Adaptation of Integrated irrigation system to mitigate climate change with respect to gender-sensitive

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Abstract: Water shortage due to climate change is becoming a global concern. Consequently, improved irrigation technology resulted in water-saving and reduced workload of women's workload by ensuring investment returns. This study aims at investigating the effects of the adoption of drip irrigation combined with hand-dug wells on crop water productivity and crop yield of smallholder farmers and their perception of the scheme over two cropping seasons at Haramaya districts, Ethiopia. It was observed that the integrated irrigation system was an efficient and cost-effective method to improve crop productivity. Consequently, the drip irrigation system with water supply from hand-dug wells is recommended as a flexible system that can accommodate various farm sizes and is particularly suitable for adaption by smallholders. Nearly 40% of the farmers were women that contributed to the easy adoption of the technologies. Therefore, capacity building needs to be prioritized for interventions that aim to enhance food self-sufficiency and improve livelihood of smallholder's farmers mentioned in such a devastating environmental-climate dynamic.

Keywords: climate change mitigation and adaptation, crop yield, gender-sensitive, integrated drip irrigation, water use, water efficiency.

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1 Introduction

The United Nations Food and Agriculture Organization (FAO) stated a need for timely agricultural intervention to assist Ethiopia people affected by the drought-induced by climate change (FAO, 2016). The recent (2015-2016) drought and flood in this region left over 10.2 million people without consistent access to adequate food. One-quarter of all Ethiopia districts were classified as experienced food insecurity and malnutrition that put the livelihood in crisis (FAO, 2016). Subject to extreme climatic conditions, the region is experiencing a hard time dealing with seasonality, spatial and temporal variability, and rainfall (FAO, 2016).

The change in climate was reported to affect the ecosystem and irrigation system of agricultural practices that affect water consumption and agricultural production (Kløve *et al.*, 2014; Gadédjisso-Tossou *et al.*, 2018; Ndulue *et al.*, 2019). Moreover, Bailey et al. (2016) reported that water resources and management might contribute to temperature-sensitive species' control as a

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sanctuary under the future seasonal dynamic climate nature. Consequently, global climate changes affect the hydrological cycle of groundwater, surface water, and recharge to aquifers and influence human activities and natural ecosystems that affect agricultural practices (Treidel et al., 2011; Duran-Encalada et al., 2017; Lemessa et al., 2019). Moreover, climate change can affect the biochemical reactions, saltwater intrusion, water storage, groundwater discharge and chemical transport fate (Treidel et al., 2011; Duran-Encalada et al., 2017). Hence, it has a potential effect on the quality and quantity of water resources (Treidel et al., 2011). Several research types are recently underway to study water resources' response to the global climate changes (Green et al., 2011). Several researchers suggested technology adoptions were critical in tackling the problem to combat climate change effect on agricultural production. Moreover, Africa's gender issue, particularly in Ethiopia, is yet at the infant stage. In agricultural production practices, the gender-sensitive approach is ultimately not secured in Ethiopia (Ogato *et al.*, 2009; Arora *et al.*, 2014; Ambaw *et al.*, 2019). Moreover, Lambrou et al. (2006) described that climate change and the policies endorsed to mitigate and adapt to its impacts on the development to adapt gender-sensitive approaches to mitigation measures, adaptation projects and national regimes.

Poor smallholders and pastoralists, who are largely dependent on rain-fed subsistence agricultural system for their livelihood, are the worst affected with similar crises happening in different parts of the world and with larger intensity. It has become apparent that the Ethiopian people cannot depend on food aid and emergency response actions to address such recurring problems. Instead, the search for localized, large-scale and sustainable solutions need to take the front line in defeating food insecurity and mitigating the impacts of extreme weather conditions/events, whose effects have worsened by the El Niño increasing population. Awulachew et al. (2005), stated that Ethiopia needed to double its current cereal production by 2025 to meet the food needs of its rapidly growing population and secure food self-sufficiency. Therefore, to meet this demand, there is a need to review the current agricultural practices chain. According to the second Ethiopian Growth and Transformational Plan (2015-2020), the government planned to intensify agricultural production and increase the size of arable and irrigated land. Irrigation has received particular attention in supplementing to rain-fed farming for smallholders. It provides a major water source, enabling farmers to cultivate crops year-round and improve farm-level productivity. As a result of this, the plan envisages 60% increase in irrigation system from its status in 2020.

