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Rainwater Harvesting Practices for Smallholder Farmers for Climate Change Adaptation: Evidence from Minjar Shenkora Woreda, North Shewa Zone of Amhara Region, Ethiopia

BY

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THESIS SUBMITTED TO CENTER FOR ENVIRONMENT AND DEVELOPMENT STUDIES, COLLEGE OF DEVELOPMENT STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS IN DEVELOPMENT STUDIES (ENVIRONMENT AND SUSTAINABLE DEVELOPMENT)

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March, 2021

Addis Ababa, Ethiopia

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

COLLEGE OF DEVELOPMENT STUDIES

This is to certify that the thesis prepared by Zewdu Geda Asfaw, entitled: Rainwater Harvesting Practices for Smallholder Farmers for Climate Change Adaptation: Evidence from Minjar Shenkora Woreda, North Shewa Zone of Amhara Region, Ethiopia and submitted in partial fulfillment of the requirements for the degree of master of arts in development studies (environment and sustainable development) complies with the regulation of the university and meet the accepted standards with respect to originality and quality.

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DECLARATION

I, the undersigned, declare that this thesis is my original work performed under the supervision of my research advisor Dr. Shimeles Damene and has not been presented as a thesis for a degree in any other university, and that all sources of materials used for this thesis have also been duly acknowledged.

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Date of submission: March, 2021

Acknowledgement

First and for most I would like to thank the Almighty God for giving me the opportunity of this thesis preparation and for all achievements which I have been able to attain in my entire life. Next, I would like to thank my advisor, Dr. Shimeles Damene, for his ongoing guidance, encouragement and comments throughout the development of this thesis. I would like also to thank Ato Yitbarek Abreham, Head of Minjar Shenkora Woreda Agricultural Development Office and his staff member experts, for providing me with all the information and support required for this paper.

My sincere thanks also goes to W/ro Addis Mekasha (DA) in Dire kebele, Ato Sisay Nigatu (DA) in Bolo Selasse kebele and Ato Shawule Kefale (DA) in Cherecha kebele for those who have valuable support in data collection process and provision of valuable information. My grateful acknowledgements are extended to the sample participants of household survey, Focus Group Discussions and key informant Interviews who co-operated in supplying relevant information for this thesis process. My heartily appreciation goes to my wife W/ro Tewobista Basazinew for her endless support and encouragement throughout the ups and downs of my academic and personal life.

Finally I want to thanks my parents, friends (especially Ato Tegegnu Getu for his advice throughout this paper work) and all others who participated and supported me in all aspects in this research work.

Zewdu Geda Asfaw

Abstract

Climate change, which manifested in the form of temperature increases and rainfall variability, has been increasing over the last two decades. The change has been influencing crop and livestock production particularly in vulnerable areas including the study area. In tackling the problem, the Ethiopian government and non-profit making organization has been promoting water harvesting over the last two decades in different parts of the country with due attention in drought prone areas. However, limited empirical based research conducted so far so as to examine role and contribution of the practice for climate change adaptation. Therefore, this research is designed to assess rainwater harvesting practices of smallholder farmers for climate change adaptation tacking Minjar Shenkora Woreda, North Shewa Zone of Amhara Region, as a case. The research applied mixed research design approach that used both qualitative and quantitative data, where the quantitative and qualitative data were generated through household (HH) survey, Focus Group Discussions (FGDs), Key Informants Interviews (KIIs) and filed observation. The survey covered 100 HHs, 6 FGDs were conducted with 24 participants and KIIs were conducted with 9 participants. The survey data were analyzed using simple descriptive statistics. The analysis revealed that climate change is the existing reality in study area over the last two decades that manifested through increasing temperature and erratic rainfall. The survey respondents indicated that they have been experiencing real climate change incidences such as rainfall amount has been highly decreasing, emergence and expansion of new weed types, expansion of invasive plant species, incidence of livestock and crop diseases. The analysis also verified that in response to the climate change effects most farmers in the study area have been adapting different types of rain water harvesting (RWH) practices for production and domestic purposes. Thus, farmers engage in construction and usage of traditional and plastic lined ponds for the purpose of small scale irrigation. The study showed that rainwater harvesting practices improved the crop and livestock production. Nevertheless, the farmer efforts to adopt the RWH practice have been challenged by finance, labor, technical skills and management capability problems. Therefore, there should be policy and strategic measures to support farmer's effort in adapting climate change impact through promotion and support of RWH practice. The support could be formulating enabling policies and cost-sharing strategies, providing different technologies, facilitating capacity building modalities to enhance the technical skill of farming communities in RWH practices.

Keywords: *Rainwater harvesting, climate change adaptation, crop, livestock.*

Table of Contents

List of tables

List of figures

List of Acronyms

CBO	Community Based Organization
CSA	Center of Statistics Agency
DA	Development Agent
FAO	Food and Agricultural Organization of the United Nations
FGD	Focus Group Discussion
FTC	Farmers Training Center
GDP	Gross Domestic Product
GPS	Global Positioning System
HHs	Household
IPCC	Intergovernmental Panel on Climate Change
KA	Kebele Administration
KII	Key Informants Interview
MIS	Management Information System
MSW	Minjar Shenkora Woreda
MSWADO	Minjar Shenkora Woreda Agriculture Development Office
NAPA	National Adaptation Program of Action
NGO	Non-Governmental Organization
NMA	National Meteorological Agency
RWH	Rain Water Harvesting
SFSB	Stone Faced Soil Bund
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
SSI	Small Scale Irrigation
SWC	Soil and Water Conservation
TLU	Tropical Livestock Unit
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

Climate change is a change of climate which is attributed directly or indirectly due to human activity. It affects the composition observed over comparable periods of time of the global and/or regional atmosphere and natural climate variability. The types of changes (temperature, precipitation, extreme events) are climate variability; the extent and rate of climate change affecting public health, agriculture, food security, forest hydrology and water supplies, coastal areas, biodiversity, human settlement, electricity, industry and financial services (UNFCCC, 2007). Climate change is a global threat to the environment that significantly impacts agricultural productivity and affects people in many respects, including its direct effect on food production (Entete and Amusa, 2016). While climate change is global, due to its low level of adaptive capabilities, developing countries such as Africa are the most adversely affected by climate change (Japtap, 2007).

Agriculture is the most important sector in sub-Saharan Africa. It remains the economic heart of many sub-Saharan African countries, employing about 60% of the workforce and contributing about 30% of the gross domestic product (GDP) Thornton et al., (2011), but climate change is expected to have a negative effect. It is clear that climate change would lead to significant losses in welfare, especially for smallholders whose main livelihood comes from agriculture (Paulos and Belay, 2018). Ethiopia is one of the country's most vulnerable to the agricultural consequences of climate instability and transition (Kassie et al., 2013). The fifth report of the IPCC suggests that future climate change will lead to arise in climate variability and extreme events in Africa, including Ethiopia, in frequency and severity (Niang et al., 2014). In combination with warming patterns, the changing rainfall pattern could make rain fed agriculture in Ethiopia more risky and aggravate food insecurity. Such new challenges require new agricultural adaptation practices, such as rainwater harvesting (RWH) to cope with the adverse effects of climate change.

Rainwater harvesting is one of the simplest and oldest methods of self-supply of water for households and residential uses, where household scale projects usually financed by the users (Mays et al., 2013). RWH is the gathering and storing of rain instead of allowing it to run off. Rainwater is collected from a surface like a roof and diverted to a tank, cistern, deep pit (well, pipe, or borehole), percolation aquifer or reservoir (UN-Habitat, 2005). Therefore, rainfall is the main source of agricultural water supply for most of the subsistence farming system in SSA, including Ethiopia (UNEP, 2009). Rainfall in the arid and semi-arid regions is generally insufficient to meet the basic needs of crop production for the growing human population Rebeka, (2006). However, farmers have a long history of responding to climate variability. Traditional and newly introduced adaptation practices can help farmers cope with both current climate variability and future climate change (Bilow, 2010).

Climate change adaptation refers to natural or human system adjustment in response to real or anticipated climate stimuli, or their consequences, which reduces harm or exploits beneficial opportunities (IPCC, 2007). In Ethiopia cases, traditional and contemporary coping mechanisms to climate variability and extreme includes: Changes in cropping and planting practices, decreases in consumption levels, collection of wild food, use of inter-household transfers and loans, increased production of small commodities, temporary and permanent migration in search of jobs, storage of grain, selling of assets such as livestock and agricultural instruments, land mortgages, merchant and money lender loans, use of early warning devices (NAPA, 2007).

The main goal of climate change adaptation is to reduce vulnerability and build resilience to the impacts brought by climate change (Brooks and Adger, 2005). Therefore, this paper assessing Rainwater Harvesting Practices for Smallholder Farmers for Climate Change Adaptation specifically at Minjar Shenkora Woreda, North Shewa Zone of Amhara Region, were the main purpose of the thesis along with this research paper was recommending some possible suggestion to improve their Rainwater Harvesting Practices.

1.2. Statement of the Problem

Climate change is the major environmental challenge which faces societies in the world. The poorest countries and peoples will suffer more than the others, although their contribution for the change is minimal. As the economy of these countries mostly depend on natural resource, where the natural resources are susceptible to climate change. Like other developing countries, climatic and ecological changes caused by global warming have resulted in several negative consequences on health, economy and livelihoods of Ethiopian people (Eriksson, 2006). Moreover, study conducted by National Meteorological Service Agency NMSA, (2007) revealed that climate change induced weather variability has been significantly affecting agriculture, health, water resources and natural resource of the country. The problem is severe in semi-arid and arid areas including peoples of the rift valley areas where the study area (Minjar Shenkora) is situated. In line with this, as livelihood of farmers depend on crop and livestock production as farmers are highly vulnerable to climate change induced climates and production loss.

Studies indicated that rift valley areas including the study *Woreda* are characterized by irregular rain fall and recurrent drought that end up in, crop yield reduction, flood hazards, landslides and soil erosion (MSWADO, 2020). Evidence suggests that recurrent droughts and associated food insecurity and famine in Ethiopia are primarily caused by climate, especially the variability of rainfall (Seleshi et al., 2004). Droughts and floods are devastating for the country's lowland pastoralists and mixed cropping systems (Tesfaye et al., 2015). The relocation of suitable areas of production for different crops is another Evidence of the effect of climate change on Ethiopian agriculture. Evangelista et al., (2013) showed that by 2020 the major cereal crops of Ethiopia such as maize, teff, sorghum and barley will loss over 14%, 11%, 7% and 31% of their current suitable area of production, respectively. According to the study of Deressa, (2006), for Ethiopia, by using Heckman sample selection model both increasing temperature and decreasing precipitation are harmful Ethiopian agriculture. According to FAO, (2011), climate change has strong impact on the agricultural and forestry sectors by modifying or degrading productive capacities and by directly and indirectly increasing the risks associated with production. Another shock caused by climate variability in Ethiopia is also an outbreak. Epidemics, both human and livestock, are yet another shock caused by climate change that contributes to greater famine, such as the Great Famine of Ethiopia (Adane et al., 2006).

All these climate shocks have been degrading people's livelihood, as they factors have been deteriorating climate changes adaptation capacity of the people (NMSA, 2007). Hence, to minimize the problem, government and development partners have been promoting rain water harvesting practices. In response to the promotion of rain water harvesting practices for production and domestic use, the practice has been widely in use at many parts of the country, particularly in arid and semi-arid areas including the rift valley. Minjar Shenkora woreda is among such areas, where rain water harvesting is largely implemented. Recognizing that the practices of rainwater harvesting through construction of household ponds, cisterns (of various shapes, sizes and construction materials) and hand dug wells are proposed as practical and more effective alternative to reach individual households and smallholder farmers in adaption climate change impact (FAO, 2014). Despite, the various efferent to reduce impact of climate change through implementation of rain water harvesting technologies in enhancing adaptive capacity of the people, little research has been made so far to understand real role of practice. Therefore, the aim of this study is to assess rain water harvesting practices for climate change adaptation by smallholder farmer's lesson from Minjar Shenkora woreda, of the Amhara region.

1.3. Objectives of the Study

1.3.1. General Objective

The general objective of the study is to assess rainwater harvesting practices for smallholder farmers for climate change adaptation in Minjar Shenkora woreda of the Amhara region, Ethiopia.

1.3.2. Specific Objectives

The specific objectives of the study are:

- To identify farmers perception and variability to Climate Change in the study area.
- To identify rainwater harvesting practices implemented by smallholder farmers in the study area.
- To assess soil and water conservation practices to response climate change in the study area.
- To identify the major challenges in the implementation of the rainwater harvesting practices in the study area.
- To identify the role of rainwater harvesting practices for climate change impacts adaptation.
- To assess the difference agricultural output due to rainwater harvesting practices.

1.4. Research questions

To achieve the objectives, the following basic research questions were formulated.

1. What are the perceptions of farmers on the variability of Climate Change?
2. What are the major RWH practices implemented in the study area?
3. What are the major challenges faced by smallholder farmers to implement RWH practices?
4. What is the role of rainwater harvesting practices for smallholder farmers?

1.5. Significance of the study

This research document has the following significant terms of aspects:

I. Assess the overall advantages of RWH practices for climate change adaptation.

II. Ensure the sustainability of the RWH practices in the study area by identifying the challenges and gaps in the implementation process. Additionally it helps to extend the practices to other climate change vulnerable *Woredas,* zones, regions and in a country level by providing information about the benefits of the intervention of climate change victims. Also the study outputs may suggest to the policy makers, local administrators, the local farmers of the study area to look for host of strategies and instrument towards the improvement of farmer's livelihood. Similarly, it may help households to make informed decision for better practices on RWH.

III. Besides, It will serve as a document for other researcher who would like to study the same Issue widely in the study area context and others.

1.6. Scope of the study

The findings of the research would be more fruitful if it were conducted widely by including other similar *Woredas*; however, due to time, labor, and money constraints the scope of the paper was limited to study rainwater harvesting practices for smallholder farmers for climate change adaptation evidence from Minjar Shenkora Woreda, North Shewa Zone of Amhara Region.

1.7. Organization of the thesis

This thesis has been structured in five chapters. Hence, chapter one presented introduction that include background of the study, problem statement, research objectives and questions, significance and scope of the study. Chapter two provided comprehensive and empirical literature review as well as theoretical framework of the study. Chapter three focuses on the description of the study area and applied research methodology that include study design, data collection methods and tools, data sources, sampling, and data analysis. Chapter four presents the results and discussion. Chapter five presented conclusion and the recommendations of the study findings.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. The Concept of Rain Water Harvesting

The harvesting of rainwater can be broadly defined as collecting and accumulating runoff for productive purposes such as crop production, forage, pasture or trees, livestock and domestic water supply (Ngigi, 2003). Since ancient times rainwater collection and storage has been a common practice for various purposes. There are four facets of rainfall, which include parts of rainfall surface flow to the rippling fields, the runoff occurs in the drainage region at the lower end of the slope, where a large portion infiltrates and deposited in the root zone, whereas after the absorption has stopped, the soil water deposited is then retained in the ground (Kaumbutho and Simalenga, 1999).

In general, crop production rainwater harvesting (RWH) systems are divided into three different categories essentially defined by the distances between catchment area and cultivated basin area, Hatibu and Mahoo (1999) classified rainwater harvesting systems in to three types as briefly described hereafter.

2.1.1. In-situ RWH

In any RWH program, the first step includes methods to increase the quantity of water contained in the soil profile by trapping or holding down water. This can include tiny movements of rainwater as a surface runoff to focus the water where it is most desired. In-situ RWH is sometimes referred to as water conservation, and is essentially the avoidance of net runoff from a given cultivated area by maintaining rainwater and increasing the infiltration times (Hatibu and Mahoo 1999). This system works better where the soil's capacity to hold water is sufficiently large, and the rainfall is equal to or greater than the requirement for crop water. Essentially, it covers both traditional soil and water management strategies designed to enhance rainwater absorption. Examples of RWH techniques in situ include deep tillage, dry seeding, mixed crop cultivation and ridges (Hatibu and Mahoo 1999).

2.1.2. Micro-catchment (land based water harvesting)

This is a scheme where the catchment area and cropped basin (storage area) are independently separated but the areas are adjacent to each other. It is a process by which surface runoff from a specific catchment area is collected and stored in the root zone of an adjacent infiltration basin. This method is mainly used to grow medium water crops which require crops such as maize, sorghum, groundnuts and millet (Hatibu and Mahoo 1999).

2.1.3. External (Macro) catchment RWH

This is a system involving collecting runoff from large areas at a significant distance from their sources. This system is sometimes extended for later use as supplementary irrigation with intermediate storage of water outside the cultivated basin. This system involves the processing of water from catchments ranging from 0.1 hectares to thousands of hectares situated either near or far from the agricultural basin (Hatibu and Mahoo 1999).

2.2. Pre-Conditions for Rainwater Harvesting

Water is one of the basic requirements for life, economic and social growth (Ramakrishnan et al., 2009). Water is needed by humans, plants and animals, and for the functions of the environment. In the production of drinking water sources, farming and industrial activities, adequate water supply is important. The demand of water increases linearly as population increases. According to WWO (2010) the global water consumption rate doubles in every 20 years a rate that is twice the population growth rate. As a result, optimal, efficient use and management of freshwater resources with increase in population are paramount to counter the concerns caused by the observed dwindling trends of the water resources. And Rainwater harvesting is the process of concentrating runoff from a large area within the catchment. The concentrated runoff can later be used in a smaller area for various activities. Rain water harvesting deals with a large number of spatial data that can be easily handled using geospatial techniques (Bakir and Xingnan, 2008). Moreover, rainwater harvesting has many advantages, such as free acquisition, good quality, and in situ use, reduction of surface runoff and nonpoint source pollution, and mitigation of the demand peak and expansion of existing water supply systems. Moreover, many individuals and local communities throughout the world have developed a variety of RWH systems. A number of factors in addition to cost should be considered when choosing appropriate water sources or a specific rainwater harvesting system. Climate (rainfall pattern and rain intensity), technology, socio-economic factors, local livelihood, political system, and organizational management all play an important role in the eventual choice. An essential starting point when considering a rainwater catchment system for domestic water supply is to determine its environmental, technological and socio-economic feasibility (Worm, van Hattum, 2006).

2.3. Factors Influencing Rainwater Harvesting

There is enough freshwater available every year to fulfill the needs of the present population of this planet. However, in certain regions and countries the annual renewable supply of water is less than $500m^3$ (Qadir et al., 2007). This need for RWH, as mentioned above, arises from many factors such as low rainfall and irregular distribution, high losses due to evaporation and runoff, and an increased demand on water due to population growth (Abu-Awwad and Shatanawi, 1997). As RWH becomes a significant strategy to deal with water scarcity or water stress, it is significant to consider the factors that go into selecting the appropriate RWH techniques to maximize hydrological returns. There are a number of critical factors that need to be taken into consideration when selecting the appropriate RWH method (Prinz and Singh, 2000). For example, technological variations such as stone availability or rainfall intensity may occur, and (Critchley and Siegert, 1991) may have distinct socio-economic differences. Furthermore, according to Roger, (2003) the innovation decision process involves different stages namely knowledge, persuasion, decision making, implementation, confirmation and adoption. At the decision point, a person makes the decision to reject or accept the program. The weighing of benefits, drawbacks, costs, advantages, and trade-offs includes this personal process.

2.4. Climate Change

Climate change is already happening, with multi-faceted effects on human society and the environment (Gomoro, 2014). Precipitation patters are sporadic in the dry lands of Africa, like northern Ethiopia; rain intensity varies from one area to another and rainfall occurs within a short span of a year (Asayehegn, 2012). In addition, high population growth rates in drought prone areas and weak institutions coupled with low adaptive capacity have been identified as major challenges for the region (Satterthwaite et al., 2007). There have been repeated droughts and famines in many developing countries that have affected many people and their livestock (Baro, 2006). Drought occurs once every three to four years in Ethiopia, leading to increased soil erosion, deforestation and the incidence of pests, leading to accelerated food insecurity (Fentaw, 2011). And these extreme events result in economic losses and negative impacts on ecosystems and human health due to the warmer climates, nutrient depletion, dissolved organic carbon, pathogens, and pesticides and salt (Mulatu et al., 2016).

