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Keynote Address by Professor Chemeda Fininsa
President of Haramaya University

Excellencies, Distinguished Delegates, Ladies and Gentlemen,

It is a great pleasure for me to make an opening speech on this important workshop with the theme '*Building Resilience and Reducing Vulnerability in Moisture Stress Areas through Climate Smart Technologies and Innovative Practices'*.

Food security is a critical issue for Africa today, as the continent struggles with declining agricultural stocks and high food prices. The Horn of Africa, especially, is one of the world's most food-insecure regions with large proportion of the population living in areas prone to extreme food shortages.In the future, the impacts of climate change, as well as growing population and declining per capita agricultural capacity, will further threaten already weakened productivity and the situation is precarious.

The current trend also shows a rapid increase in demand and consumption of agricultural products. To satisfy this growing demand, it is therefore necessary to increase production by improving productivity and/or increasing land under cultivation though the later has a limited scope. These require, among others, utilization of important inputs including water. However, it has become a well-established fact that scarcity of water resources is the most severe constraint to agricultural development. Arid and semi-arid areas, in particular, are susceptible to devastating droughts and hence to high risk of food insecurity.

This is especially serious in countries like ours where the vast majority of the land area is under pastoral and agro-pastoral systems with high moisture deficit. As you all know, the current drought compounded by the occurrence of the El Niño weather conditions has affected millions and worsens food insecurity in the country. Delayed seasonal rains are causing livestock loss and risk of food shortage in some parts of Ethiopia especially in the Eastern and Southern Oromia, Afar, Somali and Southern nations.Unfortunately, this has happened when the country officially launched the second Growth and Transformation Plan (GTP II), following the success of GTP I. We are also aware of the tremendous effort being made by the government and some NGOs for ameliorating the problem by mobilizing resources from within and outside for humanitarian support of the people affected by drought. Other than humanitarian emergencies, it is in fact necessary to strengthen the ability of the community to build long-term resilience and tackle the root causes of vulnerability. Efforts are underway in this regard as well.If we pursue agricultural development as a multi-dimensional concept, encompassing the economic, social, institutional and physical elements, in a wider sense, it would be possible to effect positive changes in the livelihoods of the communities in moisture deficit areas and beyond.

Besides the efforts being made by the governmental and non-governmental organizations, a lot is expected from the academic and the scientific community in terms of proposing science-based solutions as knowledge is a crucial tool for overcoming problems of economic development. These expectations may include, among others, generating and disseminating climate smart technologies and practices for building resilience and reducing vulnerabilities of the local communities to moisture stress. In this regard, the theme of this workshop is very pertinent.

Using Haramaya's tradition of working with various institutions and organizations, we are happy to co-organize this workshop with the ZOA, an organization focusing on Relief, Hope, and Recovery in moisture stress areas. In fact, organizing such scientific forum is among the very important inputs for our triple mandates of teaching, research, and community services. As we are aspiring to become a research university, we must be part of an active wider community; we need to contribute to the development efforts through the production and distribution of knowledge; and we must involve in research endeavours carried out in collaboration with funding and sponsorship from non-university sources. We appreciate the steps taken by ZOA in this regard.

Indeed, it is gratifying to note that the agenda of the current workshop covers a wide range of very interesting topics for you to attentively follow, comment, enrich, share ideas, and engage in thoughtful scientific dialogue. In addition, I feel that the workshop provides adequate opportunities for researchers to share the information they generated through rigorous research. This is because undertaking a research cannot be an end by itself, if the outcomes are not adequately and timely shared to the users and policy makers. In this regard, I assure you that the organizing committee will exert utmost effort to timey publish the outcomes in the form of proceedings from this workshop for its further distribution.

Finally, wishing you a very pleasant stay here at Haramaya with a productive and successful deliberationsduring the two days, I declare the workshopofficially opened.

Keynote Address by Adhana Dargie
Program Manager of ZOA Jigiga Field Office

Professor Chemeda Fininsa, President of Haramaya University;
Distinguished faculty members of this university;
Distinguished invited guests;
Ladies and Gentlemen

Mr. Chairman,
On behalf of ZOA Ethiopia country director and myself, I would like to thank Haramaya University for hosting this national workshop in its main campus and for co-funding the workshop expense. Special thanks must go to the faculty members who worked very hard to make this workshop a reality and to FAO/DFID for funding the project.
ZOA Relief | Hope | Recovery is an international NGO which supports people who suffer because of armed conflict or natural disasters, in helping them to rebuild their lives and livelihoods. ZOA has been operating in Ethiopia since 1993 and currently has four programs in four regional states of the country. ZOA Ethiopia works with internally displaced people, host populations, returnees, and a large population of refugees undertaking activities in the sectors of livelihoods development, food security, water, sanitation, and hygiene (WASH), education, and environmental protection.
ZOA has four major key values:

- Human dignity - We treat all people equally and with respect. We make no distinctions based on race, ethnicity, religion, or gender.

- Faithfulness - The people we serve face constant uncertainty about their future. Our responsibility is to provide them with support that they can count on, honouring our commitments and being faithful and accountable to them.

- Stewardship - Stewardship encompasses both people and their environment. The people we serve have a variety of valuable capacities that are worthy of significant investment. We aim to be good stewards to them, nurturing their abilities through capacity enhancement and development in order to facilitate their independence from external support and in order to provide them new opportunities for the future.

- Justice - ZOA stands up for vulnerable and marginalised people

And it has three major goals it envisages to achieve by its involvement. These are

- Sustainable access to basic services and resources;
- Good community governance ; and
- Peaceful and stable community.

It has regularly updated its management tools and for the year 2015 – 2017 its vision will focus on the principles of

- Inclusion;
- Ownership ;
- Participation;
- Accountability and transparency;
- Sustainability; and
- Do no harm.

These principles govern our activity. ZOA is a full member of HAP (Humanitarian Accountability Partnership) which has recently transformed itself into CHS (Core Humanitarian Standard)

"which is a global alliance of more than 200 organizations committed to improving the effectiveness of humanitarian and development assistance".
We started implementing Innovative Agricultural Solution that was started back in April 2014 in Midega Tola and have successfully implemented the project in a timely manner as ascertained by a private consultant who did the end line impact survey.
According to Emergency Nutrition Coordination Unit (ENCU), Midega Tola has consistently suffered the highest malnutrition rate since 2008and has been named as the number one Hotspot Woreda in all of the 19 Woredas of Hararghe zone of Oromia Regional State. Midega Tola is identified as moisture stress area by the Ministry of Agriculture.

ZOA introduced mung bean seed multiplication, production and marketing project to alleviate the recurrent crop failure and subsequent drought. Trainings such as pest control, seed quality control and storing, gender mainstreaming, and marketing were provided in close collaboration with Fedis Research center and the Midega Tola Woreda Agriculture office. One seed bank has been constructed and four cooperatives formed for marketing purpose.

We are still operational in the Woreda in response to the recent drought that has been brought about by the global climatic condition dubbed as El Nino. El Nino has been the cause of drastic flood in some areas and drought in others such as Ethiopia.
I want to thank all of you who are in attendance to day and to those of you who will shade some light on building resilience in moisture stress areas such as Midega Tola. I hope this workshop will bring good results that will benefit the whole country in its endeavor to tackle recurrent drought and in improving the lives and livelihoods of its citizens.
Thanks very much and God bless you!!!

1. Greening the Economy through Climate Smart Agriculture: A Brief Review of Global Experience

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Abstract
Green economy and climate-smart agriculture/CSA/ share the common goal of integrating the three dimensions of sustainable development. Both make sustainable development concrete by focusing on issues that can and must be addressed right now in local communities but that have global, long-term consequences. Climate-smart agriculture brings together global and local concerns, climate change to be addressed, global impact of agriculture, climate change to get adapted to, local impact of a global change; and first of all, food security, both local and global. To do so, it brings together practices, policies and institutions which are not necessarily new. What is new is to bring together practices and policies in order to address multiple challenges, faced by agriculture and food systems, now and for the future. What is new is to avoid having contradictory policies by internally managing the trade-offs and synergies in the pursuit of multiple objectives. Addressing food security and climate change require concerted and coordinated involvement and action of many actors, farmers, private sector, and public actors national and international, civil society and NGOs. It is especially challenging as they are very different, sometimes have conflicting objectives and there is a need to work on a long term perspective while most of them have to consider first a short term outcome. This requires the involvement of all stakeholders. Integrating food security and climate change concerns has to be done at every level and pursued at different scales. It needs to be done on a day-to-day basis at farm level. Moreover, it also must be carried out with a long-term perspective at the landscape and country levels to design locally specific, coherent, inclusive and cohesive policy packages.

Keywords: green economy; climate-smart agriculture; food security; climate change; resilience

1. Introduction

Twenty years after, the United Nations Conference on Sustainable Development, commonly called Rio+20 or the Rio Earth Summit 2012, was also held in Rio. While some progress has been made towards sustainable development between 1992 and 2012, challenges remain huge as human footprint on the planet is increasing and some 'planetary boundaries' are (or are close to be) exceeded. We are now at a time when it is urgent to give a new and more concrete expression to the classical theoretical apparatus of sustainable development, make it more operational, and pave ways on how to integrate its three dimensions. This is also why the concept of the 'green economy' was developed.

One of the first planetary boundaries, perhaps the most important one, is that the world needs to feed itself. However, today, almost one billion people are hungry. Another billion is malnourished, lacking essential micronutrients. While, globally, enough food is being produced to feed the entire world, one-third of it is lost or wasted, and stable economical and physical accessibility to food is still a problem for one out of six people on our planet. By 2050, food production has to increase, both in quantity, quality, and diversity, especially in developing countries. Population and income growth will drive up an ever increasing demand, especially in developing countries (Foresight, 2011a; Foresight, 2011b; Lutz and Samir, 2010; Cirera and Masset, 2010). Assuming these trends to continue, FAO estimates that production has to increase by 60 percent between now and 2050, especially in developing countries (Conforti, 2011; Bruinsma, 2009). Food systems have to satisfy this growing demand, both in quantity, quality and diversity.

Agriculture is also an essential driver of economic growth, particularly in rural areas and least developed countries. At the national level boosting agricultural production stimulates overall economic growth and development, particularly in those countries with a high economic dependence on agriculture. According to World Bank (2008) investment in agriculture is particularly efficient in creating new jobs. Agricultural and rural development acts as an engine for sustainable economic development, making an effective contribution to national economic growth. At the community level, agricultural development increases farm productivity, reduces food deficits, increases food surpluses and raises incomes. Improved agricultural production provides opportunities to sustainably reduce poverty, food insecurity and malnutrition and thereby improves livelihoods. At the same time, food production and consumption already exerts a considerable impact on the environment (FAO, 2012b; UNEP, 2010). Food systems rely on resources, especially land, water, biodiversity, and fossil fuels, which are becoming ever more fragile and scarce.

As stated in the outcome document of the Rio+20 conference, the "green economy in the context of sustainable development and poverty eradication will enhance our ability to manage natural resources sustainably and with lower negative environmental impacts, increase resource efficiency and reduce waste."[1]. Agriculture is essential for a green economy. In fact, FAO considers that there can be no green economy without agriculture. This is why FAO proposed "Greening Economy with Agriculture" as the key message for Rio+20 (FAO, 2012b).

Climate-smart agriculture (CSA), as defined and presented by FAO (FAO, 2010a) at the Hague Conference on Agriculture, Food Security and Climate Change, contributes to the goals of making sustainable development concrete. It integrates the three dimensions of sustainable development in addressing food security and climate concerns in a forward-looking perspective.

Climate change is real and happening now. The average global surface temperature has warmed by 0.8 °C in the past century and 0.6 °C in the past three decades (Hansen *et al.,* 2006), in large part because of human activities (IPCC, 2001). A recent report produced by the U.S. National Academy of Sciences confirms that the last few decades of the 20th century were in fact the warmest in the past 400 years (National Research Council, 2006). The Intergovernmental Panel on Climate Change (IPCC) has projected that if greenhouse gas emissions, the leading cause of climate change, continue to rise, the mean global temperatures will increase by 1.4 – 5.8 °C by the end of the 21st century (IPCC, 2001).

"We need to convince the world that humanity really is the most important species endangered by climate change." Margaret Chan, MD, Director General, World Health Organization

Estimates show that world population will grow from the current 6.7 billion to 9 billion by 2050 with most of the increase occurring in South Asia and sub-Saharan Africa. Taking into account the changes in the composition and level of consumption associated with growing household incomes, FAO estimates that feeding the world population will require a 70 percent increase in total agricultural production (Bruinsma, 2009).

At the same time, climate change threatens production's stability and productivity. In many areas of the world where agricultural productivity is already low and the means of coping with adverse events are limited, climate change is expected to reduce productivity to even lower levels and make production more erratic (Cline, 2007; IPCC, 2007; Stern Review, 2006; Fisher *et al.,* 2002). Long term changes in the patterns of temperature and precipitation, that are part of climate change, are expected to shift production seasons, pest and disease patterns, and modify the set of feasible crops affecting production, prices, incomes and ultimately, livelihoods and lives.

Preserving and enhancing food security requires agricultural production systems to change in the direction of higher productivity and also, essentially, lower output variability in the face of climate risk and risks of an agro-ecological and socio-economic nature. In order to stabilize output and income, production systems must become more resilient, i.e. more capable of performing well in the face of disruptive events. More productive and resilient agriculture requires transformations in the management of natural resources (e.g. land, water, soil nutrients, and genetic resources) and higher efficiency in the use of these resources and inputs for production. Transitioning to such systems could also generate significant mitigation benefits by increasing carbon sinks, as well as reducing emissions per unit of agricultural product.

2. Food Security and Climate Change

2.1. Impacts of Climate Change on Agriculture

Climate change is suspected of having already significantly impacted agriculture (Lobell *et al.,* 2011) and is expected to further impact directly and indirectly food production. Increase in mean temperature; changes in rain patterns; increased variability both in temperature and rain patterns; changes in water availability; the frequency and intensity of 'extreme events'; sea level rise and salinization; perturbations in ecosystems, all will have profound impacts on agriculture, forestry and fisheries (Beddington *et al.,* 2012b; HLPE, 2012a; Thornton *et al.,* 2012; Gornall, 2010; IPCC, 2007a). The extent of these impacts will depend not only on the intensity of the changes but also on their combination, which are more uncertain, and on local conditions. Anticipating appropriately the impacts of climate change on agriculture requires data, tools and models at the spatial scale of actual production areas. Since the last Intergovernmental Panel on Climate Change (IPCC) report in 2007, some studies have attempted to anticipate these impacts and provide projections at such a scale, enabling us to have a more concrete vision of projected changes.

A prospective study in Morocco (World Bank, 2009a) points to gradually increasing aridity due to reduced rainfall and higher temperatures, with negative effects on agricultural yields, especially from 2030 onwards. Rain fed crops are expected to be particularly affected. If irrigation water continues to be available in sufficient quantities, irrigated crop yields might continue to increase in spite of climate change. However, this will depend on the availability of water for irrigation. In this study it is anticipated that, if agricultural yields will remain more or less stable up to 2030, they are predicted to drop rather quickly beyond this date.

A study in Brazil, (EMBRAPA, 2008), shows that climate change can have dramatic impact on the potentials for the various crops analyzed and their potential geographic repartition. Globally, the increase of evapotranspiration leads to an increase of the areas at high climatic risk for seven of the nine crops analyzed (cotton, rice, coffee, beans, sunflower, millet, soya bean) and a decrease for cassava and sugar cane. It will also cause important displacements in areas suitable for crops, especially for coffee and cassava. In traditional production areas, coffee would be affected by lack of water or high temperatures. In the States of São Paulo and Minais Gerais coffee would no longer be cultivated in areas where it is currently cultivated. On the other hand, with the reduction of the risk of frost, there could be an increase of the production area in Paraná, Santa Catarina and Rio Grande do Sul. As a result, the global area at low climatic risk for coffee would be reduced by 9.5 percent in 2020, 17 percent in 2050, and 33 percent in 2070. On the other hand, favorable areas for sugar cane will considerably increase.