East- and South-African regions have seen declining crop yields and recurrent crop failures associated with drought. However, the real problem lies not with the amount of rainfall received but also with the inappropriate water management. In Ethiopia, there is a need for the development of expertise, appropriate technology and investment capital related to its agricultural water management. Most smallholder farms are on a small land plot, usually half a hectare. In the past, there have been attempts to introduce water harvesting for supplementary irrigation to most of the rural farmers in the region, but, it has largely failed due to lack of customized approach and evidence-based knowledge sharing and practices (Awulachew *et al.*, 2007; Dile *et al.*, 2016; Grum *et al.*, 2017). Suppose erosion and depletion of shallow wells in Ethiopia continue at the present pace. In that case, the groundwater table will lower significantly to a level where it requires motorized drilling and pumping systems beyond the capacities of individual smallholders before water can be gotten from the ground (Tadesse *et al.*, 2010; Wakeyo *et al.*, 2017). Therefore, it is necessary to develop catchment rehabilitation measures, improved water utilization and management practices.

Modern irrigation systems are not widely practiced in

Ethiopia, particularly among smallholders. Access to irrigation water, improved water storage systems, enhanced farmers' capacity to manage irrigation systems, and efficient irrigation technologies become among the essential transformations required in improving productivity and increasing food production. The technology developed for enhancing crop water productivity while reducing water wastage or loss in the irrigation loop is a drip system, which is particularly designed for water-scarce environments with a high rate of evaporation.

This study investigates the impacts of drip irrigation systems with access to agriculture water, using hand-dug wells, on smallholder farms in the Haramaya catchment of Eastern Ethiopia. The research was aimed to enhance the crop water productivity and crop production by improving agricultural water management by integrating simple and low-cost water-lifting using hand-dug wells and small-scale irrigation technology such as drip irrigation to improve the livelihoods of Haramaya smallholders. Moreover, gender sensitivity that contributes to technology adoption will be investigated.

2 Materials and methods

The study area is located at East Hararghe zone, Oromia region within Lake Haramaya catchment. The total area of the catchment is 5032 ha of which the area of the Lake Haramaya is 2.26 km^2 (Setegn et al., 2011). The climate of Haramaya Woreda (district) falls under *Woina Dega* (wet and cool, 70%) and *Kolla* (dry and hot, 30%). The area receives a bimodal rainfall type with the mean annual precipitation of 751 mm (Alemayehu et al., 2007). According to Muleta et al. (2006), the dry period (less than 30 mm per month) extends from October to January; December with 9 mm being the driest. The first wet season starts in February (37 mm) and extends up to March (67 mm). The second wet season, which is the biggest in intensity, runs from April to September; with August having an average rainfall of 144 mm being the wettest month.

The major land-use types in the study area are farmland (78.3%), grazing land (7.6%), settlement (4.5%), shrub (4.6%), swamp (4.5%) and forest (0.6%) (Tadesse *et al.*, 2009). Lake Haramaya is the biggest surface water source followed by seasonal rivers that are tributary to the lake system. The area is endowed with groundwater; there are several shallow wells within the catchment. The major crops grown in the area are sorghum and maize; these also staple grains. Farmers close to the lake develop shallow wells for irrigating '*Khat*' or '*Chat*' and vegetables (lettuce, carrot, onion, tomato and cabbage) (Setegn et al., 2011). The livelihood of the community in lake catchment is predominantly based on farming and livestock rearing (Muleta et al., 2006); with the majority of the population living under the poverty line. Some proportion of the population is dependent on food aid for 3-6 months of the year. Therefore, food security is a major issue, particularly in years of drought. The area does not have significant problems related to access to the market. Farm products, such as livestock, *Khat*, sorghum and vegetables are sold at nearby local markets.