2.5. Climate Change and Rainwater

Climate change is one of the biggest global problems posing challenges to sustainable livelihoods and economic development, particularly for developing countries like Tanzania. In several countries, including Ethiopia, the negative impacts of climate change on the atmosphere, human health, food security, human settlements, economic activities, natural resources and physical infrastructure are already visible (URT, 2009). Of all the parts, semi-arid areas of central Tanzania have been hit severely making the adaptation strategies difficult. In 2008 an assessment of climate change impacts in Tanzania was done (URT, 2009). Moreover, climate change is a reality. The freshwater resources of the planet have been dramatically depleted by climate change, population growth, increasing water demand, overexploitation of natural resources and environmental degradation (Ngigi, 2009). The impacts of climate change are already being felt, mostly by the world's poorest people. These sectors are closely linked to agriculture and therefore effects of climate change and variability on such sectors will further negatively affect both crops and livestock production systems.

2.6. Climate Change Adaptation

Adaptation is adjustment in ecological, social, and economic systems by improvements in procedures, behaviors, and frameworks to minimize vulnerability to climate change, instability, and extremes in populations, areas, and activities (Smit and Pilifosova, 2001). Adaptation classification, suggested by Smit et al., (1999) composed of pairs of overlapping categories: autonomous vs. Planned, spontaneous vs. purposeful, automatic vs. intentional, natural vs. policy, passive vs. active, responsive vs. anticipatory, reactive vs. proactive, ex post vs. ex ante, short-term vs. long-term, instantaneous vs. cumulative, and localized vs. widespread. Additional more action-oriented adaptation categories are also presented in Smit and Pilifosova, (2001) viz bear losses, share losses, modify threats, prevent effects, change uses and change locations.

Climate change adaptation is expected to be more flexible, reflective and iterative in a staged process of building on short-term strategies to get to long-term results (NCCARF, 2012). That is to say, it must be incremental, with the aim of improving efficiency within existing technological, governance and value systems; as well as transformative, involving changes in the basic attributes of the systems (IPCC, 2012). The distinction made between short-term behavior and long-term goals is important to make adaptation efforts more practical and appealing to everyone involved. The reality of climate change is that the transition is a normal change. Mean ideals can only be formulated without being interpreted. It is just like the difference between the computed trend, representing mean values and the actual or observed distribution. Decision-making for adaptation to climate change is encouraged or more often discouraged, based on the observed uncertainty and extremes, rather than by the theoretical measured mean. The IPCC, (2001) confirms this that a transition in climate patterns is actually experienced by uncertainty and extremes. That is why people are more inclined to make weather-based decisions on climate change, where the effects of climate change are viewed as abrupt and extreme (Henry, 2000). It is argued in Adger et al., (2005) that adaptation requiring large-scale intervention is likely to be caused by extreme events that raise awareness of climate change within policy making and, ultimately, give legitimacy to government action. This is the compelling reason why current climate-related disaster risk reduction policies provide a clear entry point for mainstreaming adaptation policies (Lebel et al., 2012). Consequently, the most important point of integration of disaster risk management and climate change adaptation is to focus on reducing exposure and vulnerability, thus growing resistance to the impacts of extreme climate change (IPCC, 2012).

Adaptation to climate change need not be, and could not be, a separate operation. The impacts of climate change are so systemic, affecting almost all industries and regions in time and space, that independent planning and execution of adaptation measures will bring little value (Lebel et al., 2012). Alternatively, adaptation would promote its development and implementation by mainstreaming into current development planning, exploiting much larger financial flows in sectors affected by climate risks rather than just the sums available separately to fund adaptation (Lebel et al., 2012). Nonetheless, one of the key practical challenges of mainstreaming adaptation is the project-oriented approach in global, regional, and local development, in which funding lasts for a few years and contributes insignificantly to the long-term reduction of climate risks (Lebel et al., 2012).

2.7. Training and their Influence on Rain Water Harvesting

According to Prackash, (2011), training in rainwater harvesting provides guidance on the definition and technology of domestic rainwater harvesting and how it fits into the overall picture of the sufficient supply of rural and urban water, which is important to the current situation. And also according to Agriculture Research Centre (2008), the problem is that farmers and communities do not have the awareness or the means to implement suitable techniques in the appropriate way. Furthermore, others must be checked under the current conditions. In addition, Kariuki, (2003), reported that government ministries, societies, individuals, development partners, research and higher education institutions, NGOs, CBOs and private companies are promoting rainwater harvesting technologies.

2.8. Challenges of rain water harvesting practices

Different problems in the household rainwater harvesting practices to make Rainwater harvesting a viable alternative to traditional water supply sources are generally listed as:-policy issues, technical challenges and managerial constraints (KRA, 1998).

2.8.1. Policy Issues

In many cases community-based organizations, NGOs, government departments, and even some donor agencies lack policy guidance to promote rainwater harvesting (KRA, 1998). Those who have are generally inadequate, and inappropriate for the prevailing local conditions. Some of the challenges faced by most rainwater harvesting ventures are:

- Inadequate legal advice on the formation of projects and the objectives outlined in the relevant constitutional framework;
- Lack of collaboration and networking among stakeholders;
- Limited community mobilization policy for water related activities;
- Low level of community participation and contribution to project development;
- Inadequate structures for improving water quality, control and use;
- Limited training and technological transfer at project level for rainwater harvesting;
- Lack of guidelines for operation and maintenance of rainwater infrastructure.

2.8.2. Technical Issues

No matter how well built a rainwater harvesting system is, unless it is technologically successful it will not produce or perform the anticipated functions. Many projects are not sustainable, or cannot be replicated, due to inadequate technical interventions, particularly in rural areas. Selection of technology by a community means acceptance, indicating an appreciation and willingness to be associated with it, irrespective of some shortcomings in community participation. As per KRA, (1998), the technical challenges facing many local initiatives in rainwater harvesting practices have been listed in particular as follows:

- Inadequate construction guidelines for tanks, gutters, filters, etc.;
- Inadequate technological transfer to beneficiaries;
- Lack of appropriate training programs for rainwater harvesters;
- Poor technical selection and use of local materials;
- Sizing of storage tanks, with regard to rainfall data and costs;
- Lack of water quality management and control structures;
- Inappropriate guttering system in architecture, installation (support) and maintenance.

2.8.3. Managerial Issues

Water projects owned by the large government have a high potential to overcome the managerial challenges of low-cost community based water projects (KRA, 1998). Legally developed by-laws and self-help water projects registration, developing financial and management skills through local training would improve effective and safe use and control of water. In the management of community-based water projects, there is a sense of ownership, community participation and commitment unlike in government projects where the water managers have little or no passion for management issues. The managerial issues raised by major concerns included amongst others:

- Weak use of local resources;
- Inadequate community involvement and participation due to approaches;
- Inadequate community-based project management skills;
- Poor financial management and accounting resulting in financial loss;
- lack of adequate water use and control measures;
- lack of awareness and lack of willingness to obtain legal status as a result of taxation;
- donor dependency syndrome;
- Political interference with community projects.

2.9. Benefits of Rainwater harvesting practices

Rainwater harvesting provides long-term responses to the water scarcity problem. Rainwater harvesting offers an ideal solution in areas where sufficient rain is present but insufficient groundwater supply and surface water resources are either lacking or insufficient. In hilly areas humans, vegetation, and animals can use rainwater (CAWST, 2011). Rainwater harvesting system is particularly useful in remote and demanding terrain, as it is capable of operating independently. The entire process is environmentally friendly. There are a number of ways a group could profit from water harvesting. Water harvesting makes it possible to collect and store rainwater effectively, making it available and substitutes for water of poor quality (CAWST, 2011). A water harvesting system collects and stores water within reach from its place of use. While traditional sources are located in peri-urban areas, especially away from the community, collecting and storing water close to households, villages or pastures greatly enhances the accessibility and convenience of water supplies.

The captured rainwater can be processed for direct use or recharged into the groundwater to improve groundwater quality and increase water levels in drying wells and bore wells, as well as minimize soil erosion as the surface runoff decreases. Rainwater harvesting is an ideal solution to water problems in areas with inadequate water resources, and is helpful in mitigating the effects of drought and proving drought (CAWST, 2011). Water harvesting offers a seasonally or even year-round alternative source for good quality water (rainwater is the cheapest form of raw water). This is important for areas where harmful chemicals or pathogenic bacteria or pollutants contaminate soil or surface water and/or in areas of acidic surface water.

The rainwater harvesting systems can be operated and managed individually, as well as by community/utility. Rainwater collected using different methods has less of a negative impact on the environment compared to other water resource development technologies. The rainwater's physical and chemical properties are usually superior to groundwater sources which may have been contaminated. Rainwater is relatively clean and for many purposes the quality is usually acceptable with little or no treatment (CAWST, 2011).

The technologies for rainwater harvesting are flexible and can be built to meet almost any requirements. No labor-intensive construction, operation, and maintenance (UN-Habitat, 2005). Global warming predictions could have a major effect in increasing significantly the demand for water in many cities. Increased evaporation from reservoirs and reduced river flows in some areas may also decrease the surface water supplies available. Further uncertainty about returns from large reservoirs and well fields is likely to make future investments in diversification of water sources, better water quality and water conservation even more prudent. The role of rainwater harvesting systems as sources of supplementary, back-up, or emergency water supply will become more important, particularly given the increased climate variability and the possibility of higher droughts and flood rates in many areas. This will be particularly the case in areas where the existing water resources are put under increasing pressure.

Throughout history Rainwater catchment systems have been used successfully by people all over the world. It is a technology that is flexible and adaptable to a wide range of conditions, used by the world's richest and poorest communities, as well as in the world's wettest and driest areas (UN-Habitat, 2005). Although rainwater harvesting may not be the definitive answer to all problems with household water, there are several technology advantages that make it a choice to be considered for domestic use in developing countries as indicated in articles 2.9.1.1 to 2.9.1.14 presented here under;

- Rainwater harvesting is convenient in the sense that it can provide water at or near the point where water is needed or used, resulting in time savings for women in need of extracting water from other distant sources and eliminating the need for complex and expensive distribution systems (article 2.9.1.1).
- Rainwater harvesting will supplement other water sources and facilities, thus reducing the pressure on limited supplies of water (article 2.9.1.2).
- Rainwater harvesting provides a buffer for use in emergency or failure periods of public water supply systems, particularly during natural disasters (article 2.9.1.3).

- People have full control over their own catchment systems, significantly improving household water safety and water conservation while reducing operational and maintenance issues (article 2.9.1.4).
- Technology is based on traditional methods and is fairly easy to build, install and run (article 2.9.1.5).
- Rainwater harvesting systems are versatile and can be designed to meet almost any requirements. Reconfiguring, expanding, or, in some cases, relocating systems is relatively simple (article 2.9.1.6).
- Local people can be equipped to build and install systems to harness rainwater, and construction materials are also readily available (article 2.9.1.7).
- Free Rainwater tool. While the design and installation of a catchment system entails capital costs, households can save money over the long run as they don't have to buy water from private vendors or pay for public services (article 2.9.1.8).
- The running and maintenance costs are also almost negligible (article 2.9.1.9).
- Rainwater's physical and chemical properties are generally superior to surface and groundwater supplies that may have been subject to pollution (article 2.9.1.10).
- Water collected from catchments on the roof is typically of acceptable quality for domestic use and application (article 2.9.1.11).
- Building a rainwater harvesting system in conjunction with household water treatment allows people to enjoy better water supply and quality linked to improved health (article 2.9.1.12).
- Because rainwater is captured using existing structures (e.g. rooftops, parking lots, playgrounds, parks) not specifically built for this purpose, rainwater harvesting has few negative impacts on the environment relative to other water supply technologies, such as dams and piped systems (article 2.9.1.13).
- Domestic rainwater harvesting emphasizes the production of small scale, community-based self-help (article 2.9.1.14).

2.10. History of water harvesting in Ethiopia

The history of water harvesting in Ethiopia dated back to 560 BC when rainwater was harvested and stored in ponds for agricultural and water supply purposes (Getachew, 1990). However, Alison et al., (2013) suggested that rainwater harvesting has a higher cost per household in rural areas than other water source solutions such as safe springs and hand pump boreholes (Alison et al., 2013). Moreover, in Ethiopia, there is evidence that ancient churches, monasteries and castles used to collect rainwater from roof tops, and the history of RWH by the Aksumite Kingdom dates back as early as 560 BC (Mitiku et al., 2001). During this period, rainwater was harvested and stored in ponds for agricultural and domestic water supply purposes. The anthropologist Fattovich, (1990) documented evidence of remains of ponds that were once used for irrigation during this period. The roof is still evident in the ruins of one of the oldest palaces in Axum, the residence of the famed Queen of Sheba. Other evidence includes the ruins of one of the old castles in Gondar, built in the 15th-16th century, which used to have a water collection facility and a pool used by the kings for religious rituals.

The Konso people in the country's south have a long and well-established tradition of building level terraces for harvesting rainwater to successfully grow sorghum in extremely harsh environments; low, unpredictable, and unstable rainfall conditions (Hailemichael, 2011). It is indeed one of this country's wonders and has been practiced for millennium; a symbol of the Konso people's struggle for survival against nature's adversaries Hailemichael, (2011) shows that everybody in the farming system acquires terrace building skills as part of routine farming practices. Thus the rainfall is essentially diverted by walls and channels carefully constructed. Researchers noted that this is a country where indigenous knowledge and traditions are recognized as having been listed as a UNESCO World Heritage Site by the' Konso cultural landscape (Alamerew et al., 2002). Over the past few decades, efforts to promote water harvesting have created some bright spots, particularly with micro watershed initiatives, including water harvesting as part of an integrated participatory approach to sustainable land management. In addition, there are various half-moon ponds in Tigray, Northern Ethiopia promoted for water resource conservation (Mekonnen and Haile, 2010).

Agriculture in Ethiopia is predominantly rainfed, with a potential of almost 3.5 million ha of land suitable for irrigated farming (Awulachew et al., 2005). Over the past three decades, the population has grown rapidly, growing from 25 million in the 1960s to almost 90 million in 2014, placing increased pressure on agricultural land, forests and the atmosphere. Rainwater harvesting and management (RHM) therefore play a paramount role in can benefit yields and sustaining the growing population (Awulachew, 2010). Run-off irrigation (run-off farming), flood spread (spate irrigation), in-situ water harvesting (ridges, micro basins, tillage storage, etc.) and roof water harvesting are the most commonly used RWH techniques in Ethiopia today.

The value of these methods was not recognized until recently, although they date back to the antiquity, following the catastrophic drought and famine of the 1980s (Getachew, 1999). RWH is a simple low-cost technique that requires minimal knowledge or expertise and provides several advantages. It has restored interest in Ethiopia as an essential replacement or supplementary water resource (Desta, 2003). The use of rainwater is now an option along with more ' conventional ' water supply technologies, especially in rural areas, but also more and more in urban areas. RWH has been shown to be of great value to arid and semi-arid countries or regions such as Ethiopia where more than 66 per cent of the country is classified as arid and semi-arid (Georgis, 2000).

Irrigation production and farm water management have tremendous potential to improve productivity and reduce vulnerability to climate instability in any country (Awulachew, 2010). Though Ethiopia has plenty of rainfall and water resources, its agricultural system still does not fully benefit from water management and irrigation technologies (Georgis, 2000). Most of Ethiopia's rural residents are among the country's poorest, with limited access to agricultural technology, limited opportunities to diversify agricultural production despite underdeveloped rural infrastructure and little or no exposure to agricultural markets and technological innovations (Awulachew, 2010). A field experiment was conducted under natural rainfall conditions to investigate the effects of manure and straw mulch on runoff, soil loss, in-situ water conservation and yield and yield components of an improved bread wheat variety (HAR-1480) grown on the Vertisol of Sinana district, southeast Ethiopian highland. The results revealed a very significant difference ($P<0.0001$) between the treatments with respect to their effect on runoff depth, soil loss and in-situ water conservation (Birru et al., 2012).

2.11. Rain water harvesting practices in Ethiopia

Agriculture in Ethiopia is the fundamental of the country's economy, in which half of the gross domestic product (GDP) and 84% of export with 80% of total 110 million populations are engaged in this sector. The reliance of the farming system on rain-fed agriculture has, according to Conway and Schipper, (2011), made the agricultural economy of Ethiopia extremely exposed to weather and climate effects. The failure of rain and the occurrence of drought or consecutive dry periods during the growing season lead to crop with dramatic economic consequences. And Ethiopia is strongly influenced by climatic and hydrological variability's that are reflected as dry spells, droughts, and floods. Droughts and floods, with major events every 3-5 years, are becoming widespread with a growing frequency compared to two or three decades ago.

Watersheds, farms, and pastures are devastated by droughts, leading to land loss and causing crops to fail and livestock to die (Awulachew et al., 2005). Hence, there is now increasing interest in the low-cost alternative generally referred to as “Rain waters Harvesting” (RWH). Improving rainwater harvesting (RWH) can improve agricultural production by making water available during the time of dry periods. RWH is the intentional accumulation and storage in physical structures or within the soil profile of rainwater from a surface known as catchment (Mati et al., 2006). In response to the negative impacts of climate change, the Government of Ethiopia and non-governmental organizations have implemented various rain water harvesting technologies (RWHTs), defined as technologies used to collect water from surfaces on which rain falls, and subsequently storing this water with the particular aim of meeting the demand for water by humans and/ or human activities (Malmer et al., 2009). RWHTs include household reservoirs, roof water harvesting and tanks, and runoff irrigation (runoff farming), flood spreading (spate irrigation), in-situ water harvesting (ridges, micro basins, etc.) and roof water harvesting are the most widely performed RWH techniques in Ethiopia (Nasir and Fekadu, 2016).