2.2. The impact of agriculture on climate change

The agriculture sector has to produce more food and it will be certainly impacted by climate change. It has also been called upon to contribute to mitigate climate change (UNFCCC, 2008). The question is how and to what extent agriculture and food systems can contribute to climate change mitigation without compromising food and nutrition security. In 2005, agriculture (crop and livestock) accounted for 13.5 percent of global GHG emissions (IPCC, 2007b). However, agriculture's role in the climate change, and, importantly, its mitigation potential, should be considered in a wider perspective of 'food systems'. This includes the impact these systems have on forests, the energy sector and transport. Expanding our consideration of agriculture's role in climate change is warranted because some of the on farm emissions are not included in the 13.5 percent figure, but are grouped in other sectors, such as electricity used in farm buildings and fuel used in farm equipment and food transport. In addition, agriculture is a major driver of deforestation, which roughly accounts for an additional 17 percent of global GHG emissions (IPCC, 2007b). This is why agriculture is included in the study on the drivers of deforestation, which was requested by the UNFCCC's 17th Conference of the Parties (COP 17) in Cancun to the Subsidiary Body for Scientific and Technological Advice (SBSTA). Finally, within food systems, reductions of emissions in some areas could lead to increases elsewhere. For instance, depending on production systems, shorter food chains could reduce transport but increase agricultural emissions. Currently, there are no studies that quantify emissions from the global food system (Garnett, 2011). A study in 2006 estimated that 31 percent of the European Union's GHG emissions were associated with the food system (European Commission, 2006). So, when looking at challenges and opportunities to reduce GHG emissions using agriculture, it is paramount to look beyond the farm, vertically into the whole food chain and horizontally across impacted land-uses such as forests.

2.3. Ensuring Food Security

The world is producing enough food, but there are still 925 million people estimated to be undernourished in 2010, representing almost 16 percent of the population of developing countries (FAO, 2010b). In addition, another billion people are malnourished, lacking essential micronutrients. The paradox is that 60 percent of the malnourished actually are food producers, smallholders and pastoralists, with 20 percent living in cities and 20 percent landless rural people. For the poor producers, food is not only a basic need, it is the single, and often fragile, support they have for maintaining their livelihood. What is true at the household level is also true at the macroeconomic level. There are 32 countries, 20 of them in Africa, facing food crises and in need of international emergency action. In most of these countries, paradoxically, agriculture is an important, if not the major, part of economy.

Globally our food system is not sustainable, does not provide adequate nutrition to everyone on the planet and, at the same time, changes to our climate threaten the future of farming as we know it. Agriculture is both part of the problem and part of the solution to climate change (Beddington *et al.,* 2012).

The objective is to ensure food and nutrition security, worldwide. It is not only availability of calories and sufficient global production that has to be ensured. We also need to make sure that enough food is accessible to everyone, everywhere, physically and economically. In addition, we need to ensure that this food is properly utilized in the right quality and diversity. The goal is to ensure the stability of these three components of food and nutrition security: availability, access, and utilization.

3. Developing more Efficient and Resilient Systems

The concept of "climate-smart" agriculture was invented by the UN Food and Agriculture Organization (FAO) in 2010. According to the original definition, "climate-smart" agriculture "sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances achievement of national food security and development goals." The concept was first launched by FAO in 2010 in a background paper prepared for the Hague Conference on Agriculture, Food Security and Climate Change, to tackle three main objectives:

- Sustainably increasing food security by increasing agricultural productivity and incomes;
- Building resilience and adapting to climate change;
- Developing opportunities for reducing greenhouse gas emissions compared to expected trends.

To address these three intertwined challenges, food systems have to become at the same time more efficient and resilient, at every scale from the farm to the global food system. They have to become more efficient in resource use; use less land, water and inputs to produce more food sustainably, and more resilient to changes and shocks.

While concepts are still evolving, national policy implementation of CSA is generally seen to include the following elements (FAO 2012a; FAO 2012b; Wollenberg *et al.,* 2012; FAO-EPIC 2013):

1. Integrated, context-specific assessment of drivers of unsustainability and GHG emissions, potential CSA interventions – with emphasis on identifying synergies (e.g. diversified production and income sources) and trade-offs (e.g. biodiversity vs food production) – and major barriers to their implementation (e.g. weak information or legal systems);
2. Strengthening institutions and infrastructure that promote sustainable practices in farming, forestry, and fishing systems (e.g. cooperatives and community based initiatives), efficient, equitable food chains, and enhanced governance systems to manage common resources, strengthen land tenure, and improve ecosystem services;

3. Establishing a strategic framework for coordinating key actors (e.g. ministries, local governments, farmers, agribusinesses, international agencies) in development and implementation of policy and market measures (e.g. credit and market access) and blended financing sources (e.g. climate and development funds; public and private sources) to incentivize CSA practices (e.g. appropriate inputs) and to reduce and respond to disaster risk (e.g. insurance; social protection);
4. Building multi-scale capacity for information systems including research and development (R&D) (e.g. varieties and breeds suitable for future climate and vulnerable populations), advisory services (including risk assessment), information technologies, and monitoring and evaluation.

3.1. Resilience

Resilience can be described as the capacity of systems, communities, households or individuals to prevent, mitigate or cope with risk and recover from shocks. At first approximation, resilience is the opposite of vulnerability. However, resilience adds a time dimension. A system is resilient when it is less vulnerable to shocks across time and can recover from them. Essential to resilience is adaptive capacity. Adaptive capacity encompasses two dimensions: recovery from shocks and response to changes in order to ensure the 'plasticity' of the system. For example, the organization of proper seeds systems enables farmers who have lost a crop to have seeds for the next season. It also enables them to have access to seeds that are adapted to new conditions.

Resilience puts a greater emphasis on the capacity of a system to recover and transform itself over the long term, and adapt to its changing environment in a dynamic perspective. It implies that it is not only shocks, as a change relative to an average, that have to be considered, but also the change of the average itself. Ultimately, the question is until what point can a system adapt before changing to another type of system.

3.2. Increasing Diversity in the Field

Increasing diversity of production at farm and landscape level is an important way to improve the resilience of agricultural systems (FAO, 2010a; FAO-OECD, 2012; HLPE, 2012a).

3.3. Climate Data and Information gaps

Improving the use of climate science data for agricultural planning can reduce the uncertainties generated by climate change, improve early warning systems for drought, flood, pests and diseases incidence and thus increase the capacity of farmers and agricultural planners to allocate resources effectively and reduce risks. SEI (2008) cites the need for more "translators" of climate information, who can bridge the divide between science and field application, assisting communities and planners to understand the implications of results for their immediate planning decisions. Enhancing communication between producers and users of climate science is also clearly a requirement. Institutions to facilitate this exchange can be existing communications and information dissemination networks, including extension. Capacity building of policy makers as well as technical staff is another avenue. Finally, platforms for collaborative action and information share.

4. Investing in a Greening Economy with Climate Smart Agriculture

As pointed out by the World Bank (2008), agriculture continues to be a fundamental instrument for sustainable development and poverty reduction. It contributes to development in many ways. In agriculture-based countries, it generates on average 29 percent of the gross domestic product (GDP) and employs 65 percent of the workforce. In transforming and urbanized countries, as distinguished by the World Bank in the World Development Report 2008, industries and services linked to agriculture often account for more than 30 percent of the GDP. Currently, 2.5 billion people live in households that are involved in agriculture. For these reasons, there can be no green economy without agriculture. CSA can be an important driver for a green economy, directly by increasing resource efficiency and resilience and indirectly by fostering the development of associated services and enterprises. The investments needed can also create new jobs and opportunities for the rural poor.

Since the end of 2008, the promotion of the concept of a green economy has been very much linked to the idea that investments should be focused on 'green' sectors. This was because these sectors, as opposed to 'brown' sectors, were seen as the sectors of the future that were going to provide more jobs. Climate change was a leading factor in drawing the line between 'green' investments - investments in sectors and activities that are good for the economy and good for the environment – (in this case, good for the climate) and 'brown' investments that were considered bad for the climate and not economically sustainable. The energy sector is the perfect example of a sector that offers very diverging choices.

One of the questions that emerged was "How was agriculture to position itself in this debate?" The issue is of considerable importance since the idea of a Global Green New Deal, launched by UNEP in March 2009, was to devote to green sectors, an important part of the public subsidies aimed at addressing the financial crisis and its economic and social impacts. In this view, the links between agriculture, food security, economic growth and rural development, as UNEP (2009) pointed out, led to the identification of priority investments to be directed to agriculture, especially in agricultural productivity measures, freshwater management and sanitation, as these have demonstrable and exceptional social returns (UNEP, 2009).

The very often stressed (FAO, 2009c) need to invest in agriculture in developing countries is even greater when the need to address the challenges of climate change is included (HLPE, 2012; FAO, 2010a; Nelson *et al.*; 2010; Nelson *et al.,* 2009). It must be emphasized that the major part of these investments will be made by the private sector and most of them by the farmers themselves. Reducing risk and improving resilience is a key to enabling private actors, especially the more financially vulnerable, to invest. Often these private actors will also need support, particularly during the transition phase towards new systems. Payments for environmental services can play an important role to facilitate this transition (Lipper and Neves, 2011).

5. Building Resilience to Climate Change: Global Experiences

5.1. Experiences in Southern Madagascar

The coastal zone of southwest Madagascar is recognized as one of Africa's most vulnerable areas to climate change (Busby *et al.,* 2010). Climate change is already affecting the availability and stability of the marine and coastal resources in the region, exacerbating existing food insecurity and threatening livelihoods (Hannah *et al.,* 2008). Here, increasingly severe and frequent tropical storms and cyclones may cause physical damage to coral reefs, seagrass beds and mangrove forests on which the local communities so intimately depend. These habitats, vitally important to fisheries, also act as natural physical barriers that reduce the impacts of climate hazards; damage to these critical ecosystems leads to increased coastal vulnerability to sea level rise, strong winds, waves, and storm surges, all of which cause shoreline erosion (Sheppard *et al.,* 2005). Changes in water temperature can have a number of detrimental effects in such marine ecosystems, including more destructive weather, shifts in fish distribution and reproductive patterns, and coral bleaching and mortality (Nellemann *et al.,* 2009).

Climate change causes further physical risk to fishers, who are forced to harvest in harsher weather or further away from shore as shallow and near shore ecosystems become degraded (Daw *et al.,* 2009). Inclement weather also reduces the number of fishing days and can result in loss of fishing gear and damage to boats and coastal infrastructure (Sumaila and Cheung, 2010; Daw *et al.,* 2009). Widespread anecdotes reveal that local fishers have detected changes in wind and rain patterns over the last decade, making weather prediction more unreliable both in the short-term (day to day) and long term (month to month). A locally managed marine area (LMMA) called Velondriake and located approximately 200 km north of the coastal city of Toliara has been the focus of various conservation and socio-economic development programmes for nearly a decade (Harris, 2007). Coastal communities in the Velondriake region are almost completely reliant on fisheries for subsistence and endure pervasive poverty, isolation from governmental services that could reduce vulnerability, and very high population growth rates (Harris *et al.,* 2012; Harris, 2011; Harris, 2007). This LMMA encompasses more than 1,000 km^2 of marine, coastal, and terrestrial environment, and is home to nearly 8,000 people (Harris, 2007). Approximately 80% of the communities rely on the directuse of coastal and marine resources for their livelihoods (Epps, 2007).

Strengthening ecological and social resilience

The LMMA, in tandem with social development interventions discussed below, addresses vulnerabilities in an integrated socio-ecological framework and is the mechanism through which resilience to climate change is being fostered in Velondriake. Local conservation management is implemented through a local set of laws, called a *dina*, which was created, and is now enforced, by local communities through a democratically-elected local management committee. In Madagascar, a *dina* can be used to complement formal legislation and carries authority that is recognized by national law (Andriamalala and Gardner, 2010). Velondriake's dina controls access to, and use of, marine resources through various forms of fisheries restrictions, which have been developed and agreed upon by local stakeholders in village meetings and regional workshops (Andriamalala and Gardner, 2010). These issues are elaborated below:

Ecological resilience

Reducing non-climate anthropogenic stressors, such as overfishing, can help to foster ecological resilience to climate change within the marine environment (Colls *et al.,* 2009). A by-product of ecosystem-based management activities in the LMMA is the assured flow of ecosystem services to communities in the face of climate change, thereby contributing to food security and livelihoods. Restrictions ban destructive or unsustainable fishing practices such as poison fishing, beach seine netting and physical damage to corals throughout the managed area. In an ecosystem where climate change is likely to increase water temperatures and ocean acidification, leading to coral mortality, restrictions such as these are essential to reduce some key non-climate stressors to the reefs and related ecosystems. Furthermore, six zones of coral reef and one of mangrove forest have been designated as permanent no-take-areas to further reduce anthropogenic stress in Velondriake. These core protected areas were identified via a participatory process with local communities, and the coral reserves were chosen on account of their unusually high coral cover, fish diversity, and general reef health - ecological indicators generally used to infer high reef resilience to climate change (Colls *et al.,* 2009; Cripps and Harris, 2009). Protection of such areas of high biodiversity and good ecological health will increase the resilience and recovery potential of coral reef and mangrove habitats to climate change, and provide larval recruits and juvenile habitat to aid the recovery of other more degraded habitats.

Social resilience

While the LMMA enhances ecological resilience to climate stress, it also fosters social resilience by reducing sensitivity and promoting adaptation to change. A large body of literature describes key indicators of social resilience, such as diversity of income sources, the level of education, participation in decision-making, ability to self-organize, and access to credit (Andrade Perez *et al.,* 2010; Busby *et al.,* 2010; Marshall *et al.,* 2009). In communities displaying high social vulnerability to climate change, investments in social development programs such as poverty alleviation and the creation of infrastructure are central in developing basic adaptive capacity; this then allows communities to further capitalize on conservation opportunities to build adaptive capacity (McClanahan *et al.,* 2008). Social development programs elaborated below are implemented throughout Velondriake by Blue Ventures, an NGO, targeting areas of social vulnerability and building social resilience to climate change.

Increased economic opportunities

Poverty increases vulnerability to climate change, decreases resilience and hinders adaptation (Marshall *et al.,* 2009). Increasing individual, household, or community income enables people to better prepare for climate disasters – houses constructed of more durable materials are better able to withstand strong storms; and families with an income are able to purchase food if there is a shortage due to drought, a decline in fish stocks or they are unable to harvest crops due to flooded fields. More indirectly, disposable income can be used for school fees or as capital to start a small business – enabling adaptation in the longer term. Management measures in Velondriake also aim to increase and stabilize income from an important income-generating activity in the region, the harvest of octopus. Since 2004, communities have chosen to close selected reef flats to harvest within the LMMA for periods of two to three months, allowing quick-growing reef octopus (*Octopus cyanea*) to increase in abundance and size (Benbow and Harris, 2011). Octopus comprise one of the primary export fisheries for the region's fishing communities (along with sea cucumbers) and, through over 85 temporary closures to date, Velondriake communities have become experienced in managing this important export commodity, while increasing fisher income. Diversifying income-generating activities to incorporate sources that do not directly depend on natural resources further increases social resilience to climate change; in events such as droughts or storms, these livelihoods can continue to contribute to household income. Furthermore, these activities can provide environmentally sound alternatives to subsistence fishing, which further reduces anthropogenic stressors on marine resources and contributes to ecological resilience. To this end, a community-based aquaculture program within Velondriake works with local fishermen and their families to raise hatchery-reared sea cucumbers and cultivate seaweed. These mariculture products, sold on the international market through regional export companies, allow families to earn additional income without further exploiting marine resources within the LMMA. Velondriake's draw of tourists also provides some community members with opportunities for income through ecotourism and handicraft production.

