management problem	14.0	>80% crossbred cows and <20% local cows	Not specified	Ashebir*et al*., 2016
Lack of incentives	11.0	>80% crossbred cows and <20% local cows	Not specified	Ashebir*et al*., 2016
Shortage of AI inputs	21.4	Local and crossbred cows	Extensive and intensive production systems	Sisay *et al*., 2017
Inadequacy of AIT	28.6	Local and crossbred cows	Extensive and intensive production systems	Sisay *et al*., 2017
Heat detection problem	7.1	Local and crossbred cows	Extensive and intensive production systems	Sisay *et al*., 2017

Inadequate support of concerned bodies	14.3	Local and crossbred cows	Extensive and intensive production systems	Sisay *et al*., 2017
AI service interruption	15	Local and crossbred cows	Extensive and intensive production systems	Sisay *et al*., 2017
Heat detection problems	21.1	Dairy cows	Mixed crop-livestock	Hamza, 2023
Inadequate support of concerned bodies	15.7	Dairy cows	Mixed crop-livestock	Hamza, 2023
Shortage of AI inputs	14.2	Dairy cows	Mixed crop-livestock	Hamza, 2023
Shortage of AITs	18.1	Dairy cows	Mixed crop-livestock	Hamza, 2023
AI service interruption	55.9	Dairy cows	Mixed crop-livestock	Hamza, 2023
Unskilled AITs	51.7	Local cows and HF x local crossbreds	Urban and Peri-urban systems	Birhanemeskel and Kide, 2018
Shortage of AIT	35.0	Local cows and HF x local crossbreds	Urban and Peri-urban systems	Birhanemeskel and Kide, 2018
No AI service on weekends and holidays	36.7	Local cows and HF x local crossbreds	Urban and Peri-urban systems	Birhanemeskel and Kide, 2018
No training on AI service and heat detection	54.1	Local cows and HF x local crossbreds	Urban and Peri-urban systems	Birhanemeskel and Kide, 2018
Repeat breeding	28.3	Local and crossbred cows	Not specified	Edao, 2022
Heat detection problem	26.7	Local and crossbred cows	Not specified	Edao, 2022
AI service not available on time	23.3	Local and crossbred cows	Not specified	Edao, 2022
Lack of awareness	21.7	Local and crossbred cows	Not specified	Edao, 2022

Lack of awareness in the community	20.6	Indigenous and crossbred cows	Extensive (88.4%), intensive (7.1%) and semi-intensive (4.5%)	Mekonnen and Berhe, 2020
Animal management problem	18.5	Indigenous and crossbred cows	Extensive (88.4%), intensive (7.1%) and semi-intensive (4.5%)	Mekonnen and Berhe, 2020
Unskilled AITs	16.0	Indigenous and crossbred cows	Extensive (88.4%), intensive (7.1%) and semi-intensive (4.5%)	Mekonnen and Berhe, 2020
Inadequacy of AITs	14.7	Indigenous and crossbred cows	Extensive (88.4%), intensive (7.1%) and semi-intensive (4.5%)	Mekonnen and Berhe, 2020
Repeat breeding	13.5	Indigenous and crossbred cows	Extensive system	Jemal *et al*., 2016
No regular and consistent AI service	91.6	Dairy cows	Extensive system	Alilo, 2022
Shortage of AI inputs	86.7	Dairy cows	Extensive system	Alilo, 2022
Long distance travel to AI service center	83.4	Dairy cows	Extensive system	Alilo, 2022
Inadequacy of AITs	81.6	Dairy cows	Extensive system	Alilo, 2022
Heat detection problem	80.0	Dairy cows	Extensive system	Alilo, 2022
Feed shortage	76.7	Dairy cows	Extensive system	Alilo, 2022
Heat detection problem	38.3	Local and crossbreds	Extensive system	Mohammed and Getachew. 2021
Semen quality problem	23.3	Local and crossbreds	Extensive system	Mohammed and Getachew. 2021
Management problem	15.0	Local and crossbreds	Extensive system	Mohammed and Getachew. 2021

AI= Artificial Insemination, AITs= Artificial Insemination Technicians

Table 4 ***Major AI challenges of cattle breeding kept under different management options in other developing countries (Please split your tables and cascade as sub topic)***