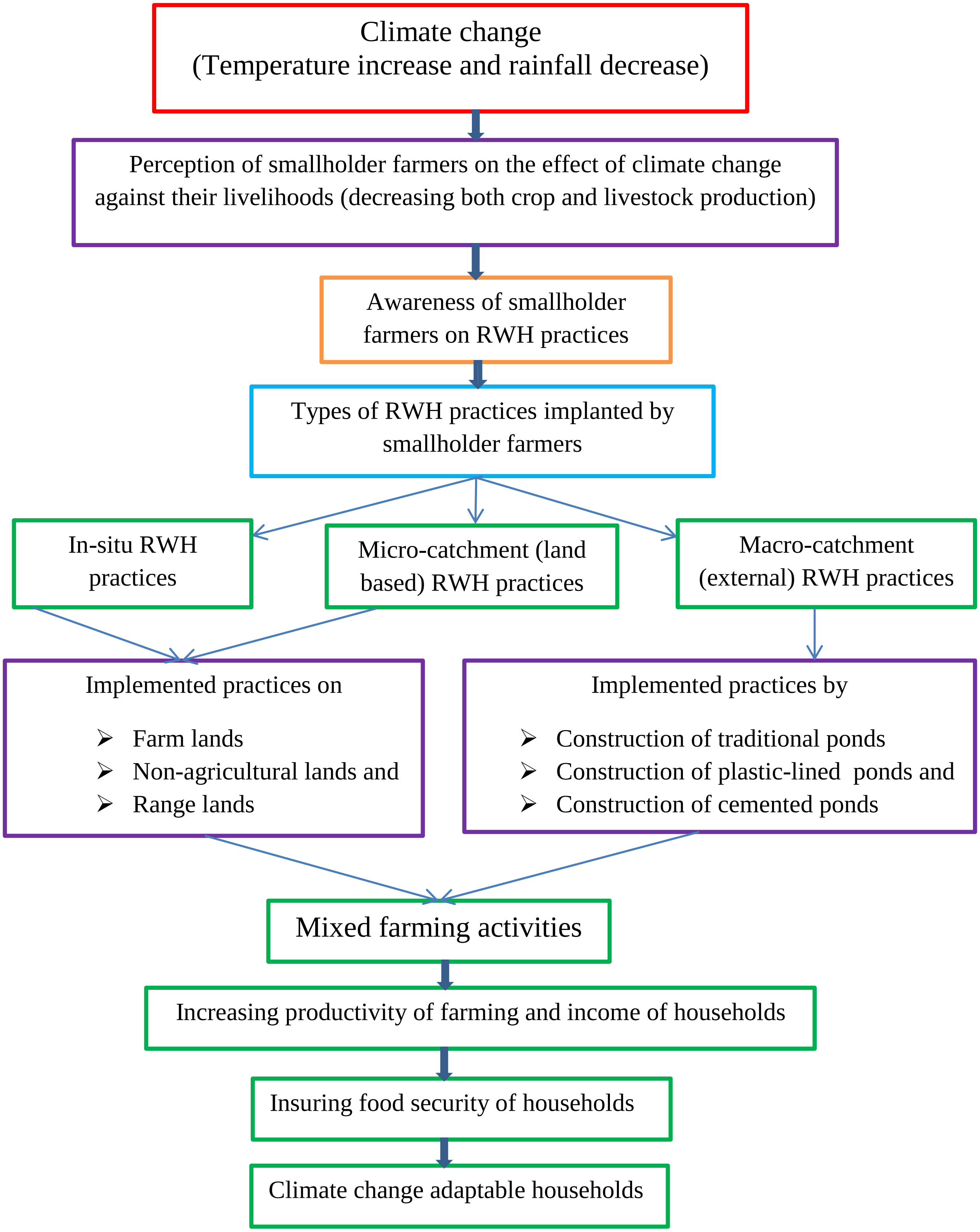
The Ministry of Agricultural development and respective regional Bureaus planned and implemented aggressive and ambitious water harvesting programs along with the country’s food security programs (Desta, 2006). Moreover, the objective is that the adoption of water harvesting technologies, households would be food self- abundant and the surplus would be generating income. Moreover, revenue has been generated through the selling of water. The results from flood diversion (spate irrigation) give the farming community trust in Kobo Ethiopia. Traditional flood harvesting systems in Kobo are that farmers who know how to apply themselves with their own tools are entirely handled by the technique (Nigigi, 2003). Similarly, the people in Konso, Gidole and many other parts of Wolayta and Wollo, the southern part region, have been exercising the art of conserving soil and water; hence, rainwater harvesting can contribute to sustainable agriculture, decrease the costs of supplementary irrigation and rise yields of crops in most semiarid lands Worldwide (Riksen et al., 2016).

2.12. Review of Empirical Literature

Drought is among the most detrimental, and least understood, of all “natural” hazards. Though some droughts last a crop calendar and affect only small areas, the instrumental and pale climate records show that droughts have occasionally continued for decades and have impacted wide areas. The negative societal consequences of drought include extreme economic losses, famine, epidemics, and land degradation (Beguería et al., 2010). Ibraimo, (2007) indicated that despite the effectiveness of some water conservation techniques, adoption by farmers has been poor mainly because of several factors among them high labor intensity. Besides, following, some of the empirical studies related to the study at hand either in the issues or methodologies used will be discussed. Azizi, (2013) conducted a research on analyzing influencing factors in adoption of RWH technology in Lanfuro woreda, Ethiopia. The study showed that among twelve explanatory variables hypothesized in affecting RWH technology adoption, man-equivalent labor availability, farm size, total owner-owned tropical livestock unit, market distance from residence, household sex, off-farm revenue, and extension service were found to be important in affecting RWH technology adoption. Ephrem, (2006) research conducted on impact assessment of RWH technologies in Tigry, Ethiopia that showed of the total users of the households include in to the survey 73% were adopted plastic lined RWH ponds. The estimation result of probit model showed that age, farm size, soil type and plot distance have statistically significant correlation with adoption of RWH technology. Age and plot distance have showed a negative correlation while farm size has showed a positive and significant association with adoption of RWH technology. The same study showed that the shallow type of soil has a positive and substantial association with RWH technology adoption. The family size, sex, and level of education showed no significant association with RWH technology adoption. Moreover, the result of a study conducted by Ngigi, (2003) in Kobo, Ethiopia showed that the household head's level of education showed a positive and meaningful correlation with RWH technology adoption. Sambrook and Akhter, (2001), however, recorded a non-significant association between household head education level and roof water harvesting use in Uganda. Meanwhile, the study undertaken by Tesfaye, (2006) in analyzing factors affecting adoption of rainwater harvesting technology in Dugda Bora Wereda, East Shewa, Ethiopia indicated that out of 13 explanatory variables hypothesized to affect farmers' decision to use RWH technology, sex, labor availability, farm experience, leadership status, off-farm income, farm size, total tropical livestock unit, extension service, plot distance and market distance showed a significant relationship with adoption of RWH technology. Rebeka, (2006) suggested that family size and level of education had an important and positive impact on the adoption of plastic-lined RWH ponds, but plot distance was found to have a negative impact on the adoption of RWH ponds. Besides Hugo, (2003) reported the failures of many RWH structures and low adoption of these technologies in Dessie Zuria Wereda, Amhara Region of Ethiopia was due to mistakes in the design of the structure and use of materials. With this particular problem, lack of awarenessraising, lack of qualified water harvesting and construction professionals, and inadequate selection of sites were justified for lower adoption and use of RWH technology in the Area. Furthermore, the study by Molla, (2005) in Dejen, Ethiopia using multinomial logit model revealed that farm size has a positive and significant impact on adoption of RWH ponds but there was a negative and insignificant association between plot distance and the use of RWH ponds. The same study reported a non-significant association between TLU and use of underground RWH technology. The negative sign of the coefficients indicates that, as the distance between the plot and the homestead is large, farmers are not interested in any type of RWH technology. It will be difficult to closely monitor RWH structures if the structures are located in a distance. Meanwhile, in studying the impact of rainwater harvesting in Tigray, Mitiku and Sorssa, (2002) found that extension services in soil and water conservation and high labor requirements for the construction and implementation of RWH activities were identified as key factors contributing to the low adoption of RWH practices. The aim of this study differs from the previous mention, mainly concerns on role of rain water harvesting practices for climate change adaptation.

2.13. Conceptual Framework of the Study

A conceptual framework is a basic structure that consists of certain abstract blocks which represent the observational, the experiential and the analytical or synthetically aspects of a process or system being conceived that researcher believes can best explain the natural progression of the phenomenon for a given study (Camp, 2001). It is well known that water is the major limiting factor for farming, forestry and animal husbandry and it is also key factor for environmental improvement. Limited and erratic precipitation often results in crop failure as well as serious soil and water loss but rainfall harvesting can change the distribution pattern of runoff generated from rainfall in time and space, which would supply humankind with steady water sources to some extent. Rainwater harvesting would provide the possibilities of setting up new agricultural ecological system and improve ecological environments. The eco-climatic conditions, rainfall quantity and pattern are the most important factors. In this regard Erickson, (2012) stated that Rainfall quantity is the most unpredictable variable in the calculation (Xiaoyan , 2002). Hence, reliable rainfall data for a period of at least ten years is considered to calculate the potential rainfall supply for a given catchment and the rain fall data from the nearest stations with comparable conditions are preferably considered. However, Goyal, (2005), stated that there are new water harvesting technologies, which involves social (such as gender issues influencing the adoption and use of rainwater harvesting systems), ecological (effect on local biodiversity and crop production, ground water levels and soil erosion) and economic (such as willingness to pay, seasonal variations in water costs etc) implications. The better rainwater harvesting practices/ technologies are driven by a clear understanding of the specification, can conserve the biodiversity in home gardens by promotion of agro forestry systems. Moreover, all the factors have different effects on the adoption rate of the rain water harvesting techniques. The important role of financial, human and land resources endowment of a household is very vital in the decision of the household on whether to adopt any newly introduced agricultural techniques; (Cheserek, 2013). In this regard, Goyal, (2005) stated that economic parameters are like the benefits to the masses in comparison to the cost in terms of water and irrigation security, food security, fodder security and ensured employment through agriculture. But the major contribution is from people's participation or social sustainability of the project. If peoples' participation is achieved it can lead to better implementation of the project, growth of the project and maintenance of the created infrastructures on sustainable basis. Rainwater harvesting practices is a paragliding term describing methods to collect and concentrate various types of runoff from different sources and for different uses. Runoff harvesting is the deliberate accumulation (catchment) of rainwater from a surface and its storage to provide water supply (FAO, 1994). Hence, according to Peshkin, (1993), the conceptual framework is linked with the concepts, empirical research and important theories used in promoting and systemizing the knowledge espoused by the researcher. Therefore, the figure below is indicated the logical processes and results in RWH practices and their roles for farmer on climate change adaptation of the selected area.



Source: own by the researcher

Figure 1: Conceptual Framework of the study

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1. Description of the Study Area

3.1.1. Location, extent and population

This study was conducted in the Minjar Shenkora *Woreda*, which is one of the 24 *Woredas* of North Shewa zone. The geographical location of the study area extended from 8°42'46" to 9°07'37" N latitude and from 39°012'57" to 39°046'53"E longitude (Figure 2). Minjar Shenkora *Woreda* has 29 *kebeles*, of which 27 rural 2 urban *kebeles* (Ararti and Balchi), where Ararti town is administrative center of the *woreda*. Minjar Shenkora *woreda* covered 1,596 km², of which 35% (55,860ha) cultivated agricultural land and 65% are non-cultivated lands (MSWADO, 2020). As per projection of CSA, (2013) data, the total population of the *woreda* in 2017 estimated to be 152,530 of which 77,872 were males and 74,658 were females. Of the total population 91.60% (139,723) reside in the rural areas.

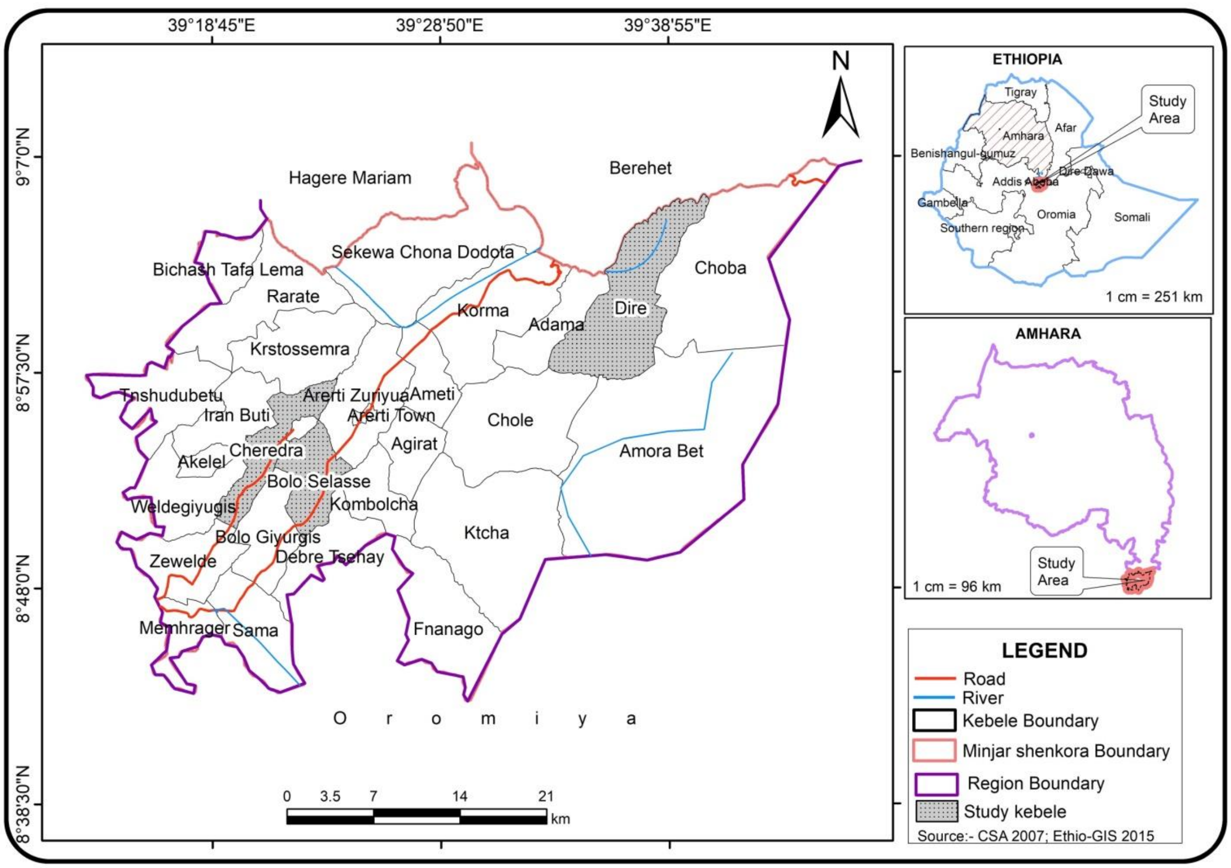


Figure 2: Location map of the study area

3.1.2. Relief and soil type

Even if there were various types of landscape in the Minjar Shenkora *Woreda*, most (84%) of the study area is characterized by plane lands and the reaming 16% areas are hilly and mountainous. The altitudinal range between 1040 and 2380 m.a.s.l. which an average of 1710 m.a.s.l. Due to flat terrain, most of the farmlands in the *woreda* are suitable for agricultural mechanization, have relatively low soil erosion problems but are prone to water lodging (Behailu, 2014). The most dominant soil type in the study area is brown soils that account for about 46.5% of the total area. Although their area coverage is very small, other types of soil also exist, these are gray, black, and red soils with account for 19.5%, 19%, and 15%, respectively (Behailu, 2014).

3.1.3. Climate of the study area

Climate has a great effect on influencing people's day-to-day social, economic, and cultural activities. Consequently, different types of climate diversified the way of life in society. Since Ethiopia is has a wide range of topographic setting varying from extremity lowlands at Danakil Depression in the grate rift valley to very high mountains like Ras Dashen country possess diverse temperature and rainfall that mainly depends on the altitudinal variation, as a result, there are five agro-climatic zones in the country (Hurni, 1998). As indicated in above section the elevation of the study area varies between 1040 and 2380 meters above sea level (m.a.s.l), agro-climatically it falls into three local class as per Hurni (1998) namely: *Kolla* (hot lowland with an elevation of 1040-1500 m.a.s.l), *Woina Dega* (warm/milled midland having 1500-2300 m.a.s.l) and *Dega* (cool highlands with over 2300 m.a.s.l). The *woreda* largest area (70.9%) is found under the *Woina Dega* agro-climatic region, which is followed by *Kolla* (24.8%) and *Dega* (4.3%), respectively Hence, the mean annual rainfall varied from 700 - 950 mm with a bimodal pattern and the main rainy season falls from July to September that contributes about 65% of the total rainfall which locally called *kiremt* season. The second-highest amount of rainfall recorded in the spring season ranges from March to May which is locally known as *Belge* season that covers 17% of the annual rainfall. The reset season autumn (locally *Tsdey* season occurring between September and November) and winter season (locally named as the *Bega*) receive 13% and 6% respectively. The mean annual temperature varies from 10.6°C to 27.4°C (MSWADO, 2020).

3.1.4. Economic activities

The livelihood of the largest (94%) number of households depends on agriculture, while the remaining people depend on non-agricultural activities like trade (3.9%), handcraft (1.2%), and daily laborer (<1%) works (Behailu, 2014). The main crops grown in the area include teff (*Eragrostis abyssinica*), wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), maize (*Zea mays*), sorghum (*Sorghum bicolor*), chickpea (*Cicer arietinum*), field pea (*Cicer arietinum*), lentil (*Lens culinaris*) and different vegetables. Of all crop types, teff is largely produced that accounts for 21.97% of crop production, which is among moisture stress (drought tolerant) and early maturing crops. Livestock production has also a major role in the farming system of the *Woreda*. The major livestock types are cattle, goats, sheep, donkeys, camels, poultry, and beekeeping. Of the different livestock types, camel and goats are among climate change adapting as they are leaf browser. According to the *woreda* agriculture office report, the average household landholding is about 1.5 ha (MSWADO, 2020).

3.2. Research Methods

3.2.1. Research design

The research employed cross-sectional research design methods to assess the overall data at one time. The analysis used descriptive statistics as the method is the best way to describe the practice, activities, and process as it currently exists (Creswell, 2014). In addition, a descriptive research design helps the researcher report what will happen or what is going to happen in a real-world setting. Also, the research also used mixed research approaches that applied both qualitative and quantitative data types.

3.2.2. Sampling techniques, procedures and sample size determination

Due to different constraints, conducting a study on the complete enumeration of all population or census survey is difficult to cover, particularly if the investigation is broad (Kothari, 2004). Therefore, that sample design is a definite plan to get a sample from a given population that applied well-planned sampling technique, procedures, and sample size determination methods as detailed hereunder.

A) Sampling Techniques

The method of sampling used depends on the existence of the population, the type of investigation, and the degree of precision at the minimum cost desired (Van Dalen, 1979). Taking this into account, stratified and simple random sampling methods were used to pick the desired population of the samples. Hence, in order to obtain the relevant data, the sample population was purposefully selected from the study area. Thus, the study's target populations were focused on the total population selected *kebeles* of Minjar Shenkora *Woreda*. Accordingly out of 27 rural and 2 urban *kebeles*; three rural *kebeles*, namely Dire (lowland), Bolo Selassie (midland), and Cherecha (highland), were purposefully selected as they represent the three agro-ecology of the study area. In addition to the agro-ecology of the sample *kebeles*, accessibility of sample *kebeles* was considered while choosing from *kebeles* with similar agro-ecological settings. These *kebeles* were selected from different agro-climate zones on the assumption that smallholder farmers may have differences in their rainwater harvesting (RWH) practices and skills across the different agro-ecological systems that might result from deferens in their adaptive capacity in the communities. As climate change can have different impacts in different agro-ecological zones, different adaptation strategies can be practiced by the farmers in the respective agro-ecologies. These strategies are also shaped by the area's biophysical, socioeconomic, and socio-cultural context (Belay et al., 2017).

B) Sampling Procedures

In order to draw a representative sample for the study, three stages of sampling procedures were used. The procedures include first purposefully identified the study *woreda* (i.e., Minjar Shenkora *woreda* of North Shewa zone), which was followed by a purposeful selection of sample *kebeles* and finally random sampling of survey households.

C) Sample Size Determination

Once sampling techniques and procedures have been identified, the remaining task was to determine the representative sample and size to be included in the study with respect to the total population of the household head of the study area. The total household head populations of the three selected *kebeles* were 2,586 from that 5% (127) of the total population of RWH practice implementer household heads by aspects of cost and time (Van Dalen, 1979). From 127 of HHs head participants, 100 of them are randomly selected for household survey, 24 for FGDs, and 3 for KIIs participants. For household survey participants, the researcher determined the sample size of each stratum population by applying the proportionate stratified sampling formula of (Kothari, 2004).

Total population size = N= 2,586

Total sample size = n = 100

The proportion of population included in stratum $i = ni$

The number of population from each stratum $i = Pi$

Number of proportion population from each stratum = $n\ (Pi\ /N)$

- Population in the strata of Dire Kebele $n1 = n.\ P1 = 100\ (974/2{,}586) = 38$
- Population in the strata of Bolo Selasse Kebele $n2 = n.\ P2 = 100\ (898/2{,}586) = 35$
- Population in the strata of Cherecha Kebele $n3 = n\ .\ P3 = 100\ (714/2{,}586) = 27$
- Total……………………………………………………………100

Table 1: Distribution of sampled households by the Kebele

Nº	Name of the Kebele by agro-ecology	Population Size	Sample Size
1	Dire (lowland)	974	38
2	Bolo Selasse (midland)	898	35
3	Cherecha (highland)	714	27
	Total	2,586	100

Source: MSWADO, 2020

3.2.3. Data Sources and Methods of Data Collection

As indicated in the previous section, both qualitative and quantitative approaches were used in the study. Since the use of both types of data is vital to offset the limitations inherent in one method with the strength of another method (Creswell, 2014). In addition, the primary data and secondary data sources were used to obtain consolidated data in order to ensure reliable findings. Primary data were collected using both quantitative and qualitative data collection methods. The employed data collection method was household (HH) surveys to generate quantitative data, while qualitative data were collected through Focus Group Discussions (FGDs), Key Informant Interviews (KIIs), and field observations. Data collection tools, such as questionnaires and checklist/guideline, were prepared as detailed hereunder.