Increased access to family planning services

Increasing access to family planning services and lowering the population growth rate can greatly improve resilience to climate change (Jiang and Hardee, 2011). A high population growth rate magnifies vulnerability to climate change by increasing the number of people living in potentially impacted areas. At the household level, large families make coping with food insecurity and insufficient resources much more difficult. Any disposable income is spent on bare necessities (basic food, shelter, and clothing) and does not allow for improved housing to withstand climate hazards, the payment of school fees, saving for times of need, or increasing income through alternative sources. Poverty is strongly correlated with the number of children in a household (Kates and Dasgupta, 2007). Where women are not empowered to plan their families, mothers are commonly overburdened by large family sizes and are less able to contribute to household income through agriculture, fishing or employment. At the community level, high population growth rates result in more exposure to climate risks and greater dependency on the direct exploitation of natural resources. Population pressures can also undermine community efforts to organize the sustainable management of their natural resources (Agrawal, 2001). At the country level, high population growth rates make it difficult to serve the growing needs of citizens for health services and education, further reducing the per capita investment available for climate change adaptation.

Educational opportunities

Access to formal education has been found to increase resilience to climate change disasters by increasing potential household income, increasing awareness and understanding of possible climate change risks, and increasing access to risk information (Wamsler *et al.,* 2012). Likewise, studies show that literacy and education rates are positively correlated with the conservation of wildlife in Africa (de Boer *et al.,* 2013).

Ongoing informal education of members of the Velondriake Association focuses on increasing local capacity for resource management. Training includes recordkeeping, bookkeeping, habitat monitoring techniques, and management and leadership skills to oversee the LMMA. A separate program has been established to help community members observe and understand the efficacy of management techniques, enhancing natural resource stewardship by participants in Velondriake's villages.

5.2. Experience from Asia

Asia faces significant risks from climate change. According to the latest report from the Intergovernmental Panel on Climate Change, Asia could see decreases in water supply and food production in many areas, increased risks to coastal areas, and increased exposure to more intense extreme events (IPCC, 2014). The climate is changing and is very likely to continue changing. The extensive efforts to curb greenhouse gas emissions will only slow climate change and not avoid it. Thus, adaptation is a necessity.

A key component of adaptation to climate change is developing applied technology. Technology can help protect society from changing climate conditions, improve productivity, and help in the more efficient use of threatened resources such as water. This report identifies a number of existing and emerging technologies that can help Asia adapt to climate change.

Frankly, technology is not the only component of a sound approach to adaptation. Improved management of resources at risk, governance, and other aspects of natural resource management are also important. This report centers on the role of some technologies in a number of key sectors that can help societies in Asia as they address the increasingly significant impact of climate change.

Technology needs in the agriculture sector

Adaptation technologies can address climate change impact on the agriculture sector in a number of ways. First, they can improve input efficiency. For example, where rainfall is not enough to sustain crop yield, measures to improve WUE (e.g., drip irrigation) can help focus the use of reduced water supplies and reduce waste. Second, new and existing technologies can also increase access to substitutes. For example, the development of sustainable alternative water supplies (e.g., water reuse) can compensate for a reduction in precipitation. Third, new and existing technologies can reduce the sensitivity of a system to changes in climate. For example, existing or new crop varieties with better tolerance to heat can be used instead of varieties that are more susceptible to heat. Table 1 summarizes the impact and technology needs in the agriculture sector, pointing to the potential for the application of adaptation technologies to reduce the vulnerability of the sector to the impact of climate change. This list of technology needs is not intended to be exhaustive.

Table 1. Agriculture technologies for climate change mitigation and adaptation.

Projected impact of climate change	Technology needs
Reduced crop yields resulting from higher temperatures	➢ New crop varieties with greater heat tolerance
Reduced crop yields in rainfed agriculture due to less precipitation	➢ New crop varieties with lower water requirements Improved water collection, storage, and distributiontechniques ➢ Improved irrigation techniques
Reduced crop yields in irrigated agriculture due to reduced availability of irrigation water	➢ Improved irrigation efficiency ➢ New crop varieties with lower water requirements ➢ Real-time and remote-sensing capabilities to improve water management and efficiency of use (e.g., soil moisture, evapotranspiration)
Reduced irrigation water availability due to saltwater intrusion	➢ Barriers to saltwater intrusion ➢ Increased sustainable aquifer recharge ➢ New crop varieties with greater salinity tolerance Improved water collection, storage, and distribution techniques
Reduced crop yields from increased flooding or water logging	➢ New crop varieties with higher moisture tolerance Improved drainage or flood control techniques
Increased incidence of crop pests and diseases	➢ New crop varieties with improved pest and disease resistance ➢ Improved pest and disease management techniques
Loss of crops due to extreme weather events	➢ Improved extreme weather event prediction and early warning systems ➢ Improved techniques to increase resilience of crops to extreme weather events

Source: Asian Development Bank, 2014.

5.3. Experience from Ethiopia: Safety Net Programs Boost Food Security and Climate Change Resilience

Ethiopia's millions of smallholder farmers, who account for some three-quarters of the country's population, largely practice low-input, low-output, rain-fed, subsistence agriculture. As a result, they are vulnerable to the vagaries of the weather in the short term and will be hard hit by climate change in the longer term.

Ethiopia has long history of droughts and famines, but they are becoming more frequent. Throughout much of the twentieth century, the country suffered from droughts that caused widespread food shortages about once every ten years but such droughts are now occurring every three years or so, and almost constantly in the southern Borana rangelands. Average temperatures in the Horn of Africa increased by 1.3 ^{0}C between 1960 and 2006 (Collins *et al.,* 2013; Kirtman *et al.,* 2013).

The increasing frequency of drought has depleted the asset base of smallholder farmers. They and their families commonly go hungry for several months even in 'normal' years, and famine is just one failed rainy season away. Whenever, the rains fail or crop yields are low, they are forced to sell off their livestock, ploughs, tools, and even their seeds, just to make ends meet (CTA, 2013).

In 2005, the Ethiopian government introduced the productive safety net program (PSNP) to improve the food security of people who suffer from chronic food shortages and live in areas that are prone to drought. The program is almost fully funded by external donors, including Canada, Denmark, Ireland, the Netherlands, Sweden, UK, USA, EU, the World Bank and the World Food Program. However, the Ethiopian Government is the driving force behind the program and has had strong ownership of it from the beginning.

6. Conclusion

Climate-smart agriculture already features in several international fora and development agenda. Climate smart-agriculture is central to the development plans of international bodies (e.g. FAO, IFAD, World Bank) and touted as the sustainable and food secure pathway in various United Nations fora on sustainable development and on agriculture and food security. The recent Intergovernmental Panel on Climate Change Meeting on Climate Change, Food and Agriculture articulated the need to situate climate issues in wider sustainable agriculture development agenda, with emphasis on multi-functionality of agriculture linking across adaptation and mitigation – in essence climate- smart agriculture.

Climate-smart agriculture approaches include four major types of actions:

1. Expanding the evidence base and assessment tools to identify agricultural growth strategies for food security that integrate necessary adaptation and potential mitigation
2. Building policy frameworks and consensus to support implementation at scale
3. Strengthening national and local institutions to enable farmer management of climate risks and adoption of context-suitable agricultural practices, technologies and systems
4. Enhancing financing options to support implementation, linking climate and agricultural finance

Therefore, through practicing and implementing climate-smart agriculture, which encompasses integration of various sectors and components (technologies, innovations and indigenous technical knowledge) capable of reducing greenhouse gas (GHG) emissions and improving natural resource conservation at all level, the cumulative effect will result in a sustainable green economy.

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2. Institutional Arrangements for Enhancing Resilience in the Arid and Semi-Arid Regions

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Abstract
Different communities in the arid and semi-arid regions have been affected by climate change, which has crashed their livelihood bases. Governments in developing countries have introduced different institutional arrangements to build and enhance the resilience of these communities. Based on the review of literature, this paper aims to provide insights on institutional options to enable communities in the ASARs to effectively respond to climate-induced shocks thereby enhancing their resilience. The generic framework for institutional analysis was used to synthesize the links among climate change, institutions and resilience. The role of social capital in facilitating cooperation and enforcement of rules and creating safeguards in mobilizing social insurance and exchange of information on climate induced shocks is critical. Some of the institutional arrangements commonly used to enhance resilience include (1) asset transfer as informal insurance, (2) improving early warning information systems, (3) reinforcing cooperation and reciprocity at different scales, (4) investment in adaptive capacity development, (5) introducing adaptive governance and (6) the application of index-based crop and livestock insurance. These arrangements could have a complementary role and choice of each or a combination of them may depend on the national capacity and conditions on the ground. For this to succeed, partnership at different scales ranging from local to international is essential to craft additional institutional arrangements and strengthen existing ones in any strategy towards enhancing resilience. Such partnership is also central to mobilize and consolidate essential resources including technical capacity (transfer of knowledge and skills) and financial capacity (investment in research and other facilities) to develop innovative practices and climate smart technologies.

Keywords: Institutions; shocks; governance; resilience; cooperation

1. Introduction
Communities in the arid and semi-arid regions (ASARs) have persistently suffered from moisture deficit and extant drought with long-term consequences in affecting livelihoods of millions of people around the world. The livelihood systems of those inhabiting the moisture deficit lowlands of Ethiopia are particularly affected by drought problems that have been occurring repeatedly. As a result, the losses of productive assets and increasing household food insecurity have become defining features (Smith *et al.,* 2001). Moreover, there are other factors compounding to the impact of climate change in these areas including land use change which includes expansion of agricultural land and encroachment of bush and other unwanted plant species, population pressure and declining terms of trade (Pantuliano and Wekesa, 2008). In the event of climate change, the effect has become significant deriving the attention of global leaders and local level policy makers calling for concerted efforts to respond to the challenge. The aim of this paper is to provide insights on institutional options to enable communities in the ASARs to effectively respond to climate-induced shocks thereby enhancing their resilience.

2. Institutions and Resilience
How do we understand institutions? There is still confusion in the literature on the definitions of institutions because some people consider organizations as institutions. Institutional economists

recognize institutions as set of rules of the game. Institutions are understood as 'formal rules (statute law, common law, regulations), or informal constraints (conventions, norms of behavior, etc…) and the enforcement feature of both' (North 1990: 3-5). Thus, a more concise definition is 'the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction with a consequence of structuring incentives in human exchange and reducing uncertainty' (North 1990: 3). When one talks of climate change and resilience from its effects, cooperation over a wide range of actions among players of the game requires a strong social networks and establishment of norms of cooperation, which is embedded in the concept of social capital, which in turn has been considered as an important component of livelihood resources. The way it mediates livelihoods and common property resources in the context of production systems in the ASARs has not been given sufficient emphasis in the contemporary literature (Mearns, 2004). Social capital is often seen as 'shared knowledge, understandings, norms, rules and expectations about patterns of interaction that groups of individuals bring into a recurrent activity' (Ostrom, 1999:176). It is used as a means to improve private or collective well-being (Coleman, 1990; Katz, 2000; Cleaver, 2005). Though it is undersupplied by market and non-transferable compared to other forms of capital (Arrow, 1999) and hard to estimate the rate of return to its investment (Solow, 1999), it can also mediate exchange relations (including risk-sharing activities) in vulnerable societies where formal insurance system is lacking. In this way, social capital enables communities to be resilient to climate-induced shocks. Some evaluate the role of social capital through its contribution to transmission of knowledge and skill between generations as well as in developing shared environmental knowledge to adapt to changes in the resource system (McCay, 2002). It assists in the development of mutually beneficial risk insurance system complementing the state and market roles (Bowles and Gintis, 2002). A number of scholars have assessed the key role played by local level institutions in building sustainable livelihoods (Grootaert and Narayan, 2004; Scoones, 1998) and collective resource management (Beyene, 2008). An extensive review on economic performance in Africa shows that informal institutions facilitate adaptation in risky environment mainly in traditional societies where "liquid" assets are limited. It is argued that establishing social connections assist livestock spread over a larger geographical area which is related to risk management activities (Collier and Gunning, 1999). A number of scholars have assessed the key role played by local level institutions in building sustainable livelihoods (Grootaert and Narayan, 2004; Scoones, 1998) and collective resource management (Beyene, 2008). In common property resource management, some argue that the role of social capital at group level is immense whereby its expression through trust and social networks increases its importance in improving coordination among resource users on the basis of established norms (Pretty and Ward, 2001; Woolcock, 1998). Where this perspective is considered, social capital is valued in laying a foundation for monitoring and enforcement of rules and may serve as a substitute for well-defined legal property rights. By doing so, it supports efficient management of the commons through creating security of rights to common property resources where state has a little role (Grafton, 2000; Katz, 2000). A livelihood system basically indicates the characteristics of resources users, the institutions and organizations that determine access to resources to generate livelihoods and the policy environment that constrains or facilitates certain action (Scoones, 1998). Argument explaining how community characteristics influence institutional arrangements in the governance of common property resources (Agrawal, 2001) gives attention to the crucial importance of social capital to sustaining livelihoods. Earlier works argued that those resources with certain attributes should remain in the public domain when the gains from specification of rights are very low or the costs are expected to be higher (Barzel, 1989). Such contextual factors lead to the emergence of institutions favouring property rights structure with non-exclusive rights to the use of resources (Van den Brink *et al.,* 1995). There are two views dominating the literature on pastoral land use policy both favouring different property rights regimes to the rangeland resources: conventional and opportunistic approaches. While the former advocates sedentarization and privatization, the latter supports flexibility in resource use and reciprocal access rights (Grell and Kirk, 1999). Having the conventional approach in mind, many African governments have designed policies for rangeland management and use. For instance, private land ownership among Ugandan pastoralists was justified on the grounds of the national interest to transform livestock production and to attain equity (Muhereza, 2001). Such a practice has resulted in the redistribution of land from large individual ranchers to squatter pastoralists posing new challenge to the communal grazing land and tenure instability. These policies have undermined implementation of opportunistic approach. Under such circumstances, donors' technical and financial support along the conventional line is usually seen as a crucial reason for governments to develop and adopt policies that hardly fit into the rangeland realities (Grell and Kirk, 1999). This contradicts the argument that pastoralists require common property regimes since such tenure arrangement facilitates mobility. Indeed, through permitting an extensive resource use system, common property is argued to be associated with a lower cost of exclusion than private, because it reduces the extent of the boundaries to be monitored and enforced (Niamir-Fuller, 1999). Many studies have questioned the efficiency[1] of common property rights by relating communal ownership with land productivity. But efficiency in pastoral land use, which is characterized variable weather condition, can be achieved through retaining common property (Nugent and Sanchez, 1993).

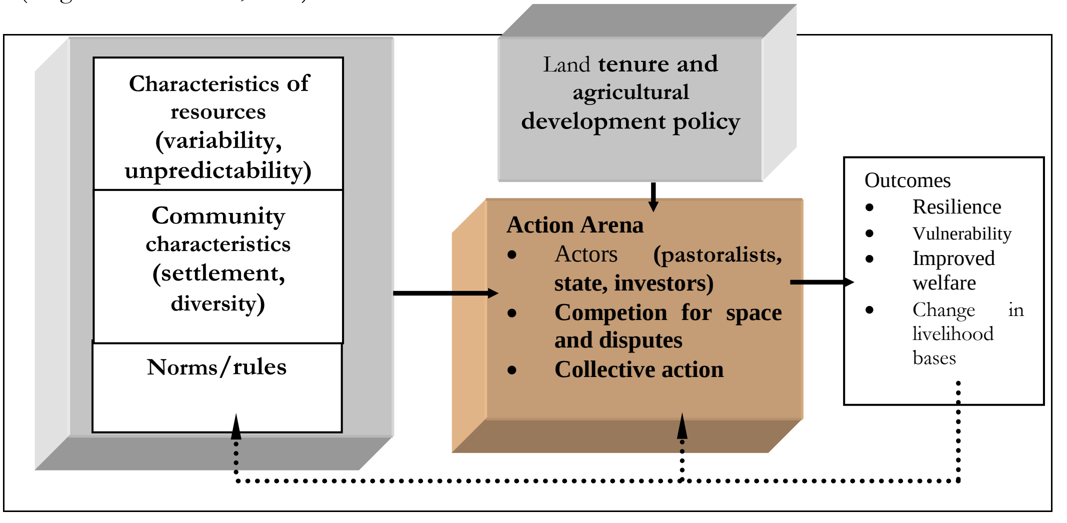

Figure 1. Conceptual framework (based on Ostorom *et al.,* 1994).