In places such as the study area (Figure 1), where traditional/surface irrigation is practiced either using shallow groundwater or surface water, often the systems face serious infrastructural, institutional and management problems. There is little investment in conserving the watershed, in recharging the groundwater source and in increasing the efficiency of the irrigation system. In recent years, there has been a nationwide watershed rehabilitation and conservation initiative that is producing promising results. However, institutional, infrastructural, and management problems around irrigation systems largely remain unsolved.

The study area is one example where these challenges prevail at farm and watershed level. Over-exploitation of the lake water and groundwater in the lake buffer zone has caused a significant decline in the volume of the lake to the extent of drying out in long dry seasons. There is also land degradation that is contributing to the erosion of the upper catchments and sediment accumulation in the lake. The study was undertaken in three neighbourhood (kebeles) of Haramaya zone, namely Damota, Finkile and Adele. Smallholder farmers characterize all the kebeles, and its over-exploitation of water resource is causing watershed degradation and depletion of the Haramaya Lake.

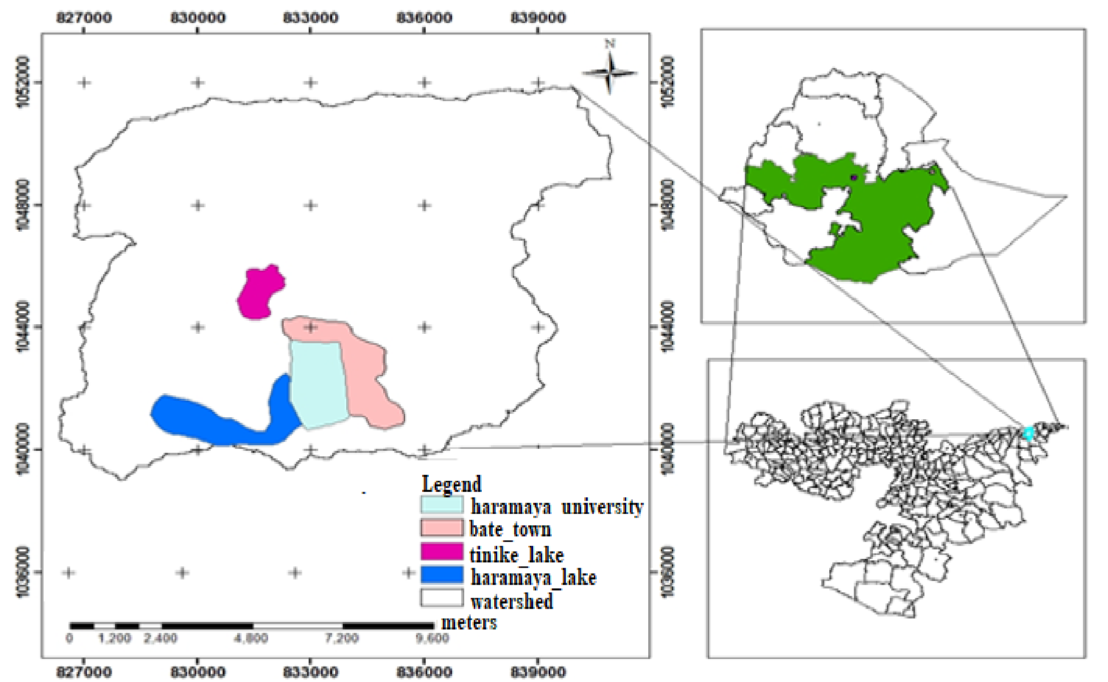

Figure 1 Location of Haramaya watershed.