A) Household Survey

Structured survey questionnaires were prepared and the survey covered randomly selected 100 sample households. The survey questioner applied closed-ended questions to get quantitative data about local farmers' perception of climate variability; its impact on their livelihood, adaptations practices, implementation challenges, and roles of RWH practices for their livelihood. The survey questioner was tested before the actual survey and then translated into the local language (*Amharic*) to ease the survey process and reduce the commendation gap. The survey data was collected by employed data collectors. Therefore, I have trained the data collectors about the survey process before the data collection.

Source: own survey, June 2020

Figure 3: Photo during household survey data collector on training

B) Focus Group Discussion

The other method of primary data collection was focus group discussion (FGD). It helps to generate data on group dynamics and allows a small group of respondents to guide by a skilled moderator to focus on the key issue of the research topic (Mwanje, 2001). The researcher selected 8 respondents with 2 groups (male and female) which have member of 4 participants in each kebele based on the COVID 19 protocol during data collection time. The FGD participants were selected purposively from each of the three chosen *kebeles* who represent model farmers, female household heads, community elders, and leaders of other social institutions (e.g., *Idir*, *Senbete*) members from each of the sample *kebeles*. In total, 2 FGDs (one male and one female FGD) conducted in each *kebele* that yielded an overall total of 6 FGD in the entire study. The in-depth discussions were carried out so as to have the views, and use of RWH practices, about climate change effects and their adaptation mechanisms.

Source: own survey, June 2020

Figure 4: Photos during focused group discussion with local farmers in the study area

C) Key Informant Interviews

KII was conducted through a semi-structured interview method because of its flexibility and makes clear any time when there is ambiguity (Mikkelsen, 2005). The KII was done with 9 purposively selected individuals from Woreda Agriculture and Rural Development office head and experts (3), Kebele development agent (3), and Kebele administration (3) at a rate of 1 from each selected three *kebeles*.

Source: own survey, June 2020

Figure 5: Photo during Key Informant Interview participants in the study area

D) Field Observation

According to Robson, (1995) field observation is used as a supportive technique to collect data that may complement or set in perspective data obtained by other means. By the time of staying in the study area, RWH activities on the ground were observed. The observation also focused on major development interventions, farming activities, topography/relief, people's perception, and related things. During the field observation, a note was taken regarding what has been happening so as to cross-check the data found through other instruments as another important primary data collection tool.

E) Secondary Data Source

Secondary data were collected from published and unpublished documents such as; conducted research papers, criteria, guidelines, internet, and policy documents which were the basis for research as well as other important reports and documents relevant to the study from *woreda* office was used as a supplement to the primary data.

3.2.4. Data analysis

Upon completion of the data collection, the analysis and presentation of the data were carried out by filtering the inaccuracy, inconsistency, incompleteness, and illegibility of the raw data to make the analysis very easy. Manual writing, labeling, data entry, and accuracy tests were done to solve these problems. Both quantitative and qualitative methods were used to analyze the data. Primary data collected from the sampled household survey was processed and analyzed using quantitative descriptive methods using the Social Science Statistical Package (SPSS v.20). The descriptive statistics analysis result was presented in percentages and frequencies. The qualitative data gathered through focus group discussion, key informant interviews, and field observations were transcribed and analyzed through the narrative analysis method. Secondary data obtained from published and other documents were used to support the primary data during the analysis and interpretation. Finally, the result was discussed and interpreted in order to draw important conclusions and come up with recommendations.

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1. Household head characteristics

The survey of household head characteristics are presented in Table 2. The survey covered sample households who participated in rainwater harvesting technology for climate change adaptation representing three agro-ecology from Dire (lowland), Bolo Selassie (midland), and Cherecha (highland). The distribution of sample HHs selected from Dire, Bolo Selassie, and Cherecha *kebeles* were 38%, 35% and 27%, respectively. Of the total sample HHs, 87% were male head households and the remaining 13% were female head households. Based on the age of the survey HHs, 22% of the participants were below 40 years old and 69% of the participants were between 41-60 and the rest 9% of the participants were above the age of 60. Thesis shows that middle age farmers adopted the practices than other age group. In line with this study conducted by Djibo and Malam Maman (2019) showed that agricultural technology adoption decisions making by farm households determined by the age.

Table 2: Household head characteristics

Characteristics	Categories	Frequency (N)	Percentage (%)
Kebele	Dire(Lowland)	38	38
	Bolo Selasse (Mid Land)	35	35
	Cherecha (High Land)	27	27
Gender of household head	Male	87	87
	Female	13	13
Age	<40	22	22
	41-60	69	69
	>61	9	9
Family size	1-3	29	29
	4-6	58	58
	>6	13	13
Education	Illiterate	36	36
	Read and write	43	43
	Primary education (grade 1-8)	18	18
	High school(grade 9-12)	3	3
Marital Status	Married	83	83
	Divorced	4	4
	Widowed	13	13

Source: own survey, June 2020

As education level is very important for agricultural technology adoption (Djibo and Malam Maman, 2019), the survey also assessed the educational level of the survey participant. The survey revealed that 36% heads of respondent households were illiterate, 43% able to read and write, 18% of the participants attended primary education (grade 1-8) and the rest (3%) of the participants educated up to high school (grade 9-12) level. In general majority (64%) of households at least can read and write, thus this tells that education status of the survey respondents might helped adoption of water harvesting technology. In relation to this *woreda* KII respondents underlined that literate farmers have more motivation and interest to involve in trainings and technology uptake. The other pertinent household character in rural areas is marital status as it has a direct relation with agricultural labor availability. Hence, the survey included the marital status of the sample household head, which revealed that the majorities 83% of the survey participants were married, 4% were divorced and 13% were widowed.

As revealed by the survey, like most rural parts of the country almost all 100% HHs livelihood depends on mixed farming, who engages both in crop and livestock production (Table 3). According to CARE, (1998), livelihood activity is used to denote the range and combination of activities and choices that people undertake in order to achieve their sources of livelihood. It is well known that agriculture, particularly crop production is the major livelihood means for rural people in the Ethiopian highland. Crop production and Livestock production and adaptive capacity of households for climate change are determined by farmland holding. Those HHs who own relatively better farmland size have a high likelihood to have higher production, thereby enabling more storage (reserve) and cope up with climate-related calamities. Hence, the assessment captured the household's farmland ownership and holding. In this regard, as shown in table 3 the assessment showed that 100% of the survey participants' household heads own farmlands even though size varies. Accordingly, the majority (44%) of respondent HHs own 1 to 2 hectares of farmlands, followed by HHS owning 2-3 ha that account for about 29% of respondents. Unlike rural HHs of the region, a considerable proportion (19%) of respondents own over 3 ha of farmlands. Like most parts of the region, HHs owning less than a hectare of farmlands also observed that account for about 8% of the survey population. In general, 73% of the respondents have 1 to 3 ha of farmlands. Agricultural labor is among critical factors that determine HHs participation in labor-intensive activities like soil and water conservation practices including rainwater harvesting. Households require family labor not only in the construction of RWH structure but also for operation purposes for water uplifting and irrigation practices using the RWH facility demand labor. Hence, the survey assessed family size disaggregation, which showed that the majority (58%) of survey respondents have 4 to 6 family members, while three fourth (29%) have 1 to 3 family members in their household and about

13% of the survey participants have more than 6 family member size in their household. Thesis shows that majority of survey households don't have critical labor shortage to involve in water harvesting technology construction and irrigated agriculture.

From the response of sample households, it was observed that 42% households have other sources of income beyond agriculture, while the rest 58% households didn't have yet (Table 3). According to the report by Temesgen et al., (2008), other source of income increases the probability of using agricultural technologies as adaptation options. In line with this, extra income has positive and significant relationships on using improved crop and early maturing crop verities.

Table 3: Sample household's means of livelihoods and income source beyond agriculture

Questions	Category/response	Frequency	Percent
Do you or any member of your family have other source of income listed from the above?	Yes No	42 58	42 58
Livelihood occupation, participated (both Crop and Livestock production (mixed farming)	Yes	100	100
Farmland ownership	Yes	100	100
Farmland size (in hectare)	<1 ha 1-2 ha 2-3 ha >3 ha	8 44 29 19	8 44 29 19

Source: own survey, June 2020

As stated earlier, a sampled household of the study area can generate income from mixed farming activities. Analysis of other sources of income types by the sampled households during the survey year was summarized and presented in Table 4. The survey result indicated that the sampled households could generate a mean annual income of Birr 1,961.54 to 4,538.46 by engaging in small business such as for the sale of additional agricultural produces (e.g., seedlings, local drinks, perennials crop produces and spices), by engaging in pity trading activities, water fetching, and also from remittance, daily labor work. This refers to whether the household has an additional income other in addition from agricultural production (crop and livestock production). In relation to this, studies conducted by Charlotte and Cathryn (2000) and

Tesfaye, (2006) on factors affecting households the adoption of water harvesting practices with additional income showed positive relationship between non-farm income and the adoption of water harvesting practices. Therefore, the analysis confirmed that non-farm income has a positive relationship with the adoption of RWH ponds.

Table 4: Other income source of sample households by income types

Types of income	Frequency	Percent	Net income in Birr in the year 2020		
			Minimum	Maximum	Mean
Sale of seedling	14	14	1,000	6,000	3,714.29
Sale of local drink	16	16	1,500	5,000	2,718.75
Pity trade	11	11	1,500	6,000	3,454.55
Daily labourer	10	10	1,500	4,000	2,650.00
Sale of water	13	13	2,000	10,000	4,153.85
remittance	13	13	3,000	6,000	4,538.46
Sale of perennials	14	14	1,000	5,000	3,171.43
Sale of spice	13	13	1,000	3,500	1,961.54

Source: own survey, June 2020

4.2. Farmers perception and variability to climate change

4.2.1. Farmers perception of temperature compared with metrological record

The result of the survey, KII and FGDs showed that participants recognized change in temperature and rainfall amount, timing and distribution over the last 10-20 years in the study area. Table 5 shows farmers view on climate change and its instability in the study areas, accordingly 58% survey participants believe that the dry season temperature showed sever increase, while 41% rated the increases as moderate. In contrast, only 1% survey participants believe that dry season temperature in the study area is not changing, suggesting that climate change has increased primarily over the last 10-20 years. The National Metrological Agency (2001) report revealed that in Ethiopia climate variability and change is mainly manifested through the variability and decreasing trend in rainfall and increasing trend in temperature. Therefore, farmer perception about climate change (mainly rainfall and temperature) aligned with report of metrological agency of Ethiopia. Climate variability is a complex phenomenon, which is caused by a mixture of natural and human induced factors. In particular, as indicated in the previous sections, a number of socio-economic, demographic, political, and environmental factors influence sustainable natural resource use and management practices.

Therefore, various individuals give different emphasis and significance to various variables related to the dimensions of climate variability and adaptation activity. For example Morid et al., (2007) emphasized that understanding climate variability is essential for better quantification of processes related to hydrological cycle in order to improve long-term forecasting of extreme events such as droughts and apply appropriate technology including water harvesting.

It is well known that droughts have potential impacts on society, environment and economy (Santos et al., 2010). In relation to this almost all (99%) survey respondents, FGD and KII informants confirmed climate change is prevailing reality of the study area which manifested through change in temperature during summer season and erratic rainfall. In fact studies showed that the globe temperature has increased by 0.7°C over the last century, where the major efforts have been made in the last decade (Santos et al., 2010; Ganguli and Reddy, 2014).

Table 5: Perceived Change in temperature

Perceived temperature change	Variables	Frequency	Percent
Dry season (Bega Temperature)	Severely Increased	58	58
	Increased	41	41
	No Changing	1	1
Summer season (Kirmet Temperature)	Severely increased	58	58
	Increased	39	39
	No changing	1	1
	Decreased	2	2

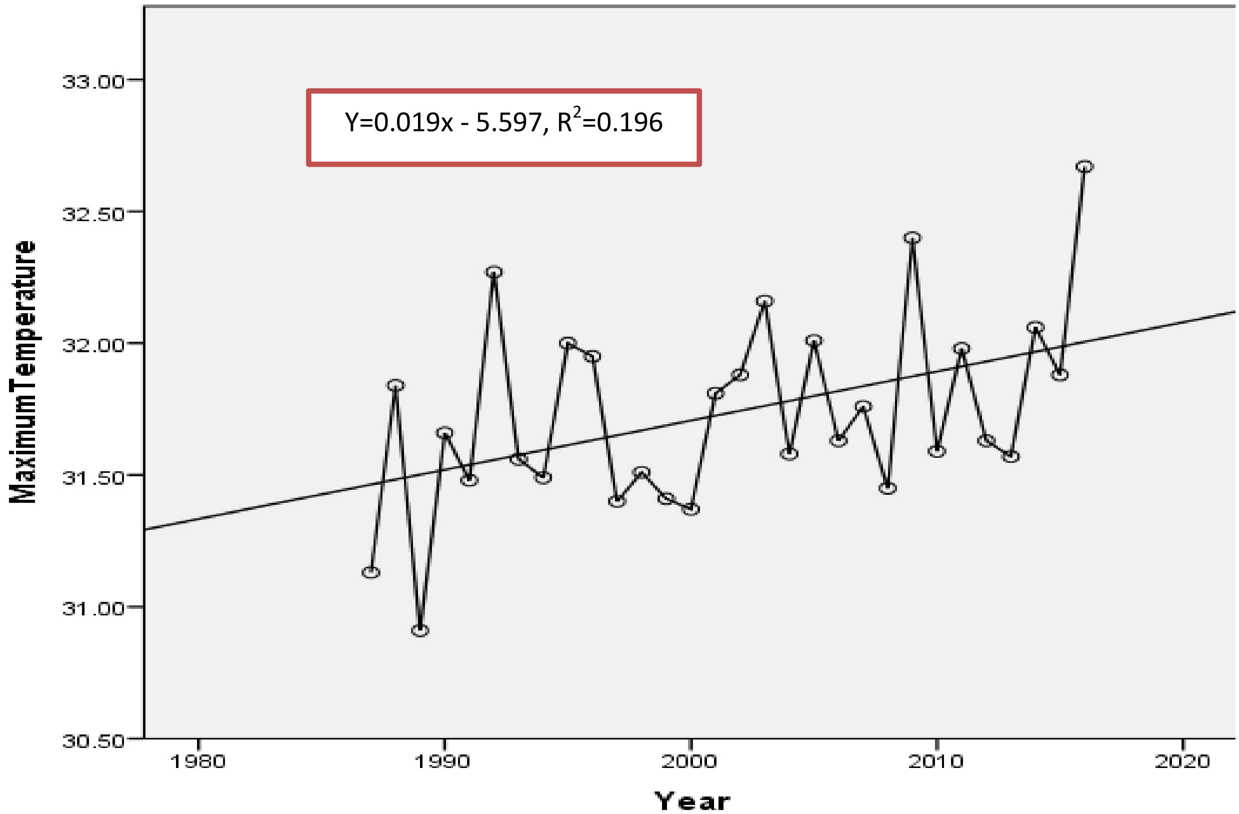
Source: own survey, June 2020

According to the data obtained from NMA in Figure 6, the annual maximum temperature ranges between 30.91ºC and 32.67ºC. The annual minimum temperature varies between 18.23ºC and 21.19ºC, whereas the annual average temperature of the *woreda* under study ranges between 25.05ºC and 26.68ºC, over the last 3 decades (Appendix I). The analysis showed that the temperature distribution of the study area was characterised by a general increasing trend and annual variability.

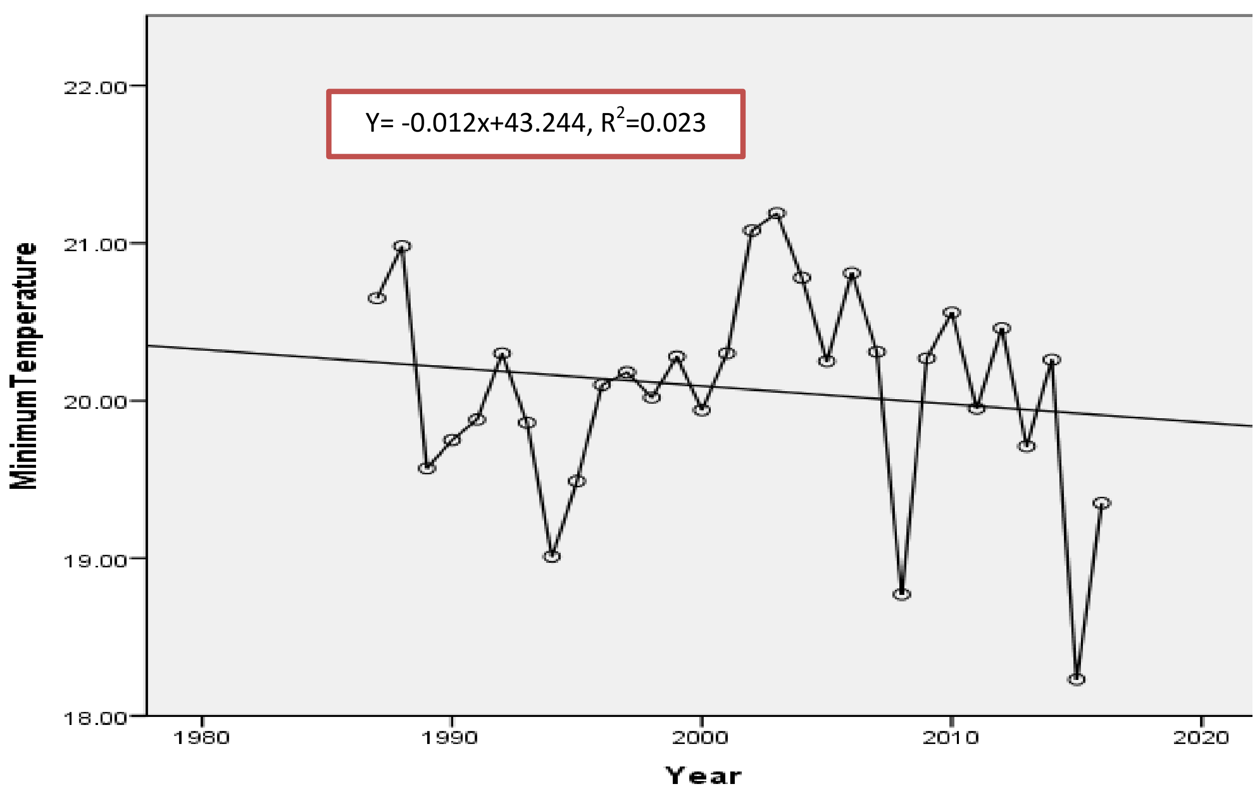
The rate of change of temperature in the area over time was defined by using a linear regression model. According to Mann-Kendall trend test (MT test) the model is significant as the p value (0.01) is less than alpha (0.05). The rate of annual maximum temperature change is defined by the slope of the regression line Figure 6, which in this case is about 0.019^{o}C; this means the maximum temperature increase by a rate of 0.019^{o}C per year and 0.19^{o}C per decade. Therefore, maximum temperature has shown significant increasing trend in the woreda.

In addition, simple linear regression model was deployed to define the rate of change in the annual minimum temperature over time. Hence, the minimum temperature is decreased by -0.012^{o}C per year and -0.12^{o}C per decade in the study woreda. In other hand, the annual average temperature change rate in the woreda was estimated by the slope of linear regression line. Hence, it increases by 0.004^{o}C per year and 0.04^{o}C per decade in this specific woreda.