In the rangeland resource use system where tenure security is much less important than access security because of variable land productivity in space and time and communities are characterized by low population density, customary property rights are more efficient in facilitating access to grazing resources than adopting formal titling to parcels of land. Some have agreed that formal titling in such systems can be expensive and futile (Migot-Adholla *et al.,* 1991). The formal land tenure policy that may involve the transfer of land use rights to other persons from a different clan or ethnic group can be a source of disputes (Figure 1). It may induce an offensive act by the indigenous people with customary rights to the land since such action is often interpreted as violation of cultural norms (Abdulahi, 2007). The generic conceptual framework displayed using Figure 1 indicates how initial context (resource attributes, community attributes and the existing rules and norms) together with government policies could influence the action arena, where actors interact with one another, cooperate, negotiate and set strategies. This condition will generate an outcome which can be evaluated differently by different actors. When outcomes are satisfying the action arena will be reinforced; otherwise, it will cause change in the rules of the game, making the process iterative. In the context of this paper, the action arena is expected to produce resilience[2]as a desirable outcome.

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[1]Efficiency can be argued from the perspective of effects of private land holding on livelihood sustainability and social stability.

[2]Resilience has been used in two ways in ecology, one focusing on recovery and return time following a disturbance, the other focusing on how much a system can be disturbed and still persist without changing function. Resilience is often defined in terms of the ability of a system to absorb shocks, to avoid crossing a threshold into an alternate and possibly irreversible new state, and to regenerate after disturbance (Resilience Alliance 2009). A more recent concept considers resilience as seen from the social-ecological systems where institutions are expected to mediate the interaction between ecology and society (Miller et al. 2010).

3. Institutional Arrangements for Enhancing Resilience

A) Asset transfer as informal insurance: An important informal insurance in the pastoral and agro-pastoral production systems is self-reliance where internal resource mobilization and asset transfers help the poor cushion against the impacts of shocks. In eastern Ethiopia, it is recognized as a "charitable obligation intrinsic to the Islamic religion" (Devereaux, 2006:57). This inter-household assistance is characterized by mutuality as current contribution produces an expectation on future reciprocation. Hence, the fluctuating[3] nature of poverty in uncertain rangeland environment necessitates understanding the norms fostering cooperation for asset mobilization. Cooperation provides a means for various members of indigenous community to rely on their own people supporting them from falling into chronic poverty. It is a system where households share resources (livestock, grain and others) with other marginal households and extend such norms to assist distant relatives. This is believed to be one alternative to overcome vulnerability and collapse of families due to deprivation of productive assets (Dixit *et al.,* 2013).

As the frequency of drought increases the reliability of informal insurance is reducing. Others provide evidence where such informal mechanisms are unable to shield households from large-scale and long-lasting shocks (Fafchamps *et al.,* 1998). This is because shocks produce persistent effects where temporary events carry over chronic impacts to the future welfare of households. This will reduce households' capacity to rebuild the assets lost that undermines their ability to contribute to economic growth (Dercon, 2003). Hence, those social relationships among community members that could have served as means of regaining assets can be weakened in the event of large-scale shocks developing persistent effects.

Informal asset transfer can occur at community as well as household levels. Transfer of resource is another economic link among pastoral households. Transfer refers to change of entitlement as resource or an asset flows from one to other person due to cultural or legislative influence. The forms of transfer identified include a gift on occasions of marriage and birth, support during time of disaster and a dowry system. A community with close interaction with the other provides gift during marriage and at birth. They also help each other at time of crises such as drought sharing food grains or contribute animals to enable the destitute to revive. The third form of asset transfer occurs most frequently and involves a large amount of livestock. The amount of asset transferred in a dowry system varies based on the status of a household.

B) Improved early warning information systems: Traditional ways of drought forecasting exist where pastoral herders experience long-existing tradition of self-reliance though there is a difference among households in terms of access to information (Beyene, 2014). Such indigenous knowledge is embedded in and central to their belief system compared to the scientific early warning practices of the national Disaster Prevention and Preparedness Commission that often pledges for food aid than saving livelihoods. The traditional practices include looking at the condition of the star, the sun and the moon as well as observing animal behaviour. These are simply shared ideologies and results of repeated observation by individuals gifted with such power. Although scientifically unexplainable in terms of cause and effect, such belief system influences the behaviour of the community. It is a practice based on indigenous knowledge. Results from the focus group discussion reveal that households with low level of network density have lower chance of access to information on such traditional early warning, which makes them mitigate the undesired effects of shocks in a very poor manner. The number of relatives living in other villages determines this showing that sharing information is again segregated on the basis of social capital. This is consistent with the evidence from other studies where exposure to risk and its perception are influenced by a number of socioeconomic factors, one of which is individual's network (Smith *et al.,* 2001).

The costliness of information, simply because of not being part of the informal network, causes differences in the way households mitigate the effects of disaster. In general, those which are part of the network take some measures subsequent to such forecast. These are isolating calves from cows, interruption of milking and searching for alternative feed for the calf. But they are often reserved from selling their animals during drought contrary to evidence from the literature on

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[3] This is referring to a situation where those wealthy households in the past have become poor while the rests with less livestock earlier have improved their livestock possession through time.

drought induced distress sale. Such local efforts based on traditional early warning information needs to be supported with more precise information based on the national meteorological information. Pre-disaster state intervention based on accurate information can contribute to resilience building. Searching ways for integrating different information sources on climate data and strengthening the national capacity to generate reliable information seems to be an urgent priority.

C) Reinforcing Cooperation and Reciprocity : Natural resource availability in the ASARs is unpredictable due to the disequilibrium condition of the environment. Such lack of uniformity in resource condition owing to the variability in rainfall and moisture condition necessitate an institutional arrangement on the basis of reciprocity. In this context, reciprocity is a norm that generally reflects an attribute that an individual is inclined to react positively to the positive actions of others and vice versa (Oakerson 1993; Fehr and Gächter 2000; Bolton and Ockenfels 2000). It is governed by moral rules where benefit granted to one party will be returned some other time in the future. The concept has been widely used to refer to the general nature of cooperation in a society where self-enforcing agreements could emerge and mutual reinforcement of behavior will take place in a repeated interaction (Figure 2). If reciprocal relations have to take place between large groups in the ASARs, self-enforcing agreements may be complicated for collective decisions are either costly or unmanageable. Reciprocal relations can also occur between any two individuals experiencing different levels of exposure to shocks.

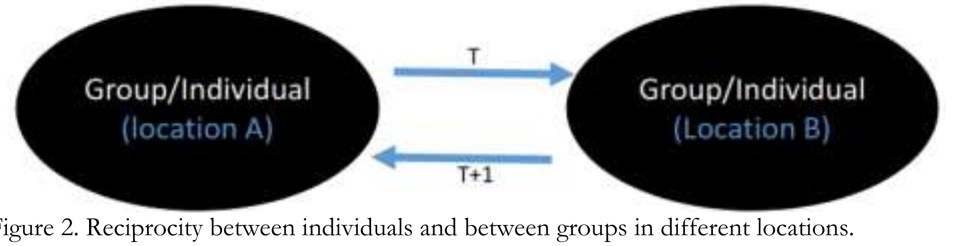

Figure 2. Reciprocity between individuals and between groups in different locations.

Figure 2 indicates a situation where households at location A provide resources for those at location B due to better resource condition at their location at time T; whereas, this situation could be reciprocated at time T+1. In many pastoral areas of the ASARs, environmental variability and unpredictable nature of land productivity has forced the community to practice such an institutional arrangement. This has been practiced among pastoralists in Ethiopia (Beyene, 2008), Sudan (Nugent and Sanchez, 1993) and Mongolia (Mearns, 2004). The failure to enforce such mutually beneficial institutional arrangement could contribute to socioeconomic instability and vulnerability while the success in effectively exercising this institutional practice builds resilience of the pastoral families.

D) Investment in adaptive capacity development : This is the role of the state and the relatively vulnerable communities in the ASARs. The adverse impact of climate change will be most striking in developing countries because of their dependence on natural resources and their limited capacity to adapt to a changing climate. Within these countries, the poorest, who have the least resources and the least capacity to adapt, are the most vulnerable (Thomas and Twyman, 2005). Climate change will impose new stresses on both natural and socio-economic systems, and that these systems will tend to adjust to such stresses through a process of adaptation (Eriksen and Kelly 2007). However, reducing vulnerability of the poor through adaptation requires investment in developing them to adapt to climate change (Lisa and Schipper, 2007). An understanding of this process is important because it will allow analysts and policy makers to assess vulnerabilities and potential future damages; explore the more subtle indirect effects of climate change; and provide knowledge for better choices about how to achieve more efficient and effective adaptation. Some argue that such an adaptation can be reinforced by political decisions and policy choices enhancing adaptive capacity (Eriksen and Lind, 2009) where external interventions (Grothmann and Pratt, 2005) and a hybrid of endogenous practices and external institutions are found to be critical to enhance adaptive capacity and resilience (Upton, 2012).

Although pastoralists in east Africa were managing climate variability for millennia, the unprecedented rate and scale of human-induced climate change is posing greater problems (Oxfam International, 2008). As climate change is likely to increase the frequency and intensity of drought and floods in many arid and semi-arid regions, those communities expected to be most affected need access to resources and services that help them grapple with impending calamities, protect their livelihood assets and increase their resilience. The level and nature of their exposure to hazard differs from fellow members of their national communities (Birch and Grahn, 2007).

Managing challenges of adaptation to climate change requires deeper understanding on the role of local innovations in reducing disaster risk and livelihood vulnerability (Tompkins and Adger, 2005). Equally important is to search for ways in which institutions and interventions addressing systematic risk can complement local capacity to manage climate related risks and to respond to shocks based on traditional norms and local information (de Loe and Plummer, 2010). Thus, it is important to understand the functioning of customary institutions and community perceptions as institutions and their effective functioning play a critical role in ensuring successful adaptation (Osman-Elasha *et al.,* 2006). The role of both formal and informal institutions at more local scales also needs to be better understood (Reid and Vogel, 2006). Along this, examining the role of social capital in reducing climate-induced risk is crucial (Beyene, 2010).

Furthermore, *private sector involvement in financing adaptive capacity* can be considered as an option (Tompkins and Adger, 2005). Investment by the sector in technologies that improve this capacity depends on the effectiveness of the market signals in creating incentives. However, uncertainty in the international framework of agreements makes it more difficult for national policy makers to give clear signals to investors (Stern, 2007). A more profound argument is the need to design strategies for enhancing adaptive capacity to accommodate the interests and perspectives of diverse actors – besides communities in the ASARs and the private sector. Along this, a recently developed framework of 'integrated governance' is particularly useful to examine and develop effective ways of improving adaptive capacity through assessing the link among markets, community and the state. It helps scrutinize private-public partnerships, co-management (state-community relations) and private-social partnerships where market mechanisms provide payments for ecosystem services resulting from collective action by the community (Agrawal and Lemos, 2006). Improved extension services in technology transfer and micro-finance institutions in providing credit services have a significant role to enhance adaptive capacity and resilience to climate change (Hassan and Nhemachena, 2008) while alternative financing of carbon sequestration through integrated rangeland management projects could augment such an effort (Admasu, 2010). Financing of such projects to enhance adaptation in developing countries is perceived to be beneficial for both developed and developing nations (Rubbelke, 2011), especially under the current international negotiations to reduce deforestation and forest degradation in developing countries (Okereke and Dooley, 2010).

Adaptive capacity development also involves investment in the development of climate resilient crops. These are crop varieties that resist high temperature, drought tolerant and disease resistant. Livestock research in the arid and semi-arid can take a new perspective emplacing the development of species that are feed efficient and fit for scarcity induced by climate change. This will reduce vulnerability while enhancing resilience to shocks. The role of partnership at local and global levels in developing research facilities and technical capacity of the scientific staff who would in turn generate climate smart technologies is essential.

E) Introducing adaptive governance: Governance in this context refers to the process of decision making on what the collective will do (activities) and how it will do (institutions and procedures) to achieve certain goals (Mearns, 2004). Adaptive governance analyzes the different aspects that build up multilevel governance and how all these aspects help build resilience for the communities in the ASARs. Within the framework of social-ecological systems, adaptive governance accounts for the integration of the formal and informal governance structures and taking a holistic perspective (institutional, economic and ecological aspects) to respond to the complex problems. For instance, in an effort to build resilience in the pastoral areas, institutional arrangements that tend to support the revitalization of the customary land administration have been advocated (Upton, 2012). With the understanding that pastoralists are well placed to manage their natural resources and familiar with their natural ecology, relying on their customary systems may help better respond to different kinds of climate related hazards than solely relying on state intervention. Therefore, the notion of adaptive governance emerges as the linkage and integration of the customary and formal systems has an added value to build resilience by addressing complexity at different levels.

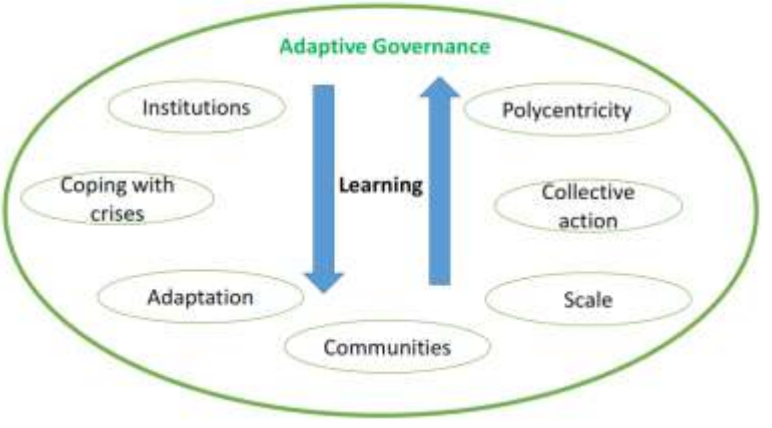

Figure 3. Important dimensions in adaptive governance.

Adaptive governance involving requires collective action and decision making at different levels that make it polycentric in nature. The adaptation strategies chosen by the different communities may not be static as ecosystems are dynamic and there is a cycle of learning from exposure to shocks. The scale of governance might vary depending on the extent of exposure to climate induced shocks. For example, governing a cross-boundary river-basin differs from governing resources in a particular watershed both in terms of complexity of collective action and institutional settings.

Adaptive governance may include reforming national disaster management agencies and establishing stronger coordination mechanisms. Institutional change in this aspect requires building the capacity of the staff at different levels to exchange climate related information and identifying measures for adaptation and implementing them. Likewise, regulations to protect the biophysical foundation of agriculture should be part of the adaptive governance. This includes creating institutions that support agro-biodiversity conservation, incentives for adoption of agro-forestry practices, soil micro-nutrient management through introducing watershed management (Stern, 2007).

F) Index-based insurance: Creating a market-based insurance mechanisms assisted by capacity building at a very local level has been considered as an innovative institutional arrangement. Such assistance is needed in the area of improving knowledge of farmers or herders to learn new practices that reduce risk of failure. Otherwise, it becomes so difficult to pay the insurance premium. To encourage participation in this insurance, less risky enterprises should be chosen in the first instance. What does index-based insurance mean? Due to the high cost of verifying losses on large numbers of small landholdings, traditional loss-based insurance is not a viable option for smallholders. Index-based insurance overcomes the obstacles to insuring smallholder farmers against weather-related risks. With index insurance, payouts are based on an objectively measured index that is correlated with farmers' losses rather than actual losses. Indexes used to represent agricultural risks include rainfall, area-average yield statistics, and vegetation conditions measured by satellites and it is often developed based on historical data. So, there is a need to do research that strengthens the knowledge and evidence for how to design, target, and implement insurance programs that enable vulnerable rural communities to manage climate risk and adapt to climate change (Greatrex *et al.,* 2015).