The three kebeles were selected based on their climate and hydrology. They have a high water table that can be accessed by manual excavation (hand-dug well) and has enough rainfall (>500 mm) required for rainwater harvesting to recharge the hand-dug wells. The pilot farms were distributed along the selected three kebeles in Haramaya instead of confining them to one kebele for two main reasons. The first one is able to take environmental factors (soil, slope, rainfall) in the different areas of the Woreda into account. The second reason is to investigate if the proposed technology is appropriate or applicable for different kebeles in Woreda, in order to check the scalability to other similar kebeles in the Woreda and outside Woreda. Figure 2 graphically describes the sequential framework of the method used in this study (Dawit et al., 2020).

A preliminary visit was carried out to select pilot and smallholder farmers to participate in the study. The selection criteria, used by Stillhardt et al. (2003) with some modifications, were employed to select the farmers that participated in the study. This included a willingness to adopt the proposed irrigation technology, early adopters, male and female-headed farmers. Application of drip irrigation was demonstrated to the farmers who are based on the hydrology and existing practices in the area, hand-dug wells were selected as sources of self-provided water supply on the farm with respect to different climate condition. Data collection was done by observing, measuring the crop water productivity and production; employing focus group discussion to get presumption and general acceptance of the drips and self-provided water supply scheme. Interviews and focus group discussions were done with farmers', representative of agricultural development workers and stakeholders to understand the change in climate with respect to gender-sensitive. Non-intervention smallholder farmers were selected based on having similar socio-economic status and results obtained comparable (Figure 3). The kebeles chosen for the intervention (pilot study) are shown in Table 1. Ten drip irrigation equipment and water lifting schemes were installed in 10 smallholder farms.

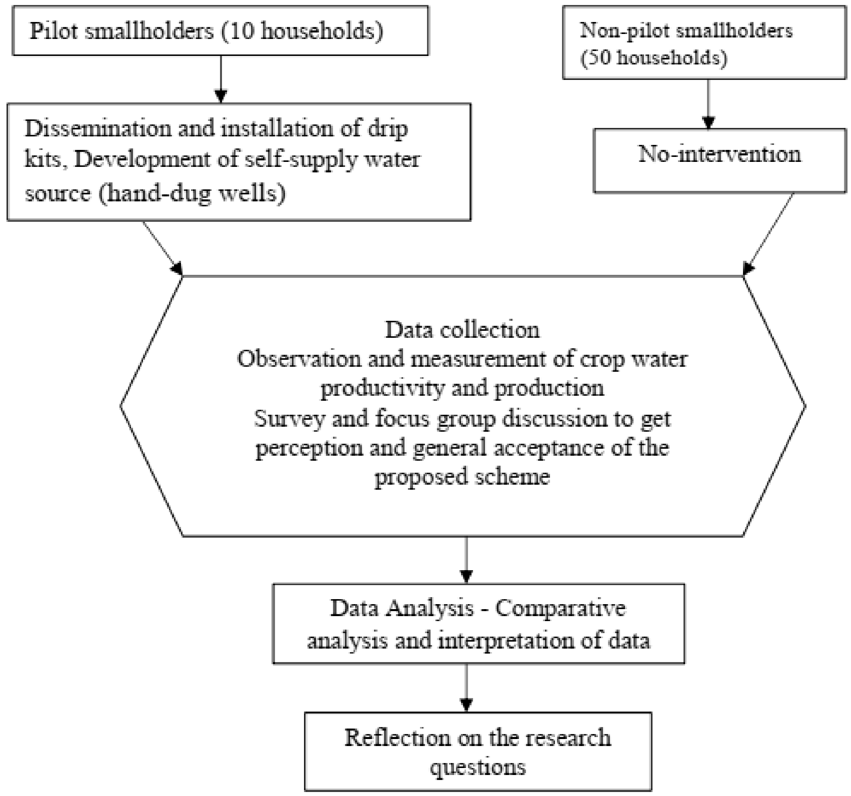

Figure 2 Schematic representation of the method used

The selected smallholder farmers were trained in the development of a hand-dug well and water lifting schemes. The farmers developed their own wells with in-house labor, and some did by collaborating with other farmers. Based on the hydrology and existing practices in the area, hand-dug wells were selected as sources of self-provided water supply on the farm.