Country	Challenges	Prevalence (%)	Cattle breed/type	Production system	Author(s)
Rwanda	Shortage of AI inputs	95.5	Dairy cattle	Not specified	Rugwiro *et al*., 2021
Rwanda	Uterine infections	95.5	Dairy cattle	Not specified	Rugwiro *et al*., 2021
Rwanda	Animal management problem	76.4	Dairy cattle	Not specified	Rugwiro *et al*., 2021
Rwanda	Feed shortage	73.0	Dairy cattle	Not specified	Rugwiro *et al*., 2021
Rwanda	High charge of AI service	34.8	Dairy cattle	Not specified	Rugwiro *et al*., 2021
Rwanda	Improper handling of semen (transportation)	33.7	Dairy cattle	Not specified	Rugwiro *et al*., 2021
Rwanda	Dystocia	25.8	Dairy cattle	Not specified	Rugwiro *et al*., 2021
Rwanda	Retained placenta	20.2	Dairy cattle	Not specified	Rugwiro *et al*., 2021
Rwanda	Heat detection problem	60.7	Dairy cattle	Not specified	Rugwiro *et al*., 2021
Rwanda	Lack of infrastructures	25.8	Dairy cattle	Not specified	Rugwiro *et al*., 2021
Rwanda	Inappropriate semen storage	59.6	Dairy cattle	Not specified	Rugwiro *et al*., 2021
Rwanda	Inadequacy of AITs	50.0	Dairy cattle	Intensive, semi-intensive and extensive systems	Eugene *et al*., 2018
Rwanda	Communication to AITs	17.1	Dairy cattle	Intensive, semi-intensive and extensive systems	Eugene *et al*., 2018

Rwanda	Delay of AITs (action)	32.9	Dairy cattle	Intensive, semi-intensive and extensive systems	Eugene *et al*., 2018
Rwanda	Repeat breeding	25.9	Dairy cattle	Not specified	Management Entity. 2022
Rwanda	Poor inseminator visit	24.3	Dairy cattle	Not specified	Management Entity. 2022
Rwanda	Communication to AITs	10.6	Dairy cattle	Not specified	Management Entity. 2022
Rwanda	Inadequacy of AITs	9.5	Dairy cattle	Not specified	Management Entity. 2022

AI= Artificial Insemination, AITs= Artificial Insemination Technicians

4. Conclusion and Recommendations

1. **Put conclusion and recommendation seperately**
2. **Be specific and make smart while concluding and don't repeat the ideas you stated in the main body of the paper**
3. **Use bulletins while you draw recommendations and not more than 5 points**

This scientific review paper summarizes information on the efficiency, major challenges and economic loss of artificial insemination (AI) service in cattle breeding in developing countries.AI selectively increases genetic gain and quality of farm animals.Planned reproductive management is paramount importantce to the profitability of dairy/beef cattle farming, for example, oestrus and oestrusdetection.The reproductive efficiency of breeding cows is influenced by different factors such as number of services per conception (NSC), conception rate at first insemination, and calving rate (CR). The NSC varies with cow breeds and production areas. The optimum recommended NSC for profitable dairy cow ranges from 1-1.7. The NSC differs under conventional AI (CoAI) and fixed time AI (FTAI) breeding methods. Poor semen quality, poor semen handling procedure, inadequate insemination skill, poor oestrus detection and wrong time of insemination resulted in low CR.CR is also influenced by AI breeding methods, CoAIvsc FTAI. Pregnancy rate is greatly affected by cattle breeds physiological status, heat detection and conception rate.

Comment [u8]: only one?

Despite its great importance, use of AI has limitations and negative impact. Long time and wide use of AI on selected high yielding genotype(s) can cause livestock biodiversity loss. Moreover, use of AI faces many challenges. The challenges include poor feed availability, diseases and parasites prevalence, climate change, weak transport, weak AI infrastructure, semen quality and handling procedures, breed type, production system, poor animal management, timing of inseminationand poor skill of artificial insemination technicians (AITs).In developing countries, AI is greatly affected by seasons of the year which results in malnutrition and poor body condition of the animals. Repeated AI servicesto achieve a unit of pregnancy brings about economic losses. Dairy producers are exposed to additional cost when their cows fail to conceive at their first AI service.Many literatures declared that A.M.-P.M. rule is the simplest practical method of timing of inseminations. To improve the efficiency of AI services, strategic interventions are required including establishing well equipped AI centers, delivering AI inputs, improving theknowledge and skill of AITs, enhancing the awareness of the community on AI service, introducing Do-It-Yourself inseminators (DIYs)and strengthening livestock extension services. Moreover, the developing countries should conduct periodic assessments of AI efficiency and risk factors to enhance cattle AI efficiency. There were criticizes in some areas on male calf birth, hence, **sex-sorted-sperm**which is in the expense of conception rate (low) should be used to enhance the number of replacement heifers of dairy herds.

Comment [u9]: squeeze and put as recommendation

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Comment [u10]: use citing references such as Endnote, wiley….etc

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