The purpose of index-based insurance is to compensate clients in the event of a loss. It is used to protect against shared rather than individual risk such as the risks associated with weather fluctuations, disease out breaks or price loss. Unlike traditional insurance which assesses loses on a case by case basis and makes payouts based on individual client's loss realizations, it offers policy holders a payout based on the external indicator which triggers a payment to all insured clients within a geographically defined space.

There are certain characteristics of an index insurance contract. Chantarat et al (2009:2) summarize such characteristics as "the first is that it requires a well-defined index and an associated strike level that triggers an insurance payout. The index must be highly correlated with the aggregate loss being insured, and based on data sources not easily manipulated by either the insured or the insurer, and with adequate, reliable historical data to estimate the probability distribution of the index for proper pricing and risk exposure analysis. Second, it requires well-defined spatiotemporal coverage with premium pricing specific to that place and period. Third, the contract requires a clear payout timing and structure to all covered clients conditional on the index reaching the contractually specified strike level".

One possible limitations of the index-based insurance is the imperfect correlation between an insured's potential loss experience and the behavior of the underlying index on which the insurance product payout is based. It is possible that individuals suffer losses specific to them but fail to receive a payout because the index does not trigger. On the other hand, lucky individuals may receive indemnity payments that surpass the value of their losses.

Index-based crop and livestock insurance has been introduced in many circumstances. In the case of livestock, livestock types are standardized into a unit known as a Tropical Livestock Unit (TLU) and an amount will be fixed for each unit. The premium to be paid and the compensation to be made for losses when the strike level is equal to the index depend on total TLU recorded but not on the number of livestock. In pastoral areas, the index could vary from one to the other location depending on the likelihood of drought risk which means a strike level that triggers payment in one location may be different from that of the other. Likewise, the premium paid by the insured can vary depending on the index. In most cases, an index for livestock can be fixed based on the vegetation coverage and forage scarcity of a specific area (Chantarat *et al.,* 2009). An important feature of index-based insurance is that as long as they might even receive a payout regardless of the condition of their livestock they could continue putting effort into ensuring their livestock. In index-based crop insurance, the index can be developed based on yield or rainfall data. In such a case, to increase reliability of the index, the data should be updated each year to capture the effect of climate change that can reduce or increase productivity of crops (Greatrex *et al.,* 2015).

4 Towards Enhancing Resilience

Resilience of communities from climate induced shocks cannot be realized by choosing a single institutional arrangement. Those intervening to build resilience may need to use a combination of institutional arrangements because one cannot be a substitute for others. These institutional arrangements could not by any means considered as exhaustive and different communities can adopt different types of institutional structures depending on the type of perceived risks and production systems. Therefore, integration of different institutional arrangements makes sense. The success of a particular institutional arrangement is determined by the presence of different policies and strategies. For instance, investment in adaptive governance requires the presence of favorable policy environment to attract funding support (financing) for project based initiatives. National regulations assist local level activities by specific communities to adopt specific adaptation strategies. The development of markets for certain technologies and investment in research in the development of those technologies is necessary. Based on the reviews of the different institutional arrangements, Figure 4 indicates that resilience is an outcome affected by different components or factors.

Figure 4. Core issues for enhancing resilience.

The first component is developing clear policies for introducing adoptive governance which succeeds through adequate financing. The second component is the research and development that demands investment in technologies that can assist the research process; for instance, meteorological data generation and the use of satellites images for decision-making make investment in technology a necessity, i.e. capacity building. The third component is creating partnerships (local, regional and global) for the purpose of mobilizing financial and technical support. Through time, such partnership is expected to develop into joint research and information exchange as well as organizing of training programs that support knowledge and technology transfer. This leads to a creation of database for knowledge management overcoming redundancy and enabling efficient use of resources. Partnerships serve the purpose of identifying climate smart technologies and innovative practices in a short time, propelling the rate at which they reach wider communities that are, otherwise, vulnerable to shocks. Finally, effective integration of the three components can enhance resilience.

5. Concluding Remarks

Development interventions that support sustainable livelihoods in semi-arid pastoral areas should consist of diverse packages that assist the success of adaptation strategies to enhance resilience of communities in the ASARs. The review of evidence reveals that there is still a potential for traditional institutions to provide social protection in a risky environment. As sources of risk become diverse and internal capacities decline with the frequency and length of droughts, asset protection tasks to save livelihoods cannot be left to the traditional leaders and informal institutions and the role of the state in investing in adaptive capacity development is crucial for enhancing resilience. Therefore, the review of the diverse institutional arrangements towards enhancing resilience enables us to make the following remarks:

- Investment in adaptive capacity development as pre-condition for resilience can be effective through co-management of natural resources by the state and the community.
- There is a need to make a right mix of the diverse institutional arrangements for building and enhancing resilience as they complement one another.
- In an index-based insurance, a lot of efforts should be made in developing index (targeting groups) to overcome bias in setting standard for triggering payment; a few of the strategies are to rely on participatory index development, experimental games or simulations to learn preferences of the insured farmers or herders.
- Partnerships for financing projects can enhance resilience only if policies support the development of markets for climate smart technologies that in turn encourage private sector participation.

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3 Conservation-Based Improvement of Livelihoods through Mung Bean Seed Multiplication and Production in Midega Tola Woreda, Ethiopia

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Abstract

In Midega Tola woreda, East Hararghe, Oromiya regional state of Ethiopia, mixed farming and agro-pastoralism are the two currently practiced agricultural systems. Communities in Midega have limited livelihood options and natural resources, which has resulted in generally weak resilience and poor coping mechanisms to deal with weather-related hazards. Aggravating factors include drought, soil degradation, pests and diseases, limited access to agricultural inputs, and lack of appropriate technologies. These factors have negatively influenced agricultural production and exposed communities to chronic food insecurity and poverty. Communities produce subsistence crops, which have low market value. Farmers have limited support systems and poor market linkages due to the limitations of farmers' organizations to provide necessary services to organization members as well as the wider community.

In response to these issues, a pilot conservation-based innovative solutions project was implemented to improve mung bean seed multiplication and marketing project in Midega. Mung beans are drought resistant, high yielding, early maturing, and feasible for the agro ecology of the semi-arid Midega. They are nutritious, highly marketable and one of the 12 pulses grown in Ethiopia which have recently been selected for export. As part of the project's strategic activity, ZOA commissioned a mung bean seed value chain assessment to determine the viability of a local seed bank (LSB) in Midega. The key objective was to ensure continuous and sustainable mung bean seed supply to the farming community while developing the mung bean value chain.

A value chain analysis for mung bean seed was carried out involving farmers and partners. The main market actors were identified, and actor relationships and network linkages were established/strengthened with various institutions including research. The assessment revealed that at input, production, marketing, and service levels all required actors are in place for value addition of mung bean products along the commodity value chain. So far, 2,503 farmers are engaged in the mung bean seed multiplication project and have prepared over 500 ha of land using three different types of farm tools they received. Severe drought in the area affected mung bean harvest greatly. Low and abnormal rainfall affected planting time and harvest of the mung bean. They were able to reserve seeds for the upcoming planting season and have shown interest to expand their production. Partners have also become involved and expressed their commitment to take the lead in scaling up and reaching more farmers to expand mung bean production. Government staffs have been engaged in the project, which has strengthened community-based institutions (specifically two local seed bank management committees and a couple of multipurpose cooperatives) and improved linkages among the sectoral offices, agricultural support agencies, and the private sector. The DRM solution identified and validated through participatory approaches in this project will be scaled-up and sustained by ensuring the active participation of the women in the community. This strategy aligns with the Ethiopian

government's climate adaptation strategies and policies on the promotion of climate smart economic opportunities. Mung bean production will steadily build the resilience of communities to environmental hazards in the future.

Keywords: Innovative agricultural support; local seed bank; Midega Tola woreda; mung bean; value chain

1. Introduction

Since 2008, Midega Tola woreda (district), which is located in the East Hararghe region of the Oromiya Regional State in Ethiopia, has consistently suffered the highest malnutrition rates of all the East Hararghe woredas. Between 2008 and 2012, 10 out of 12 Emergency Nutrition Coordination Unit (ENCU)[4] nutrition surveys named Midega Tola as the *Hotspot One Woreda*, a term reflecting the woreda's critical levels of malnutrition. Following two consecutive poorly distributed *Belg*[5] rainy seasons and a well-below average *Meher*[6] harvest in 2012, East Hararghe deteriorated into Acute Food and Livelihood Crisis Phase (IPC Phase 3[7]).

A key climate change related hazard in Midega Tola, identified by the Ministry of Agriculture, is moisture stress; the rainfall pattern in the target area has become increasingly unpredictable and erratic. According to the National Meteorology Agency, there has been a demonstrated decline in dependability of rainfall in the area for the last seven years. This, combined with environmental degradation such as deforestation and soil erosion, has significantly impacted crop production. Between 2011 and 2012, crop production in East Hararghe fell by 18% during the *Belg* season and 60% during the *Meher* season. Associated with declining rainfall contributing to low crop productivity, there is a shortage and supply of improved, drought resistant seeds. Although there have been a number of endeavors and strategies designed/implemented at the national level to address this issue, the availability of and access to improved, drought resistant seeds remains very limited in the woreda.

As part of its international mission to support and capacitate farming communities, combined with ZOA's past experiences in rehabilitation and livelihood support activities in the woreda, ZOA introduced a project of mung bean seed multiplication, production and marketing project so that the community can fully exploit their resources and potential while alleviating the recurrent crop failure and subsequent drought, called innovative agricultural support (IAS). This FAO (Food and Agriculture Organization of the United Nations)/DFID (Department for International Development) funded project is based on the following justifications:

- Mung beans are drought resistant, early maturing, weed resistant, feasible for the agro ecology, nutritious, highly marketable, and produce high yields.
- The East Hararghe Zone Agriculture office strongly supports the production of mung beans in Midega Tola, advising that the mung bean crop was tested by farmers in this woreda and proved to be a successful crop.
- Farmers have expressed considerable interest in producing this crop.

The mung bean project in Midega Tola *woreda,* or district, was designed by employing cumulative lessons, rapid assessment and consultative meetings both at woreda and zone levels. It began in 2014 in response to the food insecurity and lack of household and community resilience in the area. In the woreda, located in East Hararghe of the Oromiya regional state of Ethiopia, the communities currently use a combination of mixed farming and agro-pastoralism techniques in an attempt to sustain their livelihoods. Communities in Midega Tola have limited livelihood options and natural resources, which have resulted in generally weak resilience and poor coping mechanisms to deal with weather-related hazards. Aggravating factors include drought, soil degradation, pests and diseases, limited access to agricultural inputs, and a lack of appropriate technologies. These factors have negatively influenced agricultural production and exposed communities to chronic food insecurity and poverty. Communities produce subsistence crops which have low market value. Farmers have limited support systems and market linkages due to

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[4] ENCU is a part of the Disaster Risk Management and Food Security Sector (DRMFSS) at the federal level.
[5] Belg refers to the short rainy season in March and April.
[6] Meher is season of harvest after the heavy rains.
[7] The IPC is a means to classify varying phases of current food security situations based on outcomes on human lives and livelihoods. The IPC includes five levels of food security called 'phases.'

the limitations of farmers' organizations to provide necessary services to organization members as well as the wider community.

In response to these issues, the conservation-based innovative solutions project was implemented to improve mung bean seed multiplication and marketing project in Midega Tola. Mung beans are drought resistant, high yielding, early maturing, and feasible for the agro ecology of the semi-arid in the woreda. They are nutritious, highly marketable and one of the 12 pulses grown in Ethiopia which have recently been selected for export. As part of the project's strategic activity, ZOA commissioned a mung bean seed value chain assessment to determine the viability of a local seed bank in Midega Tola while ensuring continuous and sustainable mung bean seed supply to the farming community and developing the mung bean value chain.

Approach

The main objective of this project was to improve the economic, ecological, and organisational resilience of 1,800 (540 female headed) resource poor smallholder farmers through the introduction, marketing, and promotion of conservation based drought resistant, early maturing and high yielding mung bean seeds in the moisture deficit woreda of Midega Tola. This objective was achieved through the following three outputs: 1) Improved seed security of drought-tolerant, early maturing and high yielding crop varieties through the establishment of farmers research groups and establishing sustainable local seed production and supply systems; 2) Conservation agriculture promoted as a sustainable agriculture practice to enhance natural resource management and crop production; and 3) Innovative agricultural solutions and project best practices documented, disseminated, and shared among all relevant project actors, decision makers, communities and donors to diversify and increase diversified agricultural production practices to enhance the economic and nutritional status and organizational resilience of smallholder households.

Partners

Partnership with key stakeholders was imperative for the sustainability of the project. As a result, the project was undertaken with active participation of partners in target farmers' selection, distribution of inputs, capacity building, and monitoring and evaluation. Beneficiaries, administration offices, government line offices and the Fedis Research Centre were key stakeholders that have played a crucial role in the execution of the project. The IAS project was coordinated mainly by a woreda level steering committee comprised of representatives from the Pastoral Development Office, Cooperative Promotion Office, Women and Children Affairs Office, woreda administration, and representatives of the selected kebeles. The steering committee was formally established at woreda level with the mandate to oversee the project, monitor field level distribution and management of inputs as well as implementation. The partnership and coordination of the IAS project goes beyond the woreda including Zone Administration and Line Offices, which are key partners involved in project agreement, planning, implementation and monitoring. Moreover, the linkages with Fedis Research Centre, Haramaya University's Integrated Seed Sector Development (ISSD) project and Afrenkalo Union assisted in technical capacity building, joint review of progress, and experience sharing to improve production and marketing of the mung bean.

Implementation Area

Located in Eastern Haraghe zone and with a total area of 942 km^2, Midega Tola woreda has a total population of 93,910 individuals (45,561 female). It is located 50 km south of the ancient city of Harar. As over 80% of the woreda is lowland, Midega Tola is categorized as vulnerable to various shocks mainly due to ecological and climate related factors. The altitude of the woreda ranges from 1,403 to 1,590 meters above sea level with only 20% of the land in mid or high altitudes. Midega Tola is bordered by Fedis woreda to the North, Girawa and Mayu Muluke woredas to the West, Babile woreda to the East and Somali Regional State to the South.

In the woreda, crop yields are principally limited by the low and highly variable rainfall, both between and within seasons. This is now being aggravated by the ongoing climate change. The rainfall period is becoming shorter as it generally starts later and ends earlier. Production is also limited to the progressive decline in soil fertility, as the farming practices do not adequately restore nutrients. This loss of soil fertility is also linked to a decline in the soil's organic matter content, resulting in soil's limited water holding capacity, poor water infiltration rates, and ultimately limited availability of both water and nutrients to the crops. Increasing temperatures, leading to higher rates of evapotranspiration and heat stress, further limit potential crop yields. In addition, the crops encounter climate change induced hazards such as animal and crop diseases, pests, insects, and *Quila-Quila* (migratory birds destroying crops). The consequential decline in crop production in these areas exacerbates the food insecurity, poverty and overall livelihood conditions in the area.

Innovation

Known by its scientific name as *Vigna radiata L.*, the mung bean is a member of the Fabaceae family, categorized as a tropical legume. It is a warm season annual plant. Morphologically, it has a highly branched growth habit, having trifoliate leaves that span from one to five feet in length. Mung bean seeds are primarily used for food. The seeds are a rich source of lysine and proteins and can supplement cereal-based human diets. Research shows that mung bean is superior in nutritional value. The sprouted mung bean is also known for its high protein, fiber, calcium, and phosphorus content.

The mung bean is widely grown in Asian countries, particularly India, Myanmar, China, Thailand, Philippines, and Indonesia. Despite the fact that these countries are major producers, most of them are also major importers of the crop. In these countries, the mung bean is commonly consumed hulled or whole in a variety of forms including pancakes and sweet soups. The crop is rich in carbohydrates and proteins and other essential vitamins.[8]

The mung bean is believed to have been produced in Ethiopia for approximately 50 years. The mung bean is one of the emerging and strategically important pulse crops being produced in Ethiopia, commonly referred to as *masho* in Ethiopia's Amharic language. The importance of the crop relies on its comparative advantage in moisture stressed areas, marketability, and early maturity. The crop can be harvested 60 to 70 days faster than other legume crops. Due to these opportunities, mung bean production reduces the risks to producers in terms of their food insecurity while offering alternative livelihood options to producers. The mung bean is still unknown in most parts of Ethiopia, and it is not used as food, despite its high nutritional value.