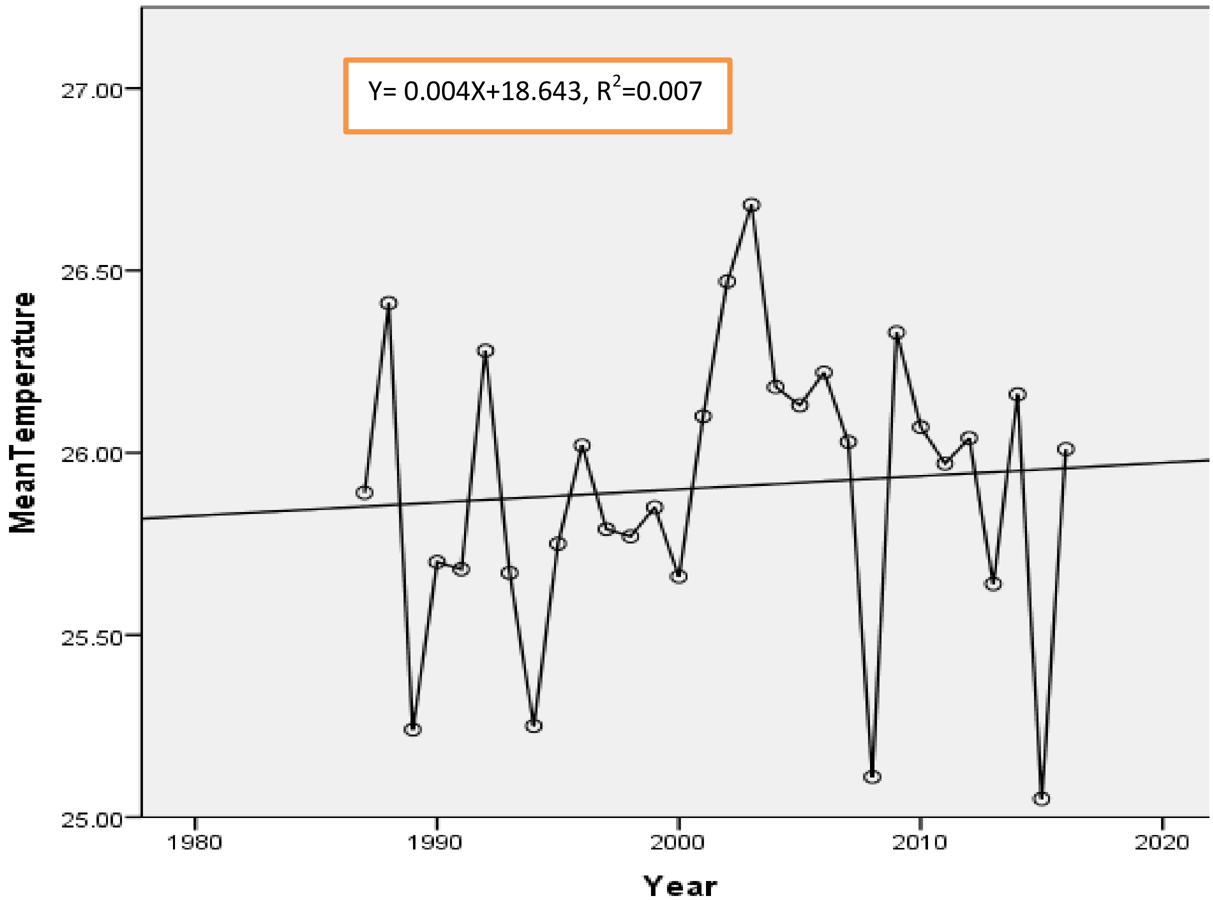
In general the NMA data reveals that, the rate of change in annual average temperature over time was defined using linear regression model the trend of temperature shows slight increment over the last 30 years. But household survey, KII and FGD participants explained that there is severe and moderate temperature increment over the last 10-20 years in the study area. As temperature is among major elements to determine the weather condition, climate and water availability for domestic and agricultural activities in an area, thus people understanding of the issue is very important to tack appropriate action and technology adoption.



Y=0.019x - 5.597, R2=0.196
MaximumTemperature
33.00
32.50
32.00
31.50
31.00
30.50
1980
1990
2000
2010
2020
Year



Y= -0.012x+43.244, R2=0.023
MinimumTemperature
22.00
21.00
20.00
19.00
18.00
1980
1990
2000
2010
2020
Year



Source: NMA, 2020

Figure 6: Trends of annual (Maximum, Minimum and Mean) temperature of Minjar Shenkora woreda over the last 30 years

4.2.2. Farmers perception of rainfall amount compared with metrological record

With respect to the change in the amount of precipitation in the dry season, 53% of reported indicated decrease of the *bega* rainfall and 45% perceived as no change in the *belg* rainfall. In converse, very few (2%) respondents reported increases of the *belg* rainfall (Table 6). Similarly 42% respondents perceived that the *kiremt* (main rainy season) rainfall amount don't show change, while 53% reported decreases of *kirmt* rainfall. Very few (5%) of survey respondents perceived an increases in the *kirmt* rainfall. In general considerable proportion (53%) of survey respondents perceived decrease in *belg* and *kiremt*. Theses is resemble with findings of other researches done on climate variability in Ethiopia (NMA, 2001; Seleshi and Zanke, 2004; Esayas et al., 2019). Seleshi and Zanke, (2004) showed that rainfall in Ethiopia is characterized by seasonal and inter annual variability, where the annual precipitation variability in most regions of the country remains above 30%. The parts of Ethiopian with greater variability are also marked by a higher probability of crop failures. The *Belg* season suffers from greater variability in rainfall than the *kiremt* season. Therefore most areas (i.e., east, northeast and south parts of the country) growing crop using the *belg* season suffer from the unreliable rainfall as the rainfall onset very delayed and occurrence of long dry spell resulting partial or complete crop failure. FGDs and KIIs affirmed that the *beilg* rainfall possess these characteristics. Like the household survey respondents, FGDs participants also witnessed that climate change particularly change in pattern and amount of rainfall and temperature have been negatively impacting agricultural production, water availability and agro-ecosystem as a whole. This reality was well explained by Watson, (2008) which indicated that, increase in temperature has already affected biological systems of the planet particularly in the tropics, which manifested through changes in species diversity and population, breeding stations and animal migration pattern, incidence of plant parasite and disease. Sivakumar and Tilahun, (2006) also showed that seasonal precipitation variation mainly changes in the precipitation amount, number of rainy days, length of growing period and dry spell frequency significantly affect crop production and productivity. Like other parts of the country, high variations in total annual and seasonal rains and rainy days perceived in the study area. In connection to this, a study conducted by Pulwarty et al. (2014) revealed that precipitation patterns change analysis mostly based on annual averages temperature and rainfall that result in misleading conclusion that lacking precipitation characteristics in the season. Understanding the average amount of precipitation per rainy day and the mean between successive precipitation events is important to understand variability and long-term models so as to arrive at sound result.

Table 6: Perceived Change in Amount of rainfall

Perceived Change in Amount of rainfall	Variables	Frequency	Percent
Dry season (*Bega* rainfall amount)	Highly Increased	1	1
	Increased	1	1
	No Changing	45	45
	Decreased	53	53
Summer season (*Kirmet* rainfall amount)	Highly increased	2	2
	Increased	3	3
	No changing	42	42
	Decreased	53	53

Source: own survey, June 2020

As indicated in Table 7, the survey households argued that the *kirmt* rains began late (93%) and withdraw earlier (76%). KII and the participants of the FGDs recognized that there was variability in the amount of rainfall, its timing and distribution over the last 20 years as corroborated by the surveyed households. For example, the FGDs participants indicated that mostly the *kiremt* rain begins late Jun and end mid-September.

Table 7: Perception of household on onset and withdrawal timing of summer (*kirmt*) rainfall

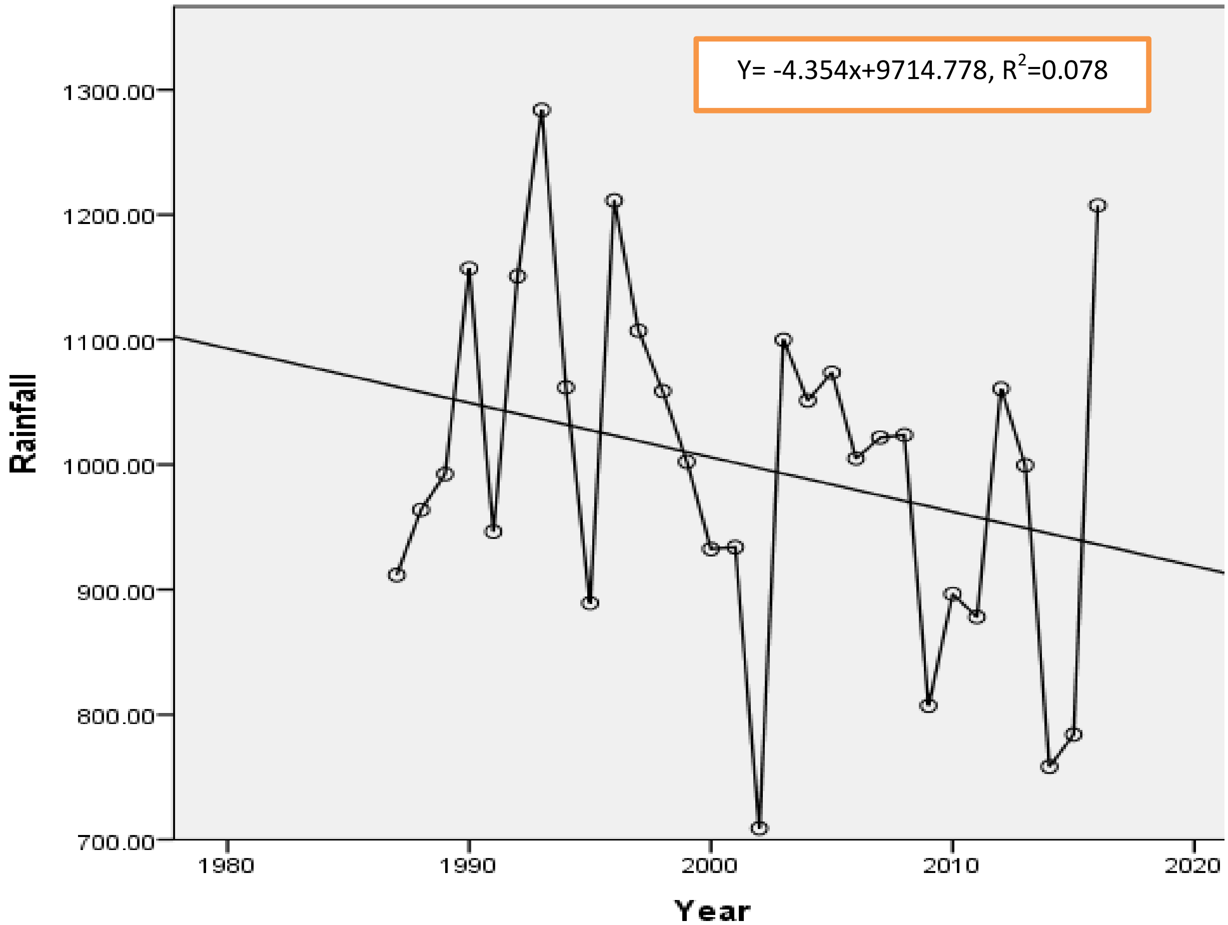
Questions	Response	Frequency	Percent
Do rainfall start late over the last 20 years?	Yes	93	93
	No	7	7
Do rainfall cessations early over the last 20 years?	Yes	76	76
	No	23	23

Source: own survey, June 2020

According to the data obtained from NMA in Figure 7, the annual maximum rainfall distribution of Minjar Shenkora *woreda* over the past three decades was 1283.99 mm, while the lowest rainfall was 708.98 mm, which that the difference is 575.01 mm (Annex I). It shows that there is a high variability in rainfall over the years.

Regarding the trend of temperature, the local meteorological data reveals that it is constant with significant decline of annual rainfall in the study area with a slope of -4.354 mm of the linear trend line. Hence, the annual rainfall declines by -4.354 mm per year and -43.54 mm per decades.

In general the NMA data reveals that, there is a high variability trend in the distribution of rainfall over the past three decades. The variability of rainfall is greater and the amount is shown gradually decreasing trend in the study *woreda* Minjar shenkora. The same as, the household survey respondents, KII and FGD participants also witnessed that climate change particularly change in pattern and amount of rainfall have been decreasing and negatively impacting agricultural production, water availability and agro-ecosystem as a whole over the last 10-20 years in the study area. The trend analysis of annual rainfall in Ethiopia shows that rainfall across the country remained more or less constant on average, while a downward trend was observed in the north and south-west of Ethiopia (IPCC, 2007). The amount and distribution of precipitation across regions and seasons varies greatly in both cases.



Source: NMA, 2020

Figure 7: Trends of annual rainfall of Minjar Shenkora woreda over the last 30 years

4.2.3. Farmers perception concerning effect of climate change on crop production

Table 8 depicted the effects of climate change on crop production in relation to the total damage or loss to crop production in the study area. Over half of survey respondents perceived that climate change has been negatively impacting the crop production, of those respondents 26% strongly agreed and the other 37% agreed the change affects crop production, while 21% of respondents disagree and 14% unable to decide effect on crop production. The perception of those farmers who unable to decide and disagreed on the effect of climate change on crop production might be related with lack of information on the effects of climate change on crop production. Concerning the effect of climate change literature also stated that the scientific consensus on climate change is that human activity that affected deforestation, greenhouse gas emissions, changes in land use patterns, agricultural production and productive and the like (Johrar, 1994). This is most likely caused by the rapid rise in global average temperatures in the past decades. Consequently, the debate has largely shifted towards ways to further reduce human impact and find ways to adapt to change that has already occurred.

In addition, a better production is obtained if the crop situated in optimal climate condition e.g., obtained adequate rainfall, temperature and humidity and receive the best management practices. However, temperature and precipitation patterns are changing rapidly with climate change (IPCC, 2014), because the vulnerability of different crops is associated with changing patterns associated with temperature, CO_2 levels and rainfall (Mall et al., 2017). The effects on crop production could in turn compromise local and global food security (IPCC, 2014 and Mall et al., 2017).

Table 8: Households perception on effect of climate variability on crop production

Types of effect	Scale of measurement	Frequency	Percentage
Agreement on climate variability on damage/loss of crop production?	Strongly agree	26	26
	Agree	37	37
	Undecided	14	14
	Disagree	21	21
	Strongly disagree	2	2
Increased crop pest prevalence	Strongly agree	57	57
	Agree	41	41
	Undecided	2	2
Increased incidence of crop disease	Strongly agree	53	53
	Agree	42	42
	Undecided	3	3
	Disagree	2	2
Emergence and expansion of new weeds and invasive plants	Strongly agree	48	48
	Agree	49	49
	Undecided	2	2
	Disagree	1	1
Loss of Indigenous Crop Varieties	Strongly agree	47	47
	Agree	43	43
	Undecided	4	4
	Disagree	5	5

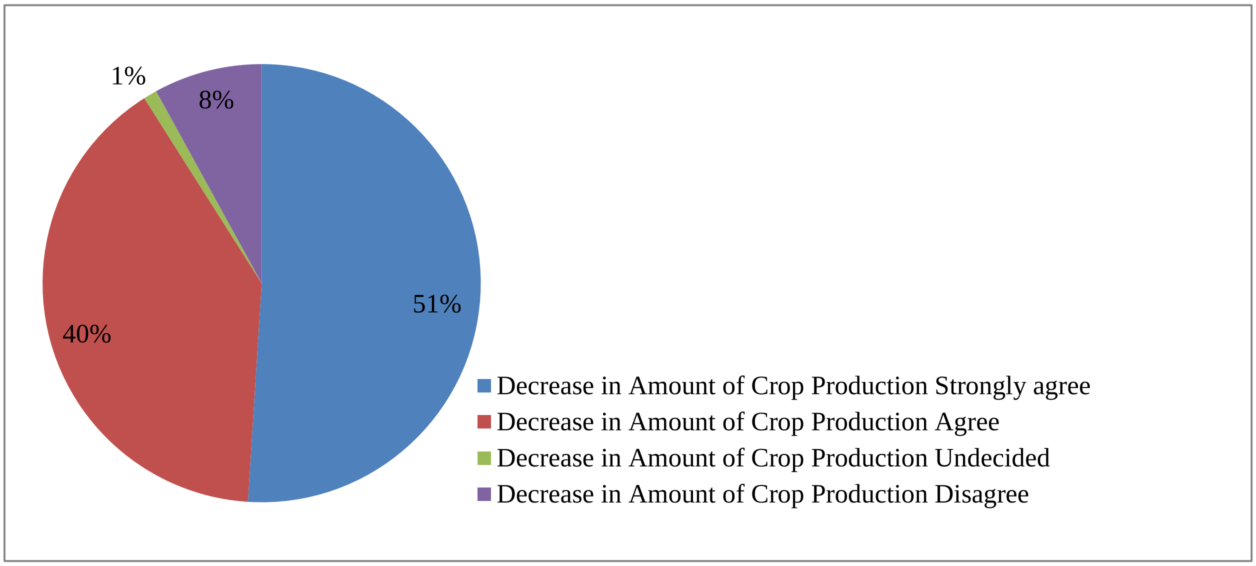
Source: own survey, June 2020

Table 8 explains that the effects of climate change on crop production and the increase in the prevalence of crop pests. Based on responses analysed, 57% and 41% of respondents respectively fully (strongly) agree and agree that the crop pests prevalence is increasing due to climate change, but only 2% of the survey respondents unable to judge the situation. In addition, FGD participants witnessed that insects are found in all types of environments and occupy just over two-thirds of the known animal species in the world. In this regard Paul (2007) reported that insects affect humans in various ways as it fed on all kinds of plants, including crop plants, forest trees, medicinal plants, and weeds. They also infest food and other products stored in go down, containers, storage structures, and packaging, resulting in enormous loss of stored food and deterioration in food quality. Insects damage plants and stored products either directly or indirectly in their attempts to secure food. Insects that cause less than 5% of the damage are not considered pests. Insects that cause damage between 5 and 10% are known as minor pests, and insects that cause damage above 10% are considered major pests (Paul, 2007).

The effects of climate change on crop production and the incidence of plant and crop diseases that also explained in Table 8, as 53% of respondents strongly agree and 42% agree that the incidence of plant diseases is increasing due to climate change that affected crop production. On other hand few (5%) respondents unable to decided (3%) about the effects of climate change on the incidence of plant diseases and 2% don't believe that as there is no change in plant diseases incidence. FGD participants also suggested that changes in weather conditions have led to rampant occurrence of crop pest and diseases, droughts, unpredictable and varied rainfall patterns and temperatures. The changes could have led to the emergence of new pests and the severity of new and existing pest and disease problems (Jassogne et al., 2012). Additionally, climate outcomes could be due to pest immigration to ecological zones where diseases that cause losses of economic importance include coffee wilt, coffee rust, and coffee berry disease. Furthermore, Kroschel et al., (2014) stated: "Severe outbreaks of pests and diseases cause local and large-scale shocks and undermine the resilience of agricultural systems. These events are characterized by a poor sanitary capacity of python for the analysis, diagnosis, monitoring and control of risks of pests and diseases. This predisposition is expected to worsen in scenarios of climate change, increased trade and human movement, as well as intensified agriculture to meet the demand for food and feed for a growing population.

Farmer´s perception regarding the impact of climate change; on crop production and affects the emergence and expansion of new weeds and invasive plants was assessed. As per this assessment nearly all (97%) the household survey respondents fully agreed (48%) and agreed (49%) that the appearance and expansion of new weeds and invasive plants related with climate change and theses have been affecting plant and animal production in the study area. Of the total survey respondents 2% were not sure and 1% does not agree of the effects of climate change on the appearance and expansion of new weeds and invasive plants. Similarly, FGD and KII participants also confirmed the spread of new weeds with the change in the climatic conditions. The participant emphasized that invasive weeds and plants affect plant and animal production as thesis species appearing everywhere damaging our plants and the environment. In this regard, Mooney and Hobbs, et al., (2000) reported that invasive species (including invasive weed species) pose a serious threat to the environment in the 21st century. Furthermore the authors reported that invasive species are considered one of the greatest threats to biodiversity, causing enormous costs to agriculture, forestry, fishing, wetlands, roadsides, natural areas and other human businesses, including human health.