Table 1 Selected kebeles and number of smallholder farmers for the intervention around Haramaya

Kebele	Number of smallholder farmers
Damota	4
Finkile	3
Adele	3
Total	10

Source: (Dawit *et al*., 2020)

After the evaluation of the hand-dug wells constructed by the farmers, water-lifting and drip kits were distributed to the selected farmers. The installation was carried out with support from Woreda Water Office technicians and kebele development agents. Farmers were also trained on the management of the kits. On the other hand, fifty smallholder farmers were selected as a control, where the drip irrigation and water-lifting scheme were not adopted (Figure 3).

Field data collection was done by observing, measuring the crop water productivity and production; employing focus group discussion to get presumption and general acceptance of the drips and self-provided water supply scheme. Interviews were also used for data collection using questioners. Interviews and focus group discussions were done with the kebele leaders, farmers' representatives, representative of agricultural development workers and stakeholders. The focal group discussion was held in the three villages of the pilot study (Damota, Finkile and

Adele). A total of 60 respondents were selected, 20 from each kebele. Ten of the respondents were intervention/pilot smallholder farmers, while 50 were non-intervention smallholder farmers (Table 2).

Table 2 Distribution of smallholder farmer's respondents.

Kebele	Intervention smallholder farmers	Non-intervention smallholder farmers	Total farmers
Damota	4	16	20
Finkile	3	17	20
Adele	3	17	20

Source:(Dawit *et al*., 2020)

The study was carried out among the intervention and non-intervention household in similar kebeles. Non-intervention smallholder farmers were selected based on having similar socio-economic status and farm size in order to make the data and results obtained comparable (Dawit et al., 2020).

Comparative analysis was carried out to investigate the productivity between the pilot and non-pilot farmlands (Figure 3). The productivity was measured as yield divided by irrigation water applied during the growing year assuming all other factors such as the use of fertilizers, seed type, and farm management to be similar. The results obtained from the pilots were compared with those of the non-pilot household farmers. Interviews and focus group discussions were used to evaluate the perception and acceptance of farmers to the self-supply water and the dynamics of climate change.

(a)

(b)

Figure 3 Comparison of farm lands (a) non-intervention site (b) pilot study (picture by authors)

3 Results and discussion

In this study, the analysis was done to identify the impacts of the drip irrigation system, coupled with the self-supply of water on plant water productivity and production. It also focused on identifying the dynamics of climate change and the improvement of agricultural production using irrigation technology. The result showed that drip irrigation in combination with supplementary water sources improved the water use efficiency and an increase in crop yields while saving water (Sijali, 2001; Palada et al., 2011; Dawit et al., 2020). The crop yield and water productivity were measured during the cropping season for the intervention and non-intervention farms. The fertility of the land for crop production, 85.7% of lands as moderately fertile, while 14% of them rated their land as slightly degraded. The majority (54.2%) of the total crop yields, 38.5% reported steady crop production and only a small minority (7.4%) reported an increase in production. The major causes for the declining trend in crop yields, include climate change, a shortage of supplementary water sources, drought, and deterioration in soil fertility cultivated land. Moreover, the results displayed an increase in crop water productivity and crop yields of the farms that applied the drip system and hand-dug wells. It resulted in water-savings that could reduce over-exploitation, a reduction in labor-intensive manual-irrigation of crops that could minimize the workload and stress on women, and flexible systems capable of accommodating a variety of farm sizes.