2. Results

As a result of the improved agriculture solution project in Midega Tola, 2,503 farmers were engaged in the mung bean seed multiplication project and have prepared over 500 hectares of land using three different types of farm tools provided to them. The farmers were able to reserve seeds for the upcoming planting season and have shown interest to expand their production. Partners have also become involved and expressed their commitment to take the lead in scaling up and reaching more farmers to expand mung bean production. Government staff have been consistently engaged in the project which has significantly strengthened community-based institutions (specifically two local seed bank management committees and a couple of multipurpose cooperatives) and improved linkages among the sectoral offices, agricultural support agencies, and the private sector. The disaster risk management solution identified and validated through participatory approaches in this project will be scaled-up and sustained by ensuring the active participation of the women in the community. This strategy aligns with the Ethiopian government's climate adaptation strategies and policies on the promotion of climate smart economic opportunities. Mung bean production will steadily build the resilience of communities to environmental hazards in the future.

Through consultative discussions with the woreda steering committee, initially 900 households were selected but finally 1,603 households participated in mung bean seed production and multiplication from the four target kebeles (villages) in the woreda: Roba, Urij, Beyoweraba and Lencha. The woreda steering committee, farmer's working groups, and seed management committee were community working groups established in the process of project implementation to facilitate the project activities.

[8] Australian Mung Bean Association (www.mungbean.org.au), Pulse Australia (http://www.pulseaus.com.au/)

Community Working Groups

In order to inform all project partners and community representatives on the project, its milestones, the breakdown of roles, responsibilities, monitoring, evaluation, and deliverables, 42 participants were drawn from woreda and zone line offices to participate in the project's launching workshop.

After consulting the community, ZOA met with beneficiaries in the four intervention kebeles to facilitate the selection and screening process while providing an orientation of the objectives, approaches, and outcomes. To ensure sustainability and ownership, farmers were organized into 60 research groups made up of 15 members each, specifically from mung bean seed producer and marketing groups, in the four target kebeles. As there were no separate seed multiplications or demonstration plots established by the project, farmers established their individual seed multiplication sites on a voluntary basis in consultation with DEA workers in the kebeles. The research groups harvested their seed and received a second round of new seed.

Contact with the zone and woreda level Agriculture and Cooperative Office was also made to consult and find previously drafted bylaws for seed bank committees. With the Cooperative Office's support in providing information and guidelines, the field office drafted committee bylaws in consultation with the seed bank committee. Seed bank committees were formed in each kebele comprising of community leaders, cooperative extension agents, women and model farmers. The role of the committee was drafted to facilitate collection, inspection, storage and redistribution of the mung bean seed with technical support of Woreda Pastoral Offices and enact the implementation of the bylaws. Trainings were given to the committee members regarding quality seed production, characteristics of quality seed, protection of seed, and store management. The community-run seed bank committees were provided with a weighing scale as well as a constructed storage unit to store the seeds.

Seed Supply

Fedis Research Centre and other seed enterprises were consulted for information and seed supply. Seed procurement was undertaken from Amhara region by FAO and transported to the target beneficiaries. After taking into account the situation in the woreda including the absence of rainfall, late arrival of seed, and occupied farm plots by other crops, the steering committee decided to minimize the original amount of seed to a maximum of 6 kg for distribution to beneficiaries. This enabled to increase the number of beneficiary households to 1,603 households. The distribution of the mung bean seed was carried out with the involvement of woreda partners (steering committee), extension workers, and kebele leaders.

A seed bank was established in Midega Tola in order to establish a sustainable supply of mung bean to the farmers. A seed bank committee was formed in each kebele comprising of kebele leaders, cooperative extension agents, women, and model farmers. A total of 1,100 kg of mung bean seed was collected from farmers and distributed to other 550 farmers at 2 kg/farmer.

Coordination

For increased coordination with government Agriculture Extension Workers, ZOA, in consultation with Fedis Research Centre and Zone Pastoral Office, provided the eight agricultural extension workers with a four-day training on mung bean production, marketing, and conservation agriculture. The trainings covered topics of agronomy (site selection, seed treatment, sowing techniques, weeding, harvesting, storing, and marketing) and conservation agriculture (soil & water conservation, catchment treatment, and run-off treatment). The training was conducted both by presentation and practical sessions in the field. The training manual was provided for the trainees. The training was cascaded to farmers at kebele level by Data Extension Agents supported by the woreda experts.

Soil and Water Conservation

Conventionally, 60 farmers were aware of moisture conservation practices that could be replicated in the mung bean seed multiplication sites. To enhance their conservation practices, training was provided to DEAs on conservation agriculture. In their respective kebeles, DEAs then identified plots in which soil and water conservation (SWC) measures could be taken. The DEAs together with woreda level SWC officers then cascaded the training to 60 farmers. The appropriate dry land SWC measures including tied-ridges, cut-off drains and bunds were then built around 54 beneficiary farmers' seed multiplication plots to help achieve sustained crop production and reduce soil degradation.

The procurement of farm tools was done by FAO for support of conservation agriculture and related crop management. Six hundred shovels, 600 pickaxes and 485 crow bars were procured and transported to the field office. The tools have been handed over to the woreda's Pastoral Development Office and were distributed by woreda DEAs.

Mung Bean Awareness

An awareness raising workshop, review meeting/workshop, preparation and distribution of brochures were conducted to increase the understanding of the value of mung bean and reveal the progresses of the IAS project among the community and stakeholders. Printing and disseminating of brochures, banners and T-shirts were done during trainings and review meetings to broaden awareness of the community and partners. A newsletter has been prepared to share the best practices of the project and disseminate information to all relevant project actors, decision makers, and communities in order to diversify mung bean production practices.

Farmers have been oriented on the use and awareness has been increased on the food value and nutritional aspect of mung bean during training on seed production. The food demonstration activity was limited as production was low due to several factors, but it was decided, for the harvest season, to limit consumption and encourage seed saving to increase mung bean production. Despite this decision, farmers and their families have consumed some of the harvested mung beans in the form of *wot* (sauce), *nifro* (boiled seed), and porridge.

Value Chain Analysis

A value chain study was conducted on mung bean crop involving target farmers and relevant stakeholders. Visits and discussions were held with beneficiary farmers, government line offices and relevant private and government institutions. The overall value chain of the mung bean was assessed in Ethiopia. The direct actors involved in the production, collection and export of the product, input aspects, the service providers and the overall context of mung bean value chain were explored. As the value chain activities related to mung beans are only in their beginning stages, some of the value chain roles including trading activities are non-existent in the project woreda. Figure 1 shows the proposed value chain for mung bean in Midega Tola.

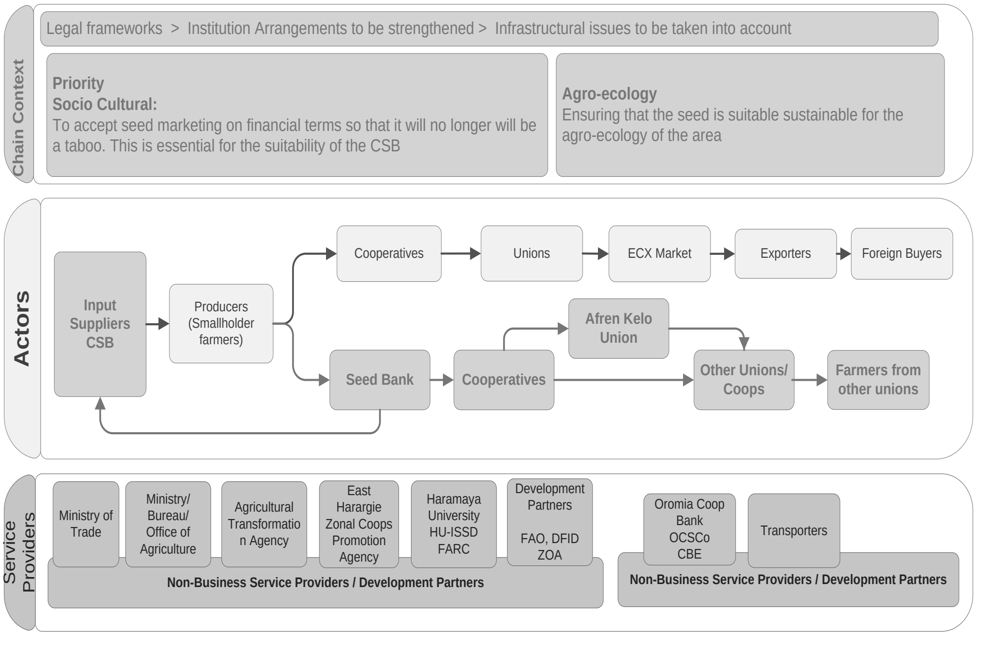

Figure 1. Proposed Mung Bean Value Chain for Midega Tola (Target Consultants, Plc).

Rainfall pattern during 2015 in Midega Tola

The following table depicts the rainfall pattern in Midega Tola town during 2015. Rainfall is usually erratic and uneven in its spatial distribution. The following data were collected to show the erratic nature of the rain.

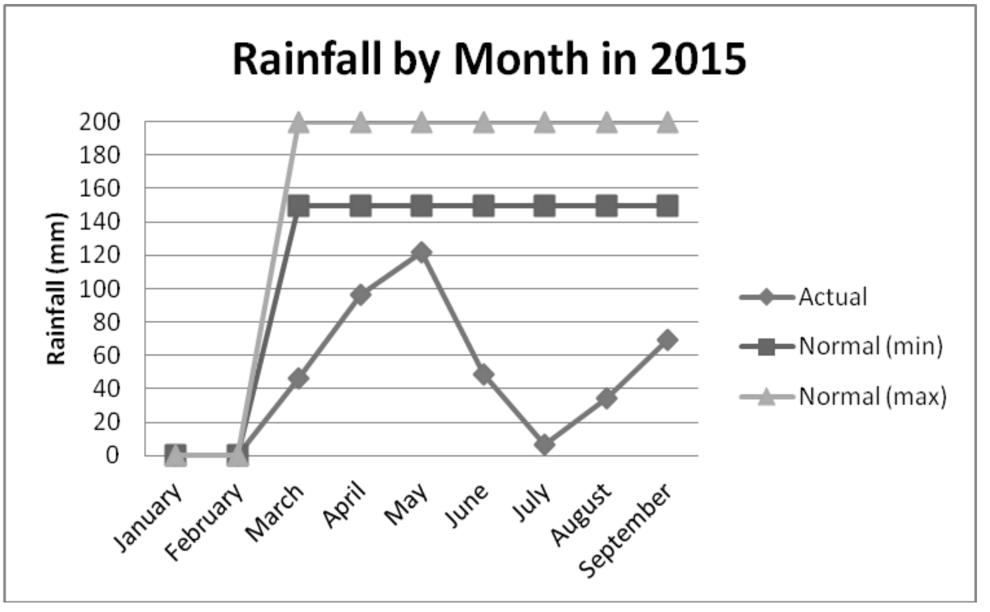

Figure 2. Rainfall by Month in 2015.

Mung Bean Harvest in 2015

As mentioned previously, a total of 5.605 MT of mung bean was harvested in August 2015. A total of 900 households planted the seed. The total area planted was 225 hectares.

Table 1. Mung Bean Harvest per Kebele.

Kebele	No. of Growers	Qty of Seeds Planted (qt)	Time of Planting	Area Planted (ha)	Mung Bean Harvested / Expected Yield (qt)
Roba	223	28	May/June	56.25	18 / 675
Uriji	225	28	May/June	56.25	17 / 675
Lencha	227	28	May/June	56.25	15 / 675
Biyyo Waraba	225	28	May/June	56.25	5 / 675
Farmer Training Center	-	-	-	-	1.05
TOTAL	900	112	-	225	5.605 MT / 270 MT

The erratic rainfall and late onset of rains greatly affected the harvest. The planting of seeds started late due to the late rains. After late planting, the small amount of rain led to very poor harvests and almost completes crop failure in some kebeles.

Experience Sharing/Best Practices

A project review meeting and experience sharing workshop were undertaken at the project level involving woreda and zone level offices, Fedis Research Centre and Haramaya University. The progress during project implementation, challenges encountered and lessons learned from mung bean production were addressed. The participants from Haramaya University's Integrated Seed Sector Development project shared their experiences in smallholder farmer seed multiplication with the involvement of the primary cooperative. The participants discussed the importance of seed multiplication demonstrations in the Farmers Training Centre and cooperative farms as well as the need to form farmers' groups with adjacent farmers to coordinate the seed multiplication process in order to help in the production of viable and marketable seeds.

Farmers' best practices and project progress was shared among stakeholders during the review meeting held at the project level as well as the workshop in consortium with FAO. Information was shared through various publications including brochures, case stories and newsletters. Sign boards and billboards were prepared and posted at different locations in the woreda to enable dissemination of information and best practices for development partners and the community.

3. Conclusions

Overall, the mung bean project greatly benefitted the Midega Tola community through its strengthening of community resilience. The beneficiaries and partners participated consistently in the innovative project. Farmers who were engaged in mung bean seed multiplication adopted the innovation and successfully reserved seed for the upcoming planting season. Promisingly, the farmers showed increasing interest to expand their production. Field monitoring and a midterm impact assessment against the project indicators were done through the inclusion of relevant stakeholders in focal group discussions, key informant interviews, and project site observation. The results of the midterm assessment showed positive project results with a promising outlook on its impact in the food security of households. Of noteworthy importance, as confirmed by the midterm assessment, the commitment of farmers and specifically the woreda pastoral and administration offices to expand the production of mung bean in the upcoming seasons is strong. Partners at woreda and zonal level offices have also shown their commitment to the innovation and have taken the lead in scaling up mung bean production to reach more farmers. The regional government offices' initiative showed that Midega Tola Woreda's Pastoral Office already incorporated mung bean production in its plan for the upcoming *Meher* harvest. Following the good collaboration with the Fedis Research Centre, the centre is now working to undertake mung bean adaptability trials around the project area.

Improving Knowledge

The key lessons since project start-up and which the project considers to scale up include:

- Dry time extended up until the month of July and into mid-August. Once rainfall began, it ended earlier than expected. As a result of late distribution and planting of mung bean seed coupled with the aforementioned factors, the production was low.
- Provision of pertinent trainings for farmers and relevant stakeholders in advance was very important for earlier adoption of the innovation by partners and beneficiaries. ZOA was obliged to proceed with the distribution and planting of seeds with orientation and on spot consultation with partners for the best use of the rainy period.
- The delivery time of inputs and related packages for farmers and partners was vital for provision of appropriate support, adoption of technologies, the possibility of tracking, recording, and documenting project processes.
- Good partnership and close collaboration with multi stakeholders improved the progress of project implementation and tangible cooperation between ZOA and the partners. Besides building the capacities of local and government organizations, ZOA facilitated the sharing and learning of new information among the development partners which in turn increased sustainability.
- Despite the weak participation of farmers research groups and the steering committee, the formation of community working groups (farmers research groups, seed committee, steering committee, primary cooperative) and strengthening of their capacity to be involved directly in the project enhanced efficiency in the adoption of innovations, production, and marketing.
- Integrating mung bean seed production with related climate proof interventions tailored to the agro-pastoral system (beekeeping, goat rearing, etc.) has been well recognised by government officials and the community to rapidly address the food security problems in the woreda.

- An innovative program intervention requires intensive data collection and analysis so that information sharing and an impact assessment can be facilitated. So, preparatory work and training for Development Extension Agents (DEAs) in data collection, compilation and documentation should be sought in such interventions.
- In dealing with seed production and supply chain, the presence of well-developed community institutions with functioning structures, human and financial capacity is required, which is not in place at the moment. So the importance of demonstrations for seed multiplication at the institutional level including the Farmers Training Centre and primary cooperative, strengthening and capacitating these groups within the framework of the cooperative structure and linking this with service providing institutions (e.g. technical, financial, etc.) ensures the sustainability of the project.