The perception of survey households concerning the effects of climate change on crop production in the study area presented in Figure 8. Accordingly 51% of respondents strongly agreed and 40% agreed that climate change has impact on crop production, 8% don't believe (disagreed) on the impact climate change on crop production. Key informants and FGD participants reported an almost similar reaction and theses analysis agree with Liu et al., (2008) findings. In this regard, studies state that food security under climate changes is important to maintain or improve both crop yield and stability as under increased climate variability crop yields are likely to be more volatile under future climate conditions (Roberts et al., 2012). Therefore, some potential benefits of climate change with lower crop production can be offset by the higher year-to-year variability, leading to the long- term food supply instability.



Source: own survey, June 2020

Figure 8: Farmers perception in decrease of amount of crop production due to climate change

Table 9 describes survey household's perception on the effects of climate change on crop production with respect to the change in farming and production seasons. Here 56% of the respondents fully agreed and 29% agreed that the climate change has been altering the farming system and production seasons. In fact some (15%)respondents have different opinion, who unable to decided (4%) and disagreed (11%) the effect of the climate change in modifying the farming and production seasons and intern affecting agricultural production. Likewise, FGD and KII discussants have had similar perception.

Table 9: households perception on Effect of climate variability starting of agricultural activities and water availability

Types of effect	Scale of measurement	Frequency	Percentage
Do you agree existence of shift in farming and production seasons due to climate variability?	Strongly agree	56	56
	Agree	29	29
	Undecided	4	4
	Disagree	11	11
Is there water shortage for crop production	Strongly agree	73	73
	Agree	23	23
	Undecided	1	1
	Disagree	3	3

Source: own survey, June 2020

Table 9 presented the effects of climate change on agricultural production with respect to the scarcity of water for crop production. Accordingly great majority (96%) reported that climate change has been inducing water shortage to carryout crop production of theses 73% of respondents fully (strongly) agreed and 23% agreed that climate change has been inducing water shortage that in turn it has been affecting the crop production. It is worthy to indicate that few (4%) survey households unable to anticipate the change (1%) and disagreed (3%) the effect of climate change on water availability for crop production. In this regard, Lionello (2012) argued that agriculture is a climate sensitive sector that has been negatively impacting the social and economic contexts due to the changes in rainfall and warming patterns over the last century. Scientific literature predicts widespread warming and reduced rainfall throughout the year for the twenties first century as it affecting the water cycle and evapo-transpiration then impacting than cause water shortages, especially in regions where resources are already at a critical level and irrigate the cultivation areas are increasing (World Bank, 2016; Scarascia et al., 2018).

4.2.4. Farmers perception concerning effect of climate change on livestock production

Table 10 presented farmers perception on the effects of climate change on livestock production and productivity. The analysis revealed that 38% and 58% of the respondents respectively strongly agreed and agreed that the livestock production and productivity decreased due to climate change impacts. FGD and KII participants indicated that climate change impacting animal feed and water availability, occurrence of diseases and pest. The effect of climate change on livestock production and productivity has been impacting rural people livelihood. It is well known that livestock is the main asset for rural people in most developing countries and provides various economic, social and risk management functions for more than 800 million people, including poor small farmers. The issue has extra ordinary importance for arid region of the world which is home to extensive livestock production based primarily on small ruminants (Ben Salem and Smith, 2008). The peoples in these areas can raise livestock for a variety of reasons, including achieving food security at the national and private level, reducing poverty through job creation, income and savings, achieving economic development through trade in livestock and animal products, and supplying the industry (Chilonda and Otte, 2003). Therefore, understanding the impact of climate change on the sector (livestock production) and farmer's perception on the change and impact will have basic role to adapt the change.

Table 10: Farmers perception on effect of climate variability on livestock production and productivity

Types of effect	Scale of measurement	Frequency	Percentage
Decreased livestock production and productivity	Strongly agree	38	38
	Agree	58	58
	Undecided	3	3
Increased incidence of animal/livestock diseases	Strongly agree	33	33
	Agree	66	66
	Undecided	1	1

Source: own survey, June 2020

As shown in table 10, the survey households also anticipated that the climate change has been causing animal diseases. Nearly all (99%) respondents agreed that (33% strongly agreed and 66% agreed) that climate change has been negatively impacting on animal production as it facilitate incidence of animal/livestock diseases occurrence.

Table 11, demonstrates the effects of climate change on livestock production and concerning the shortage of livestock feed.

The survey households (97%) related the effect of climate change on livestock production as it caused shortage of livestock feed who strongly agreed (52%) and agreed (45%) that the change facilitated condition for shortage of livestock feed. It is well known that livestock is one of the fastest-growing agricultural sub-sectors in developing countries that provide food and income thus rapidly increasing demand for livestock products, because of population growth, urbanization, and increasing incomes (Thornton et al., 2011). The increase in livestock products in turn requires an increase in different inputs for livestock production, mainly feed (Alemu 2008; Adugna et al., 2012). Nevertheless, feed shortage in terms of quantity and quality is still a major problem, and a major factor affecting the development of viable livestock production in developing countries like Ethiopia which has been aggravated by climate change (Sere et al., 2008). Poor nutrition of ruminants will not only affect animal performance, but also the immune system that will reduce animals' ability to fight diseases (Alemu, 2008). Livestock feed resources in Ethiopia are mainly obtained from natural and crop residues, and very few from improved pastures forage crops, agro-industrial by-products, and non-conventional feeds where most are affected by climate change (CSA, 2012). Seyoum et al., (2001) and Ahmed et al., (2010) indicated that the contribution of these feed resources, depends upon the agro-ecology, the type of crop produced, accessibility, and production system, where all are directly influenced by climate change. Natural pasture is the major source of livestock feed in Ethiopia, where its importance is gradually declining because of the expansion of crop production into grazing lands, redistribution of common lands to the landless, and land degradation, which has augmented by climate change impact (Berhanu et al., 2009). Therefore, the effect of climate change on livestock production as the change has been directly and indirectly influencing livestock feed availability.

Table 11: Farmers perception on effect of climate variability on feed and grazing lands and water availability for the livestock

Types of effect	Scale of measurement	Frequency	Percentage
Shortage of livestock feed	Strongly agree	52	52
	Agree	45	45
	Disagree	3	3
Shortage and loss of grazing lands	Strongly agree	56	56
	Agree	44	44
Is there shortage of water for livestock?	Strongly agree	69	69
	Agree	30	30
	Disagree	1	1

Source: own survey, June 2020

Table 11 shows the impacts of climate change on animal production and in terms of pasture land shortage and loss. In this regards, agreed (56% strongly agree and 44% agreed) that as pasture land shortage and loss due to direct and indirect impact of climate change. It is evident that communal pastures are important sources of forage in developing countries (ILRI, 1998). Inadequate feed supply, both quantitative and qualitative, is the main constraint for animal production in Ethiopia. Forage scarcity is cited as a factor responsible for the lower reproductive and growth performance of animals, especially during the dry season (Legesse, 2008), and the traditional free-range system imposed soil degradation that has existed for centuries (Mekuria et al., 2007; Taddese, 2001), which led to continuous declining of forage availability and other ecosystem services from natural pasture areas in Ethiopia (Gebremedhin et al., 2004). The causes of this forage, grazing and rangelands deterioration are generally attributed to a combination of factors, most of which are related to human activities in the struggle to coup climate change related problems that later affects the conditions of the grazing land (Harris, 2010). The loss of pastureland vegetation and the deterioration in the quality of pastureland forage are mainly due to the negative effects of human activities such as overstocking, expansion of crop production and vegetation, clearing, fire incidents and urbanization, where theses sometime resulted from climate change impacts. Oztas et al., (2003) indicated that over exploitation of communal pasture land has always led to a reduction in the plant cover (and aerial biomass production (Yayneshet et al., 2008). For example, restocking livestock beyond sustainable carrying capacity more often leads to an increase in undesirable plant species and depletion of soil quality (Kassahun et al., 2008). This is because the strong grazing pressure causes the selection of preferential forage species and thus leads to an increase in less valuable species such as livestock fodder (Retzer, 2006). In addition, land and water degradation and its effect on agricultural activities can be involuntary and unperceived can be the result of neglect or the inevitable struggle of vulnerable populations for survival needs (Teshome et al., 2016). Therefore, the effect of climate change on livestock production can be manifested through reduction livestock feed and forage availability as discussed above.

The table 11 shows survey household's perception on the effects of climate change on livestock production and concerning on shortage of water for livestock production. Accordingly 69% and 30%of the respondents respectively strongly agreed and agreed as climate change resulted in shortage of water for livestock production. In this aspect, United Nations Environment program, (2008) report revealed that the effect of climate change on water availability for livestock production will face more challenge as the global water demand is expected to increase by 50% between 1995 and 2025. The report underlined that the problem is in developing countries, not only because of larger human populations, but also because of overall increases in industrial production and consumption (mainly energy, goods and food), especially with raped increases of animal products, thus areas suffering from water scarcity likely to increase overtime. Study conducted by Rosegrant et al., (2002) estimated that 64% of the world population will live in water-deprived zones in 2025, out of which considerable shortage will be faced by agriculture sector, especially for livestock production that aggravated by climate change resulted weather variability (FAO, 2006).

4.3. Rainwater harvesting implementation practices of the study area

The field observation revealed that different types of RWH practices exist in the study area. Many RWH practices at the household level have been developed with the support of the local government. Most of the survey households started use of plastic-lined ponds since 2010. From KII it was learned that the Ethiopian government started the extensive promotion, implementation and funding of RWH practices at HHs level in 2010 (MSWADO, 2020). In this intervention, farmers contributed labor during the construction. In fact as per FGDs and KIIs, traditional ponds in the study area were constructed long years ago mainly as a source of water for domestic use and livestock.

In relation to this, Table 12 presented RWH practices uptake of survey community the traditional and improved RWH technologies. Accordingly majority (96%) of respondents were using traditional ponds, 6% indicated used traditional ponds sometimes ago and 2% didn't ever use the traditional pond. In this aspect Ayers and Westcot, (1985) indicated that due to the lack permanent water sources, agricultural ponds were source of water for household use, drinking water for animals, irrigating summer crops, and small-scale irrigation of valuable dry-season crops. Moreover the authors added that localized irrigation systems like ponds are increasingly used in agricultural systems to improve water distribution and efficiency, especially in areas with limited water resources. Traditional RWH practices, including construction and uses of pond, moisture conservation, and flood diversion are becoming essential element of household level agricultural system of agricultural production.

Table 12: Farmers adoption of water harvesting technologies

Types of implemented activities	Variables	Frequency	Percent
Construction Traditional pond(s)	Adopted	92	92
	Sometimes	6	6
	Not now	2	2
	Total	100	100
Construction of cemented pond(s)	Adopted	31	31
	Sometimes	1	1
	Not now	68	68
	Total	100	100
Construction Plastic Lined Pond(s)	Adopted	60	60
	Sometimes	38	38
	Not now	2	2
	Total	100	100

Source: own survey, June 2020

However the adaption of improved RWH technology is still remained slow as only 31% of the respondents adapted cemented pond, while the remaining (69%) didn't at the moment (Table 12). The *Woreda* agricultural development office KII participants indicated that**,** there are only 170 household level cemented ponds in use for small-scale (full-time or supplemental) irrigation purposes at *woreda* level (Figure 9).

Source: own survey, June 2020

Figure 9: Photo of cemented ponds in the study area

Beside the cemented RWH technologies, government also attempted to improve traditional ponds by lining with plastic cover (Figure 10). In this regard, the survey revealed better adoption of the improved pond which lined with plastic sheet (geo-membrane) as 60% respondents are currently using and 2% sometimes used plastic lined ponds, while 38% didn't used the technology so far (Figure 10). A opposed to the cemented RWH technology, the *Woreda* agricultural development office KIIs noted that, there are 4,218 household owned individual plastic-lined ponds at *woreda* level, which all used for multiple uses mainly for domestic, livestock and micro irrigation purpose In fact, application of plastic sheet on ponds can be determined by local condition, for example it is not recommended on pond with greater than 6 inches thick gravel and if livestock directly drink water from the pond and pass by so as to protect the plastic sheet against punctures (United States Department of Agriculture, 1988) and , when the infiltration rate of the soil is less than 10 mm (Srivastava, 2004). In addition, the lifespan of these different pond linings depends heavily on whether they are exposed or covered. Thus all these affect service time of the plastic lined ponds and might reduce currently existing improved pond (lined with geo-membrane) which calluses replacement mechanism for damaged plastic sheet so as to improve sustainable function of the RWH facilities and agricultural production as well as other uses.

Source: own survey, June 2020

Figure 10: Photos of plastic lined ponds in the study area

Promotion and implementation of improved RWH technologies enhanced adaption of small scale irrigation as about 70% of the respondents have been currently using and 10% sometimes ago used small scale (fulltime or supplementary) irrigation, while 20% didn't ever used small scale. Filed observations, KIIs and FGDs participants confirmed better awareness of the study community in relation to the adaptation of the irrigation practices after promotion and implementation of improved RWH technology (Figure 12). Farmers using RWH technologies for irrigation purpose are producing high value crops like vegetables and fruits and are also producing seedlings to be planted in the main rainy season otherwise production of crops maturing over longer period will not possible in the absences of the RWH structure. Regarding using small scale irrigation Awulachew et al., (2010) showed that ministry of agriculture of

Ethiopian started implementation of modern small scale irrigation (SSI) practice and management in the 1970´s in the response to overcome droughts caused wide spread crop failures and consequently hunger and starvation opting that the irrigation reduce the risk of crop failure resulted from the recurrent drought. At this time government paid high attention to develop the sector to fully it's potential by assessing and supporting local farmers to improve irrigation practices through promotion of modern irrigation practices. Local communities have been practicing irrigation by diverting water from rivers in the dry season for the production of subsistence food crops (Teshome, 2006). Despite its economic and social benefits, production and productivity of different agricultural crops in Ethiopia is mostly on a small scale and average crop yield is very low, as compared to other developing countries (Awulachewet et al., 2010; Kalkidan et al., 2016). Hence, promotion and implementation of irrigation can contribute much to poverty reduction primarily by enhancing labor and land productivity, which in turn leading to higher incomes, higher wages, lower food prices and also ensure economic development (Smith, 2004). In addition to this, irrigated agriculture improves water conditions in the soil, increases the water contents of plant fibers, dissolved nutrients and makes them available to plants (FAO, 1997). On the other hand, it can regulate temperature in the layer of the soil and the air available between ground layers which further control the growth and development of plants and the quality of the harvest indirectly. To sum up, irrigation agriculture is mostly appropriate in the area of arid, semi-arid, humid and sub-humid climates in order to protect crops during periods of drought and adapt climate change related impact on agriculture and people livelihoods (FAO, 2003).

Table 13: Farmers adoption of small scale (fulltime or supplementary) irrigation practice

Types of activities	Variables:	Frequency	Percent
Using small scale (fulltime or supplementary) irrigation	Adopted	70	70
	Sometimes	10	10
	Not now	20	20
	Total	100	100

Source: own survey, June 2020

Source: own survey, June 2020

Figure 11: Small scale (fulltime or supplementary) irrigation activities (photo) in the study area

The survey also captured farmer's adaption of other soil and water conservation (SWC) practices as these practices are important in adapting the climate change through in-situ water conservation. As indicated in the table 14 and Figure 13, farmers have been adapting the different SWC practices so as to reduce the impact of the climate change. Accordingly, great majority (86%) of survey respondents contour plowing, while the remaining 11% used the practice sometimes. It is known fact that contour farming reduces runoff and soil erosion on mild slopes thereby increase crop yield through the soil moisture retention in arid and semi-arid regions. The research conducted by Natural Resources University of Khuzestan Iran (2016) showed that contour cultivation reduced the annual runoff by 10% as compared with cultivation perpendicular to the and reduced soil losses by 49.5% and water losses by 32%. However, contour farming is less effective on slope exceeding 10 percent and in single storm erosion index greater than 140. Therefore, the crop grown along contours must always be associated with other practices of conservation as (Sul, 1985) the practice is not well suited to rolling topography and other several factors influence the effectiveness of contour farming to reduce soil erosion (Anonymous, 2008). Therefore, adoption of contour ploughing can be considered as climate change related risk and problem reduction with due consideration and integration of the practice with other SWC interventions.

Table 14: Farmers adoption of agronomic soil and water conservation practices on farmlands

Types of implemented activities	Adaptation status	Frequency	Percent
Contour plowing	Adopted	86	86
	Sometimes	11	11
	Not now	3	3
	Total	100	100
Crop rotation	Adopted	98	98
	Sometimes	2	2
	Total	100	100
Flash flood diversion to farmlands	Adopted	48	48
	Sometimes	41	41
	Not now	11	11
	Total	100	100
Mulching farmlands	Adopted	39	39
	Sometimes	47	47
	Not now	14	14
	Total	100	100

Source: own survey, June 2020

Source: own survey, June 2020

Figure 12: Photo of contour plowing of farmlands in the study area

The other agronomic practice adapted by 98% of the respondents was crop rotation (Table 14), while very few (2%) sometimes implementing the practise. It is beloved that crop rotation reduces reliance on a set of nutrients, the pressures of pests and weeds, and the likelihood of developing resistant pests and weeds (Natural Resources Conservation Service, 2009).

Flash flood diversion to agricultural land is among other in-situ water conservation practice that regularly and haphazardly implemented by (48%) and (41%) respondents, respectively, while few of them (11%) have never been used the practice so far (Table 14). According to El-Shamy, (1992) flood-based agriculture is possible in areas that receive regular flooding, which can form the basis of productive agricultural systems, in addition, the practices helps to reduces flood problem and influence the severity of flash floods in dry lands.

Agricultural land mulching is also other agronomic practise for in-situ water conservation and climate change adaptation in crop production. The survey revealed that considerable proportion (39%) of survey households have been regularly practicing and 47% are sometimes using agricultural land mulch, on other hand about 14% didn’t ever used the practice. In recent years, physical SWC largely promoted and implemented through the government extension services and structure (Damene et al., 2012). Accordingly the survey showed that 67% of respondents largely implemented farmland terraces and 27% sometimes used the practice on their farmlands, while the remaining 6% households still abstained from implementation of the practice (Table 15).

Table 15: Farmers adoption of physical soil and water conservation practices on farmlands

Types of implemented activities	Adaptation status	Frequency	Percent
Farmland terracing	Adopted	67	67
	Sometimes	27	27
	Not now	6	6
	Total	100	100
Construction of soil bund	Adopted	85	85
	Sometimes	13	13
	Not now	2	2
	Total	100	100

Source: own survey, June 2020

Source: own survey, June 2020

Figure 13: Photos of stone terracing on farmlands (A) and gabion check dam on gully (B)

Table 15 showed households soil bund adaption where 85% of the respondents indicated as they already adapted the practice and engaged in the construction of the structure and 13% sometimes engaged in soil bund construction on their farmlands but very few (2%) didn’t implement the structure on their farmlands. involve .