The drip irrigation system and pedal pumps used in the study area. Climate change affects the water demand and supply routes in which more than 65% of the lake water level decrease is due to climate change and overuse of surface water. The dynamics of gender to science and the environment have been in the investigation for decades and concern to science and environmental sociologists (Chaudhury et al., 2012). The research and finding show that women’s countenance and apprehension to climate change is much greater than men’s, which is a similar report to that of Lambrou & Piana (2006). The gender sensitivity and deference to the concern of environments on climate knowledge leads to suggest the need for further findings of its implication to science (Chaudhury et al., 2012). The potential of rural women as agents of change for climate mitigation and adaptation remains untapped (Ajani et al., 2013). The study shows that women’s role in farming is important to bring about household-based food security. According to Ajani et al. (2013), economic empowerment of women through climate mitigation and agricultural technology adaptation which might foster economic growth and socio-economic development, reduces poverty, keeps environmental problems in check, and increases the potential for adaptation, which is benefit to both women and men. In the study area, near 40% of the farmers were women that contributed to the easy adoption of the technologies. However, the limited use of drip irrigation and water supply schemes by household farmers in the study area were attributed to lack of awareness, unavailability of the drip kits in the local markets and lack of skills to manage and maintain the schemes. Therefore, the result of this research indicated that enhancing food self-sufficiency and improved livelihood of smallholders’ farmers mentioned in such a devastated environmental climate dynamic needed, while promoting efficient irrigation systems and self-supply to ensure quick investment returns.

Irrigation, as applied to agriculture, is the process, operation or practice of artificial application of water to the soil for the growth of agricultural crops (Newell *et al.*, 1913; Basak, 1999; Lebel, 2013; Akhter *et al.*, 2015). Irrigation has been credited with the rise and flourishing of civilizations such as those in ancient Mesopotamia, Sumeria and Babylon (Andersson, 2005). According to Sijali (2001) and Palada et al. (2011), the advantages of drip irrigation includes higher crop yields, more efficient use of water, reduced cost for application of fertilizers and other chemicals, reduced labor, and reduced salinity hazard, while it has limitations like higher initial cost, technical limitations clogging of emitters, restricted root zone and salt accumulation in the root zone. Similarly, the finding of this study identified that the most appropriate technology among the different type of irrigation technologies, the drip kits were found to be appropriate and adapted, distributed and tested with respect to climate change that accommodate gender sensitive. Moreover, similar to the recommendations of Palada et al. (2011) and Ajani et al. (2013), women can be integrated into climate mitigation and adaptation initiatives through agricultural technologies adaptations. Furthermore, Masika (2002) reported that gender and poverty considerations were needed to be included in all adaptation efforts. In addition, the study could pave the way for the possibility of modifying the technology to fit with local conditions, if necessary, depending on the feedback from the farmers and discussions with the participating institutions. Masika (2002) and Djoudi *et al.* (2011) also stressed that a better understanding of the connections between gender, food security, poverty and climate change that increase vulnerability to climate hazards, and their implications for the impacts of climate change on livelihood and survival strategies were important to be given attentions. As a result, concrete, promising project measures at the local level should therefore be combined with advisory services at the wider level related to climate change, irrigation technologies and the economic empowerment of women in the agricultural technologies adopting frameworks.

4 Conclusions

The change in climate and women empowerment in agricultural production plays a great role in sustainable livelihood development. Irrigation, as applied to agriculture, is the process, operation or practice of artificial application of water to the soil to produce agricultural crops and productivity. Irrigation has been credited with the rise and flourishing of civilizations such as those in ancient Mesopotamia, Sumeria and Babylon. In this research, the drip irrigation provided that higher crop yields, more efficient use of water, reduced cost for application of fertilizers and other chemicals, reduced labor, and reduced salinity hazard. On the other hand, it has limitations like higher initial cost, technical limitations clogging of emitters, restricted root zone and salt accumulation in the root zone. Moreover, the finding of this study identified that the most appropriate technology among the different type of drip kits that distributed and tested with respect to climate change that accommodated gender-sensitive. The female farmers took part in the adoption of the irrigation technology were about 40%. Moreover, the study might pave the way for the possibility of modifying the technology to fit with local conditions, if necessary, depending on the feedback from the farmers and discussions with the participating institutions.

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Authors Contributions

Meseret Dawit and Megersa Olumana Dinka conceptualized the research question and the concept of the paper. Meseret Dawit contributed on the design of the experiments, data generation, collection, analysis, modelling, interpretation, and final submission to the journal were achieved.

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