4. Acknowledgements

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- Special thanks to the farmers from Midega Tola woreda who participated in the focus group discussions.
- ECX staff, exporters, traders and union management members who had been contacted by the team for the value chain analysis.
- The woreda level steering committee comprising of the Pastoral Development Office, cooperative promotion, woman and children affairs, woreda administration and representatives of the selected kebeles. The steering committee is formally established at woreda level with the mandate of oversight of the project and hence undertakes monitoring at field level on the distribution and management of inputs, as well as implementation of the project at woreda level. The partnership and coordination of the IAS project also includes Zone Administration and line offices, who are key partners involved in project agreement, planning, implementation, and monitoring.
- The linkage with Fedis Research Centre, Haramya University ISSD, and Afrenkalo Union assisted in technical capacity building, joint review of progress, and sharing experiences of project in improving production and the prospective marketing of mung bean.
- Consultation was conducted with different research centers (Melkasa and Sirinka), cooperatives, and private supplier of seed. Seeds procurement was conducted by FAO. A total of 4350 kg of mung bean seed was transported to Midega Tola in June.

5. References

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4. Disease Resistant and Drought Tolerant Wheat Varieties for Small Scale Production in Eastern Ethiopia

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Abstract

Hararghe highlands are suitable for wheat cultivation; however, the average wheat yield is lower than the national average. The major factors for the low yield are: low and uneven distribution of rainfall, poor agronomic practices and serious diseases like rusts and Septoria leaf/glume blotches. A field experiment was conducted in eastern Ethiopia where eleven wheat varieties and a the oldest variety as a check were sown at several locations in Chenakasen, Haramaya, Jarso and Tollo districts using farmers' fields, Farmers' Training Centers (FTCs) and experiment stations. At each location randomized complete block design in two replications was used. The seed was drilled using the recommended seed rate of 150 kg/ha with row spacing of 20 cm during the 2nd week of July 2012. Recommended fertilizer rate for wheat production was applied and weeding was done as required. Other farm operations were carried out by farmers with close assistance and supervision of Haramaya University researchers and experts of rural and agricultural development offices. Among the 11, the two varieties (Kakaba and Tusie) were matured significantly earlier than the check. This suggested the potential of these two varieties to be used in moisture stress areas. At Haramaya, the overall agronomic performance of the test materials except the varieties, Madawolabu and Senkegna, were better than the check. Considering all the test areas, the four varieties (Kakaba, Danda'a, Shorima, and Tusie) were performing better than others. None of the varieties were infected with septoria and yellow rust at all the test locations except the variety Madawolabu that showed traces of yellow rust infection at Haramaya. At Chinaksen and Jarso all the tested varieties were not infected with any of the diseases. This may be due to the fact that the environments were not conducive for disease development. At Haramaya, the varieties Tay, Sofumar and Senkegna were susceptible while Kakaba and Tusie were moderately resistant to stem rust. But the varieties Alidoro, Hulluka, Dandaa, Madawolabu, Shorima, Digelu and Pavon 76 were resisitant. At Tullo, the variety Danda showed traces of stem rust while Pavon 76 was moderately susceptible to leaf rust. The varieties Alidoro, Hulluka, Dandaa, Madawolabu, Shorima, Digelu and Pavon 76 were resistant. However, better conclusion could be made if the trial is replicated for at least one season at more locations.

1. Introduction

Ethiopia is the second largest producer of wheat in sub-Saharan Africa, following South Africa. The hexaploid/bread wheat (*Triticum aestivum* L.) and tetraploid/durum wheat (*T. turgidum ssp. durum* Desf.) are grown at altitudes ranging from 1800-2800 masl. Ninty-eight percent of this crop is produced by resource-poor farmers. The two wheat species are grown in Ethiopia on an area of 1.5 million hectares with production of 2.9 million tons primarily as highland rain fed crops. The mean wheat yields were around 1.4 t/ha in early 1990s, well below experimental yields of over 5 t/ha (Hailu, 1991). However, it was observed the increased trend of wheat production that increased from 1.6 to 2.9 m t, area under production has increased from 1.2 to 1.4 m ha and yield also has increased from 1.4 to 2.25 t/ha (an increment of 60%) from 1998 to 2007 (CSA, 2010).

However, Ethiopia's current annual wheat production is insufficient to meet domestic needs, forcing the country to import 30 to 50% of the annual wheat grain required. The yield gap of over 3 t/ha suggests the potential for increasing production through improved crop management, particularly use of high yielding, disease resistant varieties and increased use of fertilizers.

In most of the wheat growing areas of the country, only a single wheat crop is grown during the second, longer rainy season (meher) which usually starts in June. The short rains (belg), starting in March, are less reliable in most parts of Ethiopia; however, in the southeast of the country (e.g., Bale zone of Oromiyia Region), rainfall distribution is bimodal. Growing wheat in belg season implies harvesting during meher, which often results in high grain moisture levels and sprouting. Thus, wheat crops are typically sown by broadcasting in June or July and harvested in November or December (Hailu 1991).

Bread wheat is widely grown in eastern Ethiopia. Hararghe highlands are considered to be suitable for wheat cultivation and the crop is mainly grown in the following districts: Chiro, Dedder, Chinaksen, Haramaya, Jarso, Kersa, Meta, Kombolcha, Kurfachelle, Mesela, Melkabello and Tullo. It is also grown in some areas in Harari and Somali regional states. The total area allocated to wheat production varies considerably each year and from 30 to 40,000 hectares were planted in 2010. In some areas it is an important early maturing crop of choice grown whenever sorghum and/or maize fail due to drought The average productivity of the crop in this region is about 1214 kg/ha which is lower than the average yield of other wheat producing areas in the country. Its area coverage and production is 3rd after maize and sorghum. Types of varieties grown in these areas include Kubsa (HAR1685), Wabe (HAR710), HAR1522, ET13, ET30, Pavon76 and various local genotypes. (East and West Hararghe Rural Development and Agricultural Office, 2009 and 2010).

A wide range of environmental conditions exist throughout the area that may affect the productivity of wheat in the region. The major factors for the low wheat yield are: low and uneven distribution of rainfall, cultivation of low yielding varieties, poor agronomic practices and rust diseases. In Hararghe highlands, stem rust (caused by *Puccinia graminis* Pers. f.sp. *tritici*), stripe rust (caused by *P. striiformis*) and leaf rust (caused by *P. triticina* L.) occur annually. For example, in our recent survey, we observed a near to 100% yield loss in some fields due to infection by yellow rust (Temam *et al.,* 2012). Variation in severity of rust epidemics in the area depends on differences in crop maturity at the time of infection by primary inoculums, resistance of the host used, and environmental conditions. The interrelationships among time, host, pathogen and environment are complex, and studying the interactions is very difficult. Historically, varieties with new or different rust resistance genes become ineffective after several years of large scale production and then varieties carrying new or different resistance genes must be developed and released for production. (Roelfs *et al.,* 1992). This is the typical "boom and bust" cycle of the cereal rust resistance genes in many part of the world. Sometimes, virulent and destructive races of the rust pathogen may be introduced into a country through wind-borne spores.

The rust species, meteorological variations, and cultural practices combined with varietal resistance and a changing pathogen population, result in significant variation in severity of yearly rust epidemic. The three species of wheat rust differ in their adaptability to temperature. The range of temperatures that favour the development of stem, leaf and yellow rusts are 15-30°C, 15-25°C, and 10-15°C, respectively. Stem rust is generally considered a warm temperature rust and, as such, is most important in areas with altitudes ranging from 1600 to 2000 masl. Leaf rust, on the other hand, is considered a cool temperature species, which contributes to its importance in areas with altitudes ranging from 1900 to 2300 masl. Stripe rust, which is adapted to even cooler temperatures than leaf rust, is most important at higher altitude areas (Roelfs et al, 1992).

According to earlier reports, under Ethiopian conditions, the rusts infect wheat late in the season, but if favourable conditions prevail and susceptible varieties are grown, early infections are possible. In a survey carried out this year in eastern Ethiopia, all the three rusts were encountered. The surveyed areas were situated between 09°02.223´ to 09°29.892´ N latitude and 040°54.436´ to 042°44.457´ E longitude. The altitude of the surveyed areas ranged from 1740 to 2739 masl. In the majority of the surveyed fields, wheat plants were between growth stages 7 and 9 (grain dough to ripening stages) on the growth stage scale suggested by Zadoks and co-workers (Zadoks *et al.,* 1974). The approximate sizes of the surveyed fields ranged from 0.1 to 0.5 hectares. Rust diseases were encountered in 79% of the surveyed fields. Yellow rust was encountered in 55% of the surveyed fields with severity ranging from trace to 100S particularly on the improved variety named Kubsa (HAR 1685) while each of stem and leaf rusts were found in 4% of the surveyed fields with stem rust severity ranging from trace to 40% and leaf rust ranging from trace to 100%. Yellow rust was the dominant rust species encountered. In addition to the rust problem, shortage of high yielding, disease resistant and drought varieties is the second bottleneck of wheat production in eastern Ethiopia. Therefore, this study was undertaken to search for disease resistant and drought tolerant high yielding wheat varieties that may improve the farmers' production and productivity of the crop in eastern Ethiopia.

3. Materials and Methods

3.1. Awareness Creation

Before embarking on the actual project, the goals and objectives of the project were explained to the concerned offices in the region by face-to-face round table discussion. Contact was particularly made with Agricultural and Rural Development offices of Oromia Regional Government in East and West Hararghe zones.

3.2. Selection of Target Farmers

Selection of target farmers was done in cooperation with the Agricultural and Rural Development offices of Oromia Regional Government in East and West Hararghe zones. Four districts, vs. Chinaksen, Jarso, Haramaya and Tullo were considered in this study. Selection of these is based on the interest of stakeholders and their wheat coverage. Fields were selected purposively based on farmers' willingness to participate in this project.

3.3. Research Inputs

3.3.1. Adaptation trial

Eleven wheat varieties and the oldest variety Pavan 76 released in 1982 as a check (Table 1) were sown at several locations in Chenahasen, Haramaya, Jarso and Tollo districts using farmers' fields, farmers' training centers (FTCs) and experiment stations (Table 2). At each location randomized complete block design in two replications was used. The initial plan was to use plot size of 10 m^2 for each variety at all locations, but it was difficult to get enough land or uniform land on farmers' fields and/or FTCs, therefore, the plot size was modified according to the availability of land. Plot size on the Haramaya University Campus was 10 m^2 (10 rows x 5 m long x 0.2 m apart). Recommended fertilizer rate for wheat production was used. Row spacing was 20 cm. The seed was drilled using the recommended seed rate of 150 kg/ha and planting was done during the 2nd week of July 2012. Weeding was done as required. All farm operations were carried out by farmers with close assistance and supervision of Haramaya University scientists and participating rural and agricultural development offices.

Table 1. Description of wheat varieties used for the study.

No.	Variety	Year of release	Breeder/Seed maintainer	Pedigree
1	Alidoro	2007	HARC/EIAR	HK-14-R251
2	Hulluka (Hoganna)	2011	KARC/EIAR	PYN/BAU//MILAN
3	Kakaba	2010	KARC/EIAR	KIRITATI//SERI/RAYON
4	Tusie	1997	SARC/OARI	COOK/VEE"S"//DOVE"S"/SERI
5	Danda'a	2010	KARC/EIAR	NA KIRITATI//2*PBW65/2*SERI.1B
6	Madawolabou	2000	SARC/OARI	TI/3/Fn/Th/Nar 59 *2/4/Bol'S'
7	Shorima	2011	KARC/EIAR	UTQUE96/3/PYN/BAU//MILAN
8	Digalu	2006	KARC/EIAR	SHA7/KAUZ; *CM95113-9Y-OM-OE-1Y-1Y-OM-OFC-4FUS*
9	Sofumer	2000	KARC/EIAR	LIRA 'S'/TAN"S"
10	Tay	2005	DBARC/ARARI	ET-12D4/4777(2)//FKN/GB/3/PVN"S"
11	Senkegna	2005	ADARC/ARARI	NA
12	Check (Pavan 76)	1982	KARC/EIAR	VCM/CNO "S"/7C/3/KAL/BB

Table 2. Names and locations of FTCs and/or farmers' fields where the trials were planted in East & West Hararghe zones in 2012 main crop season.

No.	District	PA	Locality	Altitude (masl)	Latitude (N)	Longitude (E)	Date of planting	Local variety used
1	Chinaksen	Dembesle	Dembesle (FTC)	1870	09°22.771'	042°40.267'	15 July	HAR 1685
2	Chinaksen	Dagder	Dagder (farmer)	1915	09°29.894'	042°37.725'	16 July	HAR 1685
3	Haramaya	HU	Haramaya University (Rare)	1980	09 o 25.178'	042 o 02.199'	10 July	Qulqullu
4	Haramaya	HU	Haramaya University (Rare)	1980	09 o 25.178'	042 o 02.199'	11 July	Qulqullu
5	Jarso	Afugug	Afugug	2538	09o29.731'	042o18.170'	14 July	HAR 1685
6	Jarso	Efajalela	Efajalela	2495	09o29.210'	042o12.878'	14 July	HAR 1685
7	Tullo	Gaaraqufa	Gaaraqufa	2320	09°09.335'	041°04.996'	12 July	HAR 1685
8	Tullo	Krakufis	Krakufis	1750	09°13.087'	041°05.357'	13 July	HAR 1685
9	Tullo	Terkanfata	Terkanfata	2050	09°10.575'	041°03.534'	13 July	HAR 1685

4. Results and Discussion

4.1. Agronomic Performance

The plots at all locations were first evaluated for stand establishment. During the evaluation it was observed that the crop stand was very good at the Haramaya University Main Campus Research Site traditionally known as *Rare* and two sites at Jarso District. In the other areas, however, there was poor stand at all locations due to shortage of moisture after sowing. Even though, the stand was poor for yield determination, the plots were visually assessed for over all plant aspect/agronomic performance using the 1 to 5 scoring scale where 1= excellent, 2 = very good, 3 = good, 4 = poor and 5 = very poor.

At *Rare,* the crop establishment was uniform and very good, thus data on days to flowering, days to maturity, plant height, 100 kernel weight, grain yield, hectoliter weight, and over all plant aspect was collected.

The performance of the 11 varieties (Table 3) as compared to the check showed that two varieties (Kakaba and Tusie) matured significantly earlier than the check while three varieties (Shorima, Digelu and Senkegna) matured later than the check. This is significant in that the two varieties, Kakaba and Tusie, could be used for moisture stress areas. There was no significant difference between the check and other varieties.

The varieties Hulluuka, Kakaba, Tusie and Madawolabu were significantly shorter but there was no significance difference between the other varieties and the check. The thousand kernel weights of 7 varieties (Alidoro, Kakaba, Madawolabu, Shorima, Sofumer, Tay and Senkegna) were significantly higher than the check, while the others showed no significant difference from the check. The grain yield of only one variety (Danda'a) was significantly higher than the check, the other varieties did not give significantly better yield than the check. In terms of hectolitre weight (HLW), two varieties (Danda'a and Tay) and two varieties (Kakaba and Digelu) gave significantly lower and higher weight than the check, respectively. The HLW of the other varieties was not significantly different from the check.

At Haramaya, the overall plant aspect or general agronomic performance of the test materials except the varieties, Madawolabu and Senkegna, were better than the check. However, across all the test areas the overall plant aspect of four varieties (Kakaba, Danda'a, Shorima, and Sofumar) was very good (Table 4). Based on data of one season, it could be concluded that nine of the eleven varieties have desirable agronomic traits at Haramaya while four varieties performed very good across locations. However, better conclusion could be made if the trial is replicated for at least one season at more locations.