Source: MSWADO, June 2020

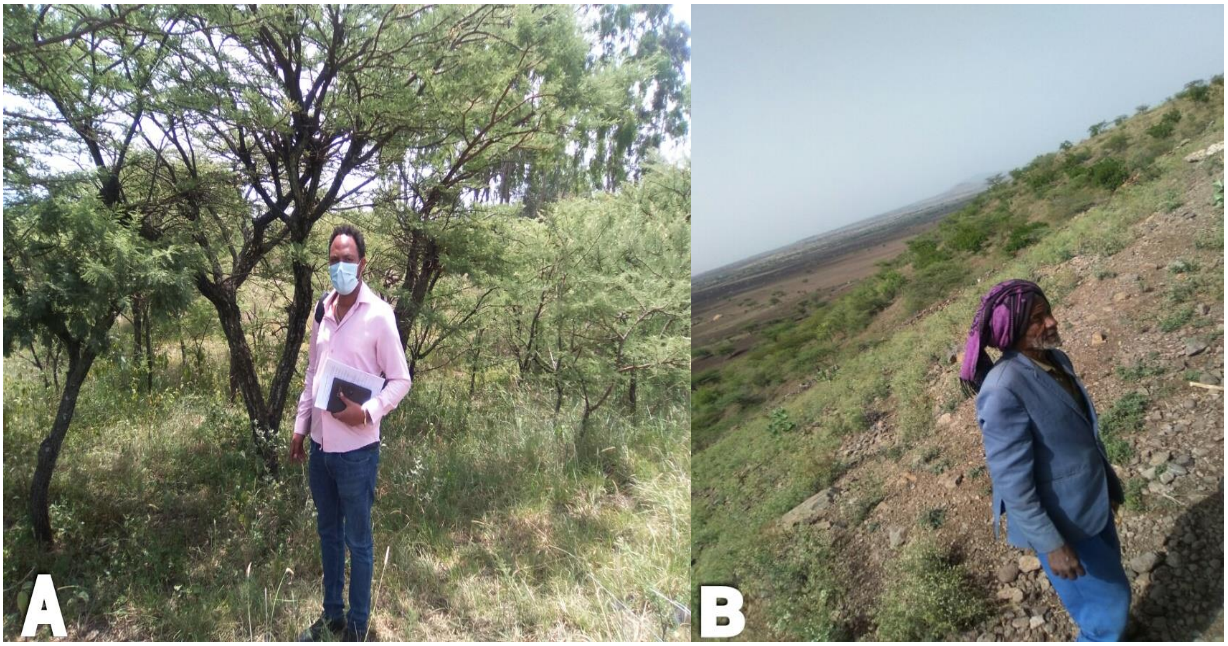
Figure 14: Photo of farmer's participation in soil and water construction

Table 16 and Figure 16 shows that the participation of farmers in the management of rangelands, where 59% of respondents indicated that they adapted and participated in the management of rangelands, 30% sometimes involved in rangelands management. In converse 11% of respondents indicated that they were not involved in rangelands management practices. In relation to theses Rao and Ginsberg, (2010) and Tache, (2013) reported that government structure gave many developing countries lesser attention for management of natural resources including rangelands through conducting and implementing appropriate land uses planning and promoting implementation of the plan among farmers and local government structure.

Table 16: Farmers adoption of soil and water conservation practices on rangelands

Types of implemented activities	Adaptation status	Frequency	Percent
Participation in managing range lands	Adopted	59	59
	Sometimes	30	30
	Not now	11	11
	Total	100	100

Source: own survey, June 2020



Source: own survey, June 2020

Figure 15: Photos of grazing land management rehabilitated (A) and degraded (B)

Table 17 shows that tree planting practice in the study area, where about 95% survey households planted tree either at homestead or on farmlands and woodlots and 4% involved in tree planting sometime in the past. KII informant from respondents selected the *woreda* Agriculture and Development confirmed that these days tree planting become priority agenda of the offices as is widely promoted by federal government. For example, the *woreda* raised and planted 6.6 million seedlings in 2020 planting period (July to August 2020). In this program, each household is expected to plant 300 to 400 tree seedlings annually, which thus enhanced household's involvement in tree plantation. The national and local level tree planting aimed at reducing impact of climate change through improving micro-climate, reduce land degradation, restore the national forest coverage and improve local and basin level hydrology (Pokorny et al, 2010; Kelley et al, 2015). In this context, studies showed that billions of people are suffering from the consequences of inadequate access to water and extreme heat events that resulted from climate change as aggravated by natural resources degradation including deforestation (Fischer and Knutti, 2015; Herring et al, 2015).

Table 17: Farmers adoption of soil and water conservation practices on non-agricultural lands

Types of implemented activities	Adaptation status	Frequency	Percent
Tree planting	Adopted	95	95
	Sometimes	4	4
	Not now	1	1
	Total	100	100
Construction of deep trenches for in situ water conservation	Adopted	63	63
	Sometimes	24	24
	Not now	13	13
	Total	100	100

Source: own survey, June 2020

Source: own survey, June 2020

Figure 16: Photos of tree seedling planting pits (A) and tree nursery with mature seedlings (B)

The above table demonstrates the construction of deep trenches for *in- situ* water conservation and facilitating condition for in-situ water harvesting which mostly applied on sloppy lands. The survey revealed that 63% households currently constructed deep trench and 24% applied the practice sometime in the past but 13% didn't ever involve in this activity on own land that used for forest, fruit or agro-forestry tree plantation. In connection with application of *in-situ* water harvesting Gollifer, (1993) and Twomlow et al. (2000) reported that smallholder farmers residing in less favourable agro-ecological conditions particularly in areas with poor soils, low and erratic rainfall, recurrent droughts and dry spells result suffer from complete crop failure, water scarcity, and livestock deaths. Therefore such farmers apply *in-situ* and *ex-situ* water harvesting technologies and practices like construction of deep trench so as to improve the crop production using the minimal rainfall. In fact, the practice of *in-situ* water conservation need selection of appropriate technology that sweet the local condition and should be supplemented by other technologies like uses of climate smart technologies for example use of early maturing and drought tolerant crop type (WCMC, 1992; Heywood et al., 1995; Edwards and Kelbessa, 1999).

Source: own survey, June 2020
Figure 17: Photo of trench constructed for in-situ water conservation on farmlands

Access to information regarding the various practices of rainwater harvesting is presented on table 18. The assessment showed that almost (100%) survey households are well informed about rainwater harvesting as they majorly learned from development agents (DAs) of agriculture office (71%), and the remaining hear from model farmers (25%), *kebele* administration (3%) and radio (1%) . FGD participants indicated that the intensive awareness creation helped them to buy the idea and engage in RWH technology. Therefore, 95% HHs voluntarily participated in RWH in order to adopt with the situation and other factors like to coup with the frequent drought (35%), increased water demand (41%), training effect (19%) and *kebele* cadre agitation (5%).

Moreover, of the sample household reported that all (100%) got training at least once on water harvesting practices. As per FGDs and KIIs, the *woreda* provide training (both theoretical and practical) on water harvesting 2 to 4 times annually in each *kebele* so as to reach most farmers in different round and years conduct. The trainings were accompanied by practical demonstration at FTCs (Farmers Training Centers).

According to Minjar Shenkora *woreda* agricultural and development office KII interviewers shows that currently, there are plans and on-going implementation activities by government to build *woreda* and *kebele* capacity in terms of RWH practices. In the context of these initiatives, the training needs of the beneficiary communities were identified in all areas related to technology, water management, operation and maintenance, input supply, and output marketing. Training is also prerequisite to decrease the complexity of technology. In this study, components of trainings such theoretical and practical demonstration trials which focus on upgrading local farmers knowledge and skills on construction and maintenance of RWH practices were assumed to improve adopting of rainwater harvesting training(RWHT);as well as *kebele* and *woreda* Farmers Training Centres (FTCs), are expected to train field level local farmers.

Table 18: Households access to information, participation and training on in RWH practices

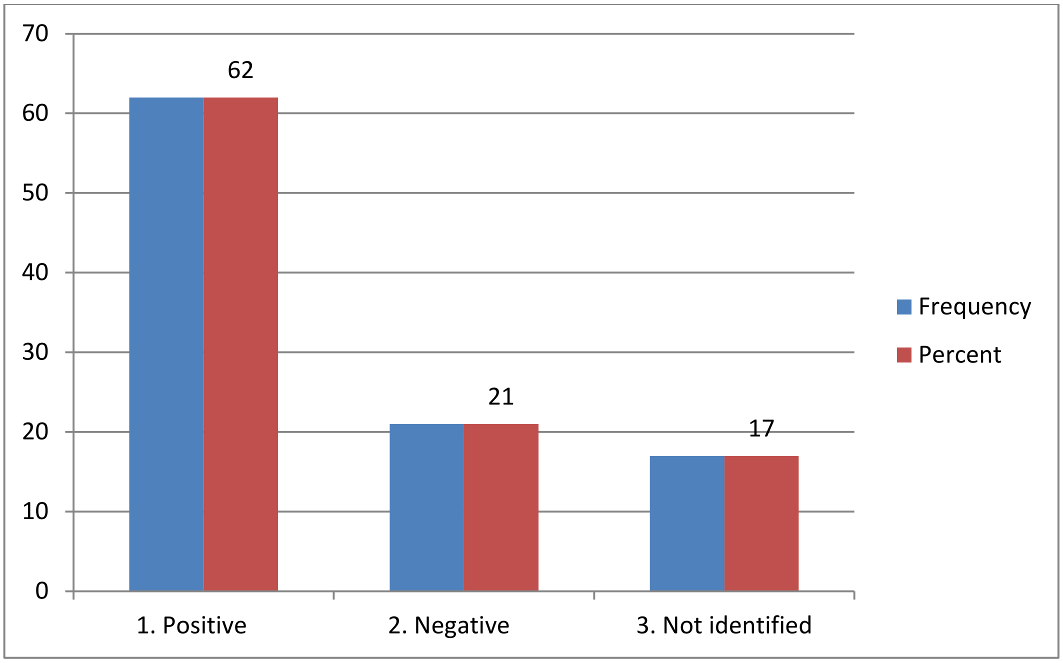
Questions	Variables	Frequency	Percent
Where do you get information regarding the various practices of rainwater harvesting?	Radio	1	1
	Kebele cadres	3	3
	DA Officers	71	71
	Model farmers /Friends/	25	25
Do you participate in rain water harvesting practices?	Yes	100	100
How was your participation in the rain water harvesting practices?	Voluntarily	95	95
	Selected by DA	4	4
	Registered by Keble leaders	1	1
What objective realities convinced you to participate in rainwater harvesting Practices?	Frequent drought	35	35
	Increased water demand	41	41
	Training effect	19	19
	Cadre agitation	5	5
Are you trained in water harvesting practices and its utilization?	Yes	100	100
How often you trained?	Once	1	1
	Twice	23	23
	Three	33	33
	Four	43	43
What type of training was offered to you?	Both theory and practice	100	100
Who trained you?	Kebele DA Officers	89	89
	Woreda Agricultural experts	11	11

Source: own survey, June 2020

Source: own survey, June 2020

Figure 18: photo of Practical farmers training

As it is shown in Figure 20, 62% of the respondents expressed their expectations of the household on benefits from rain water harvesting practices and said positive, 21% said negative and the rest 17% were non- identified respondents. Furthermore, FGD participant household heads noted in the study area that water harvesting is necessary due to its easiness to implement at individual house hold level and economically important.



Source: own survey, June 2020

Figure 19: Response of households on benefits of rain water harvesting practices

4.4. Challenges related to rainwater harvesting practices

Table 19 presented major challenges related to implementation of RWH practices by households include financial (31%), labour (20%), technical (20%), environmental (18%), management (10%) and social (1%), and. Of the above challenges, 65% of household reported that most of the challenge they faced in the process of construction and utilization of the RWH practice has been solved, while the rest, 35% households indicated that the challenges are still persisting as they can't be solved at individual level. FGD and KII Participants confirmed that the financial constraints to purchase input materials and cover skilled labour cost, quality problem of plastic sheets (geo-membrane) used to line pond and poor quality pedal pumps, lack of well-trained skilled labour for the construction and maintenance of structure are among major challenge related to adaption of RWH technology. It is recommended to build buildings for the promotion of RWH practice. UNEP, (2009) report showed that the main challenges in the introduction of RWH practices include loss of harvested water through seepage that results in irrigation water insufficiency at the medial of growing period. In addition lifting and distribution/irrigation of water from RWH structure is very labour intensive as the operation performed manually pumping water from ponds and applying it directly to the plants (Moges, 2009). The rainfall distribution is the other natural challenge for RWH practices. During extreme drought years, very little can be done to bridge a drought that occurs during the vegetative plant growth stage, when there are no overflow production events in the early growth stages (Rockstrom, 2000). Despite great efforts by the Ethiopian government and other stakeholders, the improvement of agricultural water management by RWH is hindered by restrictions in politics, institutions, technologies, etc. Therefore, removing these restrictions is crucial for sustainability of the RWH technology for agriculture use in Ethiopia (Awulachew, 2010). The challenge for agriculture in sub-Saharan Africa is the inconsistency of rainfall, which is categorized by high intensity storms and the high frequency of dry spells and droughts. RWH systems can turn these inherent challenges into good opportunities.

Table 19: Survey household's perception on major challenges to implement RWH Practices

Questions	Variables	Frequency	Percent
What is the major challenge you faced for implementing rainwater harvesting Practices in your case?	1. Social	1	1
	2. Labor	20	20
	3. Environmental	18	18
	4. Financial	31	31
	5. Managerial	10	10
	6. Technical	20	20
Are they now solved your challenge?	1. Yes	65	65
	2. No	35	35
Have you ever faced any human health problems associated with rainwater harvesting practices?	1. Yes	42	42
	2. No	58	58
What type of major diseases is identified?	1. Malaria	10	10
	2. Amoeba	14	14
	3.Giardia	19	19
Have you constructed fence for protection of any problems associated with rainwater harvesting practices?	1. Yes	91	91
	2. No	9	9

Source: own survey, June 2020

Source: own survey, June 2020
Figure 20: Photos of defected plastic sheet (geo-membrane) usage on ponds

The survey respondents also indicated some environmental and health related problems assonated with RWH technology is human health problems which was reported by 42% respondents. The health problem that farmers facing due to uses of water from RWH facility were Giardia and Amoeba reported by 19% and 14% HHs. In order to reduce risk of children and animal entry in the water, 91% of HHs fences the structure so as to prevent the entry of animals and protect children from danger.

4.5. Role of rainwater harvesting practices for climate change impacts adaptation

Survey household's response on the role of RWH for climate change adaptation is presented on table 20. The survey households reported that all (100%) have been using the RWH technology for different purposes, where most (71%) HHs use for multiple uses (i.e., irrigation, livestock and domestic use), 22% full time field crops production and 7% for supplementary irrigation.

Crops produced through irrigation using water from RWH are vegetables (53%) and field crops (39%). Very few individual (1%) use RHW for household consumption and 7% HHs use for livestock watering. FGDs and KIIs participants also confirmed that households use the harvested rainwater for supplementary irrigation, fulltime irrigation to produces field crop, household consumption, and livestock watering. Therefore, from this it can deduce that rainwater harvesting practices can have an important role in achieving the food security of smallholder farmers at household level. It also helps to bridge water supply in the dry times for human and livestock consumption. This finding agree with Ngigi, (2003) report which underlined that adoption of rainwater harvesting technology improves the quality of life by providing water for domestic use, livestock and agricultural production. The author added that the rainwater harvesting at the household or community level enables rain-fed based farms to access source of supplementary irrigation, the bay enhance their economic security.

Table 20: Survey household response on the roles of RWH practices for climate change impacts adaptation

Questions	Variables	Frequency	Percent
Do you use rainwater harvesting practices?	1. Yes	100	100
	2. No	-	-
What scale you use the harvested rainwater?	1. for Supplementary irrigation	7	7
	2. For Household consumption	-	-
	3. For Field crops production	22	22
	4. for all	71	71
For what major purposes you use the harvested rainwater?	1. Vegetable growing	53	53
	2. Livestock watering	7	7
	3. Human consumption	1	1
	4. Field crops production	39	39

Source: own survey, June 2020

Source: own survey, June 2020

Figure 21: Photos of integrated horticultural crop production (A) and livestock watering (B) by using harvested water

4.5.1. Household crop production before and after rainwater harvesting practices

Table 21 shows household crop production before and after rainwater harvesting practices. The analysis revealed that considerable increases of crop production in most crops after use of RWH. For example, cereal crops yield on average increase by 4.11 quintals, pulses by 2.21 quintals, vegetables by 7.75 quintals per *timad* at household level yearly after the practices of RWH. The higher increase was recorded in wheat (7.5 qt/*timad*) out of cereal, in chickpea (2.98 qt/*timad*) from pulses and in onion (21.12 qt/*timad*) from vegetables. All this reviled that RWH practice contributes for improvement of crops, vegetables and fruits production in the study area.

FGDs and KIIs participants of household head also confirmed that the development of RWH practices in the study area brought significant potential to improve the productivity of crops, vegetables and fruits because of the practice helped farmers use the harvested water for crop production ether as full or supplementary irrigation, the RWH also farmlands located below the structure from soil erosion and thereby decreased soil fertility degradation. The participant also revealed that because of the practice households can reduce vulnerability to climate change variability, it helps option to attain food security and ensure household's food self-sufficiency and increasing farmers cash income, as result some farmer households become food self-sufficient and able to create alternative income sources through saving cash in the bank and bought cars, Bajaj, and urban area residential compound especially onion production income from supplementary irrigation activities. Similarly, literatures also stated that one of the reasons for low crop production in semi-arid areas is marginal and erratic rainfall exacerbated by high runoff and evapotranspiration losses, which can be resolved through use of RWH technologies. For example, FAO, (2001) indicated that RWH can be used to re-establish vegetation cover to improve crop growth in order to alleviate poverty and enhance food security. In this regards, the report revealed that successful interventions in rain-fed agriculture in Somali Region, Ethiopia have transformed the livelihoods of many poor farmers. Similarly, Rockstrom, (2002) reported that improved RWH practices may result in improved crop yields, food security, and livelihood among households. Mtisi and Nicol, (2013) noted that supplementary irrigation increased crop yields by 20%. With RWH, farmers have diversified to include horticultural cash crops and the keeping of dairy animals. This has contributed to food security, better nutrition, and family income. Most of the future growth in crop production in developing countries is likely to come from intensification, with irrigation playing an increasingly strategic role (FAO, 2011). Access to irrigation water is critical to rising and stabilizing crop production as irrigation has direct benefits in terms of production and income. Besides increased yields, Ngigi et al., (2005) reports that RWH practice is also aimed at stabilizing variations in crop yields and ensuring food security.

Table 21: Crop production before and after rainwater harvesting practices

Type of crops		Average annual crop production				
		Before RWH practices (A)		After RWH practices (B)		Difference (B-A)
		Frequency	Average yield (Qt/*timad*)	Frequency	Average yield (Qt/*timad*)	Qt/*timad*
1. Cereals	Teff	99	5.41	100	9.95	4.54
	Wheat	96	6.77	96	14.36	7.59
	Barley	65	2.15	71	4.20	2.05
	Sorghum	41	6.34	43	11.37	5.03
	Maize	55	2.09	63	3.46	1.37
2. Pulses	Chickpea	45	2.86	56	5.84	2.98
	pea	18	1.58	24	3.67	2.09
	Bean	29	1.95	34	4.41	2.46
	Lentil	44	2.63	53	5.39	2.76
	Haricot Bean	10	1.00	37	1.78	0.78
3. Vegetables	Onion	25	3.00	97	24.12	21.12
	Garlic	6	1.42	34	3.38	1.96
	Tomato	0	-	27	4.39	4.39
	Potatoes	6	5.50	36	9.03	3.53
4. Fruits	Mango	0	-	36	2.86	2.86
	Orange	0	-	14	1.61	1.61
	Lemon	0	-	46	2.20	2.20
	Avocado	0	-	17	2.88	2.88
	Papaya	0	-	30	4.07	4.07

Source: own survey, June 2020

Timad = 0.25 Hectare

4.5.2. Household livestock holding before and after rainwater harvesting practices

Table 22, illustrates, household livestock holding production before and after rainwater harvesting practices. The analysis confirmed that considerable increases in number of livestock holding after use of RWH. For example, cattle holding increase by 0.33, small ruminants by

3.22, equines (donkeys and camel) by 0.35, poultry by 10.5 and beekeeping by 1.02 in numbers per house hold level after the practices of RWH. This implies that RWH practices are contributing to high livestock production and the economic development of the farmers in the study area.

FGDs and KIIs participants also confirmed that the development of RWH practices in the study area hold significant potential to increase the livestock holding of households. FGDs and KIIs participants explained that before RWH technology adoption the main sources of water for livestock watering during the rainy season are traditional excavated ponds (locally called *kurry*) and seasonal streams, these sources usually serve until some part of the dry season and forces farmers to less number of livestock as searching water for livestock create both economic and labour burden. However, after adoption of the RWH practices like plastic-lined and cemented ponds they able to watering livestock at nearly from their villages and farming lands. Because of this, they can avoid a km trekked of livestock for watering, which the available feed resources can sustainably support for increasing of the number of livestock per households and also they can keep the health of livestock from various diseases types. In addition, income obtained from crop production using RWH helped farmers to accumulate asset in the form of livestock. The participants also explain livestock plays a significant role in the mixed farming system in the area. Their main contribution is in providing draft power, cash generation, food (e.g, milk for children), and as a status symbol. Livestock types kept by the farmers include cattle, small ruminants, equines and poultry. Oxen are kept to provide draft power, cows to provide farm households with milk and butter for consumption and sale, donkeys for transporting goods, whilst sheep, goats, and poultry are mainly kept for sale. The field observation also confirmed that in the study area the feed resources for livestock commonly used by the farmers include natural grazing and crop residues also watering from harvested ponds. In the specific study area, the contribution of natural pasture as a source of feed is very limited due to the extensive coverage of the land by crops. In this regards, study showed that households with a larger size of livestock holding consume more water than those households with fewer livestock holding (Azizi and Tesfaye, 2013). Azizi and Tesfaye, (2013) reported that total tropical livestock unit owned by a household positively affected the adoption of RWH practices. Therefore, household livestock holding is expected to have a positive relationship with the adoption of plastic lined RWH ponds.

Table 22: Livestock production before and after rainwater harvesting practices

Type of livestock		Average livestock holding per household				Difference (B-A)
		Before RWH practices (A)		After RWH practices (B)		
		Frequency	Number	Frequency	Number	Number
Cattle	Oxen	100	1.98	100	2.73	0.75
	Cows	36	1.28	75	1.60	0.32
	Heifer	6	1.00	47	1.21	0.21
	Bull	13	1.31	57	1.54	0.23
	Calves	9	1.22	47	1.36	0.14
Small ruminants	Sheep	64	3.81	85	7.15	3.34
	Goat	47	7.23	70	10.04	3.11
Equines	Mules	5	1.00	13	1.00	-
	Donkeys	100	1.23	100	1.73	0.5
	Horses	1	1.00	5	1.00	-
	Camel	18	1.11	63	1.32	0.21
Poultry	Chicken	100	11.85	100	22.34	10.49
Beekeeping	Beehives	11	1.00	50	2.02	1.02

Source: own survey, June 2020

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Based on the intention of the research, after critically assessing the role of rainwater harvesting practices for smallholder farmers on climate change adaptation in Minjar Shenkora *Woreda*, important conclusions are drawn as discussed hereunder: Climate change brought about increased temperature, drought and insect outbreaks, declining water supplies, reduced agricultural yields, health problem on people and animal, increased flash flooding and erosion due to short duration erratic rainfall in the study area. The result of the survey, KII and FGDs showed that participants recognized change in temperature and rainfall amount, timing and distribution over the last 10-20 years in the study area. It was perceived that rainfall has been highly decreasing while temperature showed increasing trend in all seasons over the past two decades. Besides, climate change created great impact on crop production, due to prevalence of crop and livestock pest, disease that resulted loss of indigenous crop varieties, decreasing livestock production of the study area. Local farmers implemented different types of RWH practices in the study area to counteract climate change effects, by construction of traditional and plastic lined ponds, which they have been using for small scale irrigation. In addition farmers of the study area have been using climate change adaptation strategies like use of contour ploughing, farmland terracing, flash flood diversion to farmlands, farmland mulching, participation in rangelands management, construction of deep trenches for *in-situ* water conservation, construction of soil bund, tree planting and crop rotation. As revealed by the current analysis, the major challenges related to RWH practices implementation in the study area include finance, labor, environmental, technical challenge and managerial capability.

5.2. Recommendations

The study drew the following recommendations to improving roles of rainwater harvesting practices for small holder farmers to counteract the harmful impacts of climate change:

- Since the effect of climate change is inevitable, special attention should be given to the area by the concerned bodies.
- RWH practices for stallholder farmers should be highly promoted and supported through policy along with expertise support via the agricultural offices of the *woreda.*

- As most farmers in the area adapted and highly accepted small scale irrigation practices by using traditional and plastic lined RWH ponds, therefore the government and *Woerda* agriculture and development office shall supply durable plastic sheet (geo-membrane) and pedal pumps to lift the water.
- Even though, most of the farmers in the study area adapted crop rotation, contour farming, farmland terracing, flash flood diversion to farmlands and farmland mulching, the climate change is still greatly affecting indigenous crop types and varieties of the area, farmers are also facing shortage of livestock feed and grazing lands due to lack of technical knowledge and supporting policies. Therefore, special attention shall be given to alleviate the problems and reduce the existing challenges.
- Unfortunately, some health hazards occur as a result of using open traditional and plastic lined pond water sources as it might be polluted by bacteria and hazardous chemicals; therefore, the water from RWH should be restricted to non-potable uses and treatment should be made before usage in cases where use of water from RWH is mandatory.
- Finance, accessibility of labor, technical skills, environment and managerial capability are among the major challenge in related to RWH practices and their implementations in the study area; hence, *Woreda* agricultural and development offices or other concerned bodies need to design mechanism to deliver different supporting technologies and build the potential of the smallholder farmers.
- Finally, accessibility of market is among basic problem in the study area; especially for onion production therefore, the *woreda* concerned bodies need to facilitate market linkages for farmers with trade unions.

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APPENDIXES

Appendix I: Metrological records of temperature and rainfall

Trends of Annual temperature and rainfall of Minjar Shenkora *woreda* over the Last 30 years

No.	Year	Temperature			Rainfall (mm)
		Maximum (°C)	Minimum (°C)	Mean (°C)	
1.	1987	31.13	20.65	25.89	911.66
2.	1988	31.84	20.98	26.41	963.84
3.	1989	30.91	19.57	25.24	992.56
4.	1990	31.66	19.75	25.70	1157.09
5.	1991	31.48	19.88	25.68	946.44
6.	1992	32.27	20.30	26.28	1150.93
7.	1993	31.56	19.86	25.67	1283.99
8.	1994	31.49	19.01	25.25	1061.78
9.	1995	32	19.49	25.75	889.27
10.	1996	31.95	20.10	26.02	1211.41
11.	1997	31.40	20.18	25.79	1107.26
12.	1998	31.51	20.02	25.77	1059.03
13.	1999	31.41	20.28	25.85	1002.37
14.	2000	31.37	19.94	25.66	932.60
15.	2001	31.81	20.30	26.10	934.02
16.	2002	31.88	21.08	26.47	708.98
17.	2003	32.16	21.19	26.68	1100.04
18.	2004	31.58	20.78	26.18	1051.38
19.	2005	32.01	20.25	26.13	1073.69
20.	2006	31.63	20.81	26.22	1004.89
21.	2007	31.76	20.31	26.03	1021.77
22.	2008	31.45	18.77	25.11	1023.82
23.	2009	32.40	20.27	26.33	807.16
24.	2010	31.59	20.56	26.07	896.55
25.	2011	31.98	19.95	25.97	878.11
26.	2012	31.63	20.46	26.04	1060.78
27.	2013	31.57	19.71	25.64	999.64
28.	2014	32.06	20.26	26.16	758.31
29.	2015	31.88	18.23	25.05	784.06
30.	2016	32.67	19.35	26.01	1207.52

Appendix II: Data collection tools

1. Questionnaires for Household survey

General Introduction: The purpose of this questionnaire is to collect data about rainwater harvesting practices for smallholder farmers for climate change adaptation: Evidence from Minjar Shenkora woreda, North Shewa Zone of Amhara Region, Ethiopia. This questionnaire is prepared only for an academic purpose of writing M.A Thesis in Development Studies (Environment and Sustainable Development). Therefore, you are kindly requested to give answers freely and openly. Any information you give is to be kept confidential. Thus, your cooperation is very necessary to achieve the desired goal of the study.

Thank you in advance for your collaboration!

Zewdu Geda

Part I. Preliminary information

1.1. Kebele: --

1.2.Name of enumerator: -------------------------------

1.3. Signature -------------------------------------

1.4. Date: --

Part II. Household head Characteristics and Structure

2.1. Name of household head ------------------------- code ---------------------------

2.2. Gender of household head 1. Male 2.Female

2.3. Age of household head 1. <40 2. 40-60 3. > 61

2.4. Educational status of the respondent 1. Illiterate 2. Read and write/informal education 3. Primary education (Grade 1-8) 4. High school (Grade 9-12) 5. Collage and above

2.5. Marital Status 1. Single 2. Married 3. Divorced 4. Widowed 5. Separated

2.6. What is your major livelihood occupation? 1. Crop production 2. Livestock production 3. Mixed farming (both Crop and Livestock production) 4. Petty trade 5. Handicraft

2.7. Do you have your own farm land? 1. Yes 2. No

2.8. If the answer in question 2.7., is yes, how much is the size of your farm land in hectare?

1. <1 2. 1-2 3. 2-3 4. >3

2.9. Family size: 1. 1-3 2. 4-6 3. >6

Part III. Farmer's perception about climate change and their variability

3.1. How do you perceptive climate change in terms of temperature and/or rainfall over the last 10-20 years trend in perspectives (Changes of temperature and precipitation)

No.	Change in temperature	Variables code: 1. Severely increased 2. Increased 3. No changing 4. Decreased 5. Severely decreased	Response
1.	Dry season (Bega Temperature)		
2.	Summer season (Kirmet Temperature)		
No	Change in Amount of rainfall		
1.	Dry season (Bega rainfall amount)		
2.	Summer season (Kirmet rainfall amount)		
No.	Entry and exit period of summer rainfall	Variables code: 1. yes 2. No	
1.	Do starts lately of rainfall happen over the last 20 years?		
2.	Do early cessations of rainfall happen over the last 20 years?		

Part IV. Observed Climate change effect on crop and livestock production

4.1. Would you please indicate the extent effect of climate change has brought to your crop and livestock production over the last 10 to 20 years?

No.	effect of climate change on crop production	Variables code: 1.strongly agree 2.agree 3.undecided 4.disagree 5.strongly disagree	Response
1.	Total damage/loss of crop production		
2.	Decrease in amount of crop production		
3.	Increase in prevalence of crop pest		
4.	Increased incidence of crop disease		
5.	Emergence and expansion of new weeds and invasive plants		
6.	Loss of indigenous crop varieties		
7.	Shift in farming and production seasons		

8.	Shortage of water for crop production		
No.	effect of climate change on livestock production		
1.	Decreased production and productivity of livestock		
2.	Increased incidence of animal/livestock diseases		
3.	Shortage of livestock feed		
4.	Shortage and loss of grazing land		
5.	Shortage of water for livestock production		

Part V. Assessment of RWH practices Implementation

5.1. What are your main RWH practices implemented in your farm land encountered to Climate change effects?

No.	Implemented activities	Variables code: 1. Adopted 2. sometimes 3. not now	Response
1	Construction traditional pond(s)		
2	Construction plastic lined pond(s)		
3	Construction cemented pond(s)		
4	Using small scale (fulltime or supplementary) irrigation		
5	Contour plowing		
6	Terracing of farm land		
7	Flash flood diversion to farmlands		
8	Farmland mulching		
9	Participate in managing range lands		
10	Construction of deep trenches for in situ water conservation		
11	Construction of soil bund		
12	Tree planting		
13	Crop rotation		

5.2. Where do you get information regarding the various practices of rainwater harvesting?

1. Radio 2.PA cadre 3.DA Officers 4. Model farmers /Friends 5. Newspaper

6. Television

5.3. Do you participate in rain water harvesting practices?

1. Yes 2. No

5.4. If the answer in question 5.3., is yes, how was your participation in the rain water harvesting Practices?

1. Voluntarily 2. Selected by DA 3. Registered by Keble leaders

5.5. If voluntarily, what objective realities convinced you to participate in rainwater harvesting Practices?

1. Frequent drought 2. Increased water demand 3. Training effect 4. Cadre agitation

5.6. Are you trained in water harvesting practices and its utilization?
1. Yes 2. No

5.7. If yes, how often ayear?

1. Once 2. Twice 3. Three 4. Four

5.8. What type of training was offered to you?

1. Only theoretical 2. Only practical 3. Both theory and practice

5.9. Who is/are trained you?

1. kebele DA Officers 2. Woreda Agriculicural experts 3. Regional Agriculicural experts
4. NGO experts

5.10. What were the expectations of the household on benefits of rain water harvesting practices?

1. Positive 2. Negative 3. Not identified

Part VI. Major challenges of RWH practices

6.1. What is the major challenge you faced for implementing rainwater harvesting Practices in your case?

1. Social 2. Labor 3. Environmental 4. Financial 5. Managerial
6. Technical

6.2. Are they now solved your challenge?

1. Yes 2. No

6.3. If the answer in question 6.2., is yes. What are the measures taken to solve challenge?

1. By negotiation with societies 2.commitment of families for the practices
3. By Follow appropriate practices for the environment 4. By taking credit from the Government 5. By negotiation with Managers 6. By taking training

6.4. If the answer in question 6.2., is no., why the major challenge is not yet solved?

1. Can’t negotiation with societies 2. Limited commitment of families for the practices
3. Can’t follow appropriate practices for the environment 4. Can’t get credit from the Government 5. Can’t negotiation with Managers 6. Can’t get training

6.5. Have you ever faced any human health problems associated with rainwater harvesting practices?

1. Yes 2.No

6.6. If the answer in question 6.5., is yes., what type of major diseases is identified?

1. Malaria 2. Bilharzias 3. Amoeba 4. Giardia

6. 7. Have you constructed fence for protection of any problems associated with rainwater Harvesting practices?

1. Yes 2.No

6.8. Have you ever encountered any damage because of no fence to the member of the household or your livestock?

1. Yes 2. No

6.9. If the answer in question 6.8., is yes., which kind of rainwater harvesting practice is known to cause mechanical damage to human or livestock?

1. Traditional pond 2. Plastic lined pond 3. Cemented pond 4. Terracing of farm land

5. Construction of deep trench

Part VII. Role of RWH practices for climate change Impacts adaptation

7.1. Do you use rainwater harvesting practices?

1. Yes 2. No

7.2. If the answer in question 7.1., is yes, what scale you use the harvested rainwater?

1. for Supplementary irrigation 2. For Household consumption

3. For Field crops production 4. for all

7.3. For what major purposes you use the harvested rainwater?

1. Vegetable growing 2. Livestock watering

3. Human consumption 4. Field crops production

7.4. What are the main sources of your family livelihood income?

1. Crop production 2. Livestock production

3. Mixed farming (both Crop and Livestock production) 4. Non- farm income

7.4.1. Household Crop production before and after rainwater harvesting Practices

No.	Type of crops	Before RWH practices average yield (quintal/timad)	After RWH practices average yield (quintal/timad)
7.4.1.1	Cereals		
	Teff		
	Wheat		
	Barley		
	Sorghum		
	Maize		
7.4.1.2	Pulses		
	Chickpea		
	pea		
	beans		

	Lentil		
	Haricot Bean		
7.4.1.3	Vegetables		
	Onion		
	Garlic		
	Tomato		
	Potatoes		
7.4.1.4	Fruits		
	Mango		
	Orange		
	Lemon		
	Avocado		
	Papaya		

7.4.2. Household Livestock holding before and after rainwater harvesting Practices

No.	Type of Livestock	Before RWH practices average Livestock holding per household (number)	After RWH practices average Livestock holding per household (number)
7.4.2.1	Cattle		
	Oxen		
	Cows		
	Heifer		
	Bull		
	Calves		
7.4.2.2	Sheep and goat		
	Sheep		
	Goat		
7.4.2.3	Equines		
	Mules		
	Donkeys		
	Horses		
	Camel		
7.4.2.4	Poultry		
	Chicken		
7.4.2.5	Beekeeping		
	Beehives		

7.4.3. Other source of income

7.4.3.1. Do you or any member of your family have other source of income listed from the above?

1. Yes 2. No

7.4.3.2. If the answer in question 7.3.3.1., is yes,, indicate the type of work and the net income for the year 2011/2012 E.C

No.	Type of income (see below)	Income (Birr)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		

Types of income -

1. Sale of seedlings
2. Sale of local drinks
3. Pity trade
4. Daily laborer
5. Sale of water
6. Remittance
7. sale of perennials
8. Sale of spices

2. Questions for Focused Group Discussion (FGD)

1. Have you heard about climate change? What does climate change mean in your context?
2. Have you noticed climate change and variability in your area? Could you please describe the Climate changes you noticed in your area?
3. Please explain Climate Change related hazards that you experienced in the area in the past 10-20 years
4. Would you explain the effects that you observed on your crop and livestock production as a result of Climate change?
5. What are the major RWH practices implemented in your farm land to adapt climate change Impacts?
6. Do local government and non-government institutions supported your effort to adapt and Cope to climate change? (Who are they, what support?)
7. What are the major challenges faced to implement RWH practices?
8. What are the solutions for such problems according to your opinion?
9. What is the major contribution of RWH practices for your economic wellbeing?
10. What improvements do you observe in increasing health and environmental status of your Local area after implementation of RWH practices?

3. Interview questions for Woreda Agriculture and Rural Development Office Experts

1. How do you understand CC?
2. Have you observed change and variability in CC and its indicators in the woreda? Would you explain the indicators of climate change and variability you observed?
3. Could you explain major effects experienced in the woreda as a result of CC in the past 10-20 years?
4. What are the experienced effects of CC on the crop and livestock production of smallholder farmers?
5. As a woreda agriculture office are you working to reduce climate change vulnerability of the farmers? What agricultural adaptation practices are you promoting?
6. What are the major challenges you faced from the start up to the effectiveness of the RWH Practice?
7. How can challenges and limitations be overcome, which RWH practices be promoted or discouraged?
8. How is the RWH practice going on at present time?
9. How does your local community perceive the RWH practices as a means of water availability and alleviation of poverty?
10. Can you say that RWH practice is the best alternative source of water for the woreda?
11. Is/are there any Organization is involved in the process and system of the RWH practices in one or other way? What are their activities?
12. As a professional what further strategies do you suggest (works to be done) to cope and Adapt to CC effect and achieve food security in the woreda?

4. Interview questions for the Kebele Development Agents

1. What is your view on Rainwater harvesting practices and its implementation in your kebele?
2. Do the farmers participate voluntarily in RWH practice implementation?
3. How do you support/help the beneficiaries of RWH practice?
4. What type of training do you offer to the farmers?
5. What are the major challenges you faced undertaking extension works with farmers in Relation to RWH practices in your kebele?
6. What improvement do you recommend to solve the major challenges associated with RWH practices?

7. What do you think about the sustainability of RWH practice?
8. What do you say about the benefits of farmers in relation to RWH practices in your kebele?

5. Interview questions for the Kebele Administration

1. What do say about the acceptance of farmers for the practice of RWH in your kebele?
2. What kind of RWH practices implemented in your kebele at the past and in present time?
3. What are the major challenges you face in implementing the practice of RWH?
4. Is there any special support you have received (as a KA) from local government and non-Government Organization in relation to implementing of RWH practices?
5. What do you say about the role of RWH practices to the community as a whole for climate change impact adaptation?
6. In your opinion, do RWH practices serve as the opportunities of income growth and ensuring food security for your kebele households?

6. Check list for Field Observation

The researcher was observing:

1. Implementation level of RWH practices in the study area
2. Farming and small scale irrigation activities of the study area
3. Crop production and livestock husbandry activities in study area
4. Government and Non-government involvements on RWH practices in the study area
5. Households' Major economic activities in the study area.