Table 3. Mean yield and other agronomic traits of 12 wheat varieties tested at the experimental plot of the Haramaya University Main Campus in 2012.

No.	Variety	DTF	DTM	PHT (CM)	TKW (G)	HLW (G)	Yield (kg/ha)	OPA*	Disease reactions		
									Yr	Sr	Lr
1	Alidoro	74	111	102	43	736	3600	2	0	0	0
2	Hulluka	89	108	96	31	700	3300	2	0	0	0
3	Kakaba	78	99	91	44	781	4100	2	0	30MR	0
4	Tusie	74	102	93	28	707	2900	2	0	30MR	0
5	Danda'a	79	110	101	28	600	5500	1	0	5R	0
6	Madawolabu	81	111	95	40	710	4500	3	TrR	TrR	TrR
7	Shorima	74	113	98	37	727	3600	2	0	0	TrR
8	Digelu	96	113	110	37	785	3900	2	0	TrR	0
9	Sofumar	73	107	104	37	758	3800	2	TrR	30S	TrR
10	Tay	70	110	110	34	670	3400	2	0	40S	5MS
11	Senkegna	69	113	98	37	736	3800	3	0	60S	TrR
12	Check (Pavan 76)	75	112	99	30	702	3700	3	0	5R	5MS
LSD		6	6	12	8	76	1200	1.5			

OPA = Overall plant aspect
**1 = Excellent, 2 = Very Good, 3 = Good, 4 = Poor, 5 = Very Poor*

Table 4. Agronomic characteristics on the 1-5 scoring scale of twelve wheat varieties tested in different areas in Hararghe in 2012.

Entry No.	Variety	Chinaksen	Haramaya	Jarso		Tullo			OPA
		Dagder	HU Rare	Ifajalela	Afugug	Garakufa	Kirakufis	Terkanfata	
	Alidoro*	3	1	3	1	3	4	3	3
	Hulluka (ETBW 5496)	4	2	4	3	5	1	5	3
	Kakaba	3	2	2	2	1	3	4	2
	Tusie	2	2	3	3	2	3	4	2
	Danda'a*	2	1	1	3	3	3	4	2
	Madawolabu	4	3	2	2	3	3	2	3
	Shorima* (ETBW 5483)	2	2	1	1	3	5	3	2
	Digelu	3	2	4	4	4	5	4	4
	Sofumar	3	2	1	1	1	5	2	3
	Tay	2	2	3	2	3	4	3	3
	Senkegna	3	3	3	3	2	4	5	3
	Pavon 76 (Local check)	3	3	2	3	5	3	3	3

1 = Excellent, 2 = Very Good, 3 = Good, 4 = Poor, 5 = Very Poor OPA = Overall Plant Aspect

4.2. Disease Reactions of Wheat Varieties

Reactions of the tested varieties to leaf, stem and yellow rusts and septoria is given in Table 5. All the twelve varieties were not infected with septoria yellow rust at all the test locations except the variety Madawolabu that showed traces of yellow rust infection at Haramaya. At Chinaksen, all the tested varieties were not infected with any of the diseases. This may be due to the fact that the environment is not conducive for disease development. At Haramaya, the varieties Tay, Sofumar and Senkegna were susceptible while Kakaba and Tusie were moderately resistant to stem rust. But the varieties Alidoro, Hulluka, Dandaa, Madawolabu, Shorima, Digelu and Pavon 76 were resistant. At Jarso, all the tested varieties were not infected by any of the diseases. At Tullo, the variety Danda showed traces of stem rust while Pavon 76 was moderately susceptible to leaf rust. The two early maturing varieties, Kakaba and Tusie, can escape much of the damage by avoiding the growth period of the rust fungi.

Table 5. Disease scores of 12 wheat varieties in four districts in 2012 main crop season.

No.	Variety	Chinaksen				Haramaya				Jarso				Tullo			
		Yr	Sr	Lr	Sept	Yr	Sr	Lr	Sept	Yr	Sr	Lr	Sept	Yr	Sr	Lr	Sept
1	Alidoro*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Hulluka (ETBW 5496)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Kakaba	0	0	0	0	0	30MR	0	0	0	0	0	0	0	0	0	0
4	Tusie	0	0	0	0	0	30MR	0	0	0	0	0	0	0	0	0	0
5	Danda'a*	0	0	0	0	0	5R	0	0	0	0	0	0	0	TR	0	0
6	Madawolabu	0	0	0	0	TR	TR	TR	0	0	0	0	0	0	0	0	0
7	Shorima (ETBW 5483)*	0	0	0	0	0	0	TR	0	0	0	0	0	0	0	0	0
8	Digelu	0	0	0	0	0	TR	0	0	0	0	0	0	0	0	0	0
9	Sofumar	0	0	0	0	TR	30S	TR	0	0	0	0	0	0	0	0	0
10	Tay	0	0	0	0	0	40S	5MS	0	0	0	0	0	0	0	0	0
11	Senkegna	0	0	0	0	0	60S	TR	0	0	0	0	0	0	0	0	0
12	Check (Pavon 76)	0	0	0	0	0	5R	5MS	0	0	0	0	0	0	0	10MS	0

**Suggested for promotion and use by far farmers around Haramaya. Yr = yellow rust, Sr = stem rust, Lr = leaf rust and Sept = septoria,* R *= resistant, TR = trace, MR = moderately resistant, MS = moderately susceptible and s = susceptible.*

5. Conclusion

Two varieties (Kakaba and Tusie) matured significantly earlier than the check. This is significant in that these two varieties could be used for moisture stress areas where the condition is not favorable for rust development. They could also escape much of the damage by avoiding the growth period of the fungi in particular stem rust as it normally appears very late in the season

At Haramaya, the overall plant aspect or general agronomic performance of the test materials except the varieties, Madawolabu and Senkegna, were better than the check. However, across all the test locations the overall plant aspect of four varieties (Kakaba, Danda'a, Shorima, and Tusie) was very good. Based on data obtained, it could be concluded that nine of the eleven varieties have desirable agronomic traits at Haramaya while four varieties performed very good across locations in spite of terminal moisture stress.

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5. Evaluation of Sequential Cropping System for Diversification of Different Crops in Fedis and Mieso, Eastern Ethiopia

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Abstract

The dry lowlands of Eastern Ethiopia is victim of prevailing climate change as in many parts of the world which is mainly characterized by increasing temperature and erratic, late coming, unpredictable and low rainfall. The smallholder farmers are usually produce sorghum to have a chance of providing enough food for their family because sorghum is known to be "camel of crops 'due to its moisture stress tolerance. However, mono-cropping of sorghum whether it is long or early maturing aggravates the infestation of striga in case of susceptible varieties and has risk of crop failure in most cases due to erratic and unreliable rainfall. To alleviate this problem, it was necessary to undertake research on cropping system which can make the farmer less vulnerable to current changing climate. Thus, this study was carried out by comparing farmers' accustomed "meher" planting practice with sequential cropping of improved and early maturing crop varieties followed by planting of early maturing sorghum varieties. The objective of this experiment was to select best combination of cropping sequence that can diversify options for farmers and reduce risk of crop failure. The study was conducted in two locations known as Fedis and Mieso Eastern and Western Hararghe, respectively, during 2015 cropping season by including two sowing time; the first in April and the other during July using RCBD design. Different crops were included like two varieties of mung beans and haricot beans each, bread wheat, sorghum, pearl millet, buck wheat, cow pea, lablab, fallow and local sorghum as a preceding crops which were sown in April and succeeding crop was sorghum variety gubiye after the preceding crop were harvested except in place of local sorghum since it took eight months to mature. The preliminary result revealed that the harvested mung bean, haricot bean, cow pea and buckwheat were promising, though bread wheat, sorghum and pearl millet were on good performance, bird attack was very challenging to control during June and lablab and local sorghum were the only crops that did not mature on both locations. However, during the succeeding crop season, sorghum variety gubiye, which replaced all the proceeding crops and local sorghum, matured and harvested in Fedis but not in Mieso. The overall result was promising and best sequence will be selected after the soil analysis, productivity and monetary value of the system is finalized. Generally, to reach up on good result for recommendation for such dynamic and risky situations, the experiment must have to be repeated over years and locations since one year data is not sufficient.

1. Introduction

Rain-fed agricultural areas of East Africa are often food insecure due to rainfall variability and ongoing soil degradation that negatively impacts crop yields. Agricultural activities and consequently the livelihoods of people reliant on agriculture will be affected by changes in temperature and precipitation conditions in large parts of Sub-Saharan Africa (Muller *et al.,* 2011). Under climate change, many areas in sub-Saharan Africa are likely to experience a decrease in the length of the growing season, while in some highland areas rainfall changes may lead to a prolongation of the growing season (Thornton *et al.,* 2006).

Multi-cropping practices offer various strategies for intensification by allowing multiple uses of a single field during a single time period (such as a calendar year). Multiple cropping systems allow for this intensification by growing two or more crops on the same field either at the same time or after each other in a sequence (Francis, 1986; Norman *et al.,* 1995).

Lobell *et al.* (2008) noted that the identification of practicable adaptation strategies for cropping systems should be prioritized for regions impacted by climate change. However, few studies investigate the impact of climate change on agriculture in SSA considering the cropping system applied or make an effort to identify the least impacted cropping systems.

The most influential climatic variables for crop production in East Africa including Ethiopia and Hararghe as well are temperature and rainfall. Low and unreliable rainfall prevalent in many parts of the lowland areas of Hararghe lowlands means a high incidence of drought and crop failure, further contributing to food insecurity and poverty. Small land holdings and shortage of assets of the poor people in the area further limit the choice of crop to sorghum which is long maturing. The smallholder farmers must plant sorghum to the majority of their land to have a chance of providing enough food for their family as sorghum is known to be "camel of crops " though during harsh seasons as in the year of 2015/2016 even total crop fail may occur.

What so ever, mono-cropping of sorghum whether it is long or early maturing is their usual practice which aggravates the infestation of striga in case of susceptible varieties and has risk of crop failure in most cases due to erratic and unreliable rainfall (Tegene *et al.,* 2013). Basically, the farming system should be revised in the cropping areas of Fedis, and similar dry lowlands of Hararghe. Since eight-month-cycle sorghum being rain-fed, is simply late maturing and too vulnerable to pests, lower yielding and dependent on rainfall patterns. Additionally, in the last few years improved sorghum varieties which are early maturing, striga resistant and high yielders than the local varieties where striga and rainfall is limiting are under production in dry low lands of eastern Hararghe Zone. A re-orientation towards shorter cycle crops like early maturing sorghum, wheat, bean, pulses oil crops and vegetables would help farmer's better cope with the climatic hazards of the area (Tegene*et al.,* 2013).

However, farmers in Fedis area are accustomed to sow the local varieties from end of March to the middle of April though they know the advantage of using improved sorghum varieties reduce risk of striga and yield. This is because farmers are not volunteers to leave their land idle when the rain starts early in March/April until the right planting time of the early maturing striga resistant varieties. Whereas, these improved varieties were sown after the local varieties from middle of June to the beginning of July and farmers who are adopting improved sorghum varieties are forced to live their land idle to synchronize its maturity with long maturing sorghum varieties to reduce the high bird infestation prevailed in the area.

So, this puts the farmers in a dilemma whether to sow early at the onset of rainfall or live their land idle until the time of sowing for improved and striga resistant sorghum varieties come. To alleviate this problem, to use effectively the rainfall before the middle of June to reduce the infestation of striga, diversify risk of failure and to intensify production of farmers, it is important to undertake research on cropping system which help the farmer by comparing their already accustomed and untimely planting practice with double cropping of improved and early maturing crop varieties followed by planting of early maturing sorghum varieties and evaluation of the system. With this in background, this study was done with the objectives of:

- To select best combination of cropping sequence that can diversify options for farmers and reduce risk of crop failure.

2. Material and Methods

2.1 Description of the Experimental Site

The experiment was conducted at Fedis Agricultural Research Center (experimental station) at Fedis district, Eastern Hararghe zone of Oromia and Mieso sub-station of Melkasa Agricultural Research center at Mieso district, western Hararghe zone of Oromia. Fedis is 24km far from Harar town in the south direction While Mieso is 25 km from Chiro town. Fedis site is located at latitude between 8° 22' and 9° 14' north and longitude between 42° 02' and 42° 19' east, in middle and lowlands areas and the altitude ranges from 500 to 2118 meters above sea level, with a prevalence of low lands (Canali and Slaviero, 2010).

Commonly sorghum is the staple crops cultivated by farmers, in the vicinity of the sites. Vertisols and Afilsols soil type are common to the area (Fedis Woreda Profile, 2011). Soil is loam in texture with pH of 7.4 (FARC, 2012).

2.2. Treatments and Experimental Design

The experimental materials used for this experiment were divided into two, which were used as a preceding and succeeding crop. The crops used were selected based on their importance and mainly for their early maturity.

A field experiment were laid out in Randomized Complete Block Design (RCBD) with three replications and twelve treatment combinations consisting of two control of farmers practice as sole cropping system which are early planting in April and late planting in July. Overall the treatments for this experiment were grouped into two consisting of mung beans (N-26 and MH-97-6), haricot beans (Awash melka and Batu), pearl millet (Kola-1), sorghum (76T1#23), bread wheat (Jafferson), Buck wheat, Lablab, cowpea and controls from farmers practices of mono cropping (early planting and late planting) as a preceding crops and sorghum variety gubiye as a succeeding crop. Plot size used was 3.75 m x 3 m and overall experimental area was 13.25m x41.5 m (549.875 m sq.).

2.3. Experimental Procedures

The land was ploughed to bring the soil to fine tilth and tie ridge were made in order to conserve moisture. The plots were laid out as per plan and leveled manually. The light bunds were made to prevent the entry of runoff water.

Seeds of sorghum and pearl millet were drilled in the row of 75 cm between rows and 15-20 cm between plants and the spacing was the same for sorghum during second sowing although they were thinned to make it one plant per hill at spacing of 15-20 cm. Haricot bean were sown at 40 cm x 10 cm between rows and plants, respectively, buck wheat, cow pea and lablab's spacing were 50cm x 10 cm between rows and plants, respectively, bread wheat was drilled in the row of 20 cm between rows and mung bean was sown at spacing of 40 cm x 5 cm between rows and plants, respectively.

At first sowing, all plots received basal application of phosphorus and nitrogen in the form of DAP at the rate of 46 P_2O_5 kg/ha and 18 N except for pearl millet which was 23 P_2O_5 kg/ha and 9 N kg/ha. Additionally Nitrogen were applied in split form in the form of Urea for Bread wheat, Cow pea and lablab at the rate (23, 11.5, 11.5 N kg/ha) respectively at sowing.

Four weeks after emergence 46 N kg/ha were applied for sorghum and Mung bean, 32 N kg/ha for pearl millet, 23 N kg/ha for Haricot beans, Buck wheat and Bread wheat and 11.5 N kg/ha for cow pea and lablab were applied in the form of urea when the soil moisture was enough.

At the end of July the preceding crops were harvested and threshed after it was sun dried for one weak and grain yield per plot were recorded except the control since it took seven to eight months to mature. The succeeding crop and the control of all sorghum were harvested on maturity. The stalks from net plot were cut close to ground level and later ear were separated. The ear was sun-dried, threshed and grain yield per plot were recorded after 7 days of sun drying.

2.4. Data Collection

Data collected for phenology and growth were the same for all crops. The parameters were days to 50% emergence, days to 50 % flowering, days to physiological maturity and plant height. Data collected for yield components and yield differ depending on the crops though there are common for all crops as the likes of crop stand count, Thousand grain weights (g), Grain yield (kg ha^{-1}), Aboveground dry biomass yield (kg ha^{-1}) and Harvest Index. The remaining which differs based on the crops was as follows:

Data collected for legumes were: number of pods per plant and number of seeds per pod, data collected for sorghum and pearl millet were: number of kernels per head, kernels weight per head and unthreshed panicle weight. Data collected for wheat were: number of tiller per plant, number of seeds per head, head/panicle length and data collected for buckwheat were: number of seeds per head, number of head per branches and number of branches per plant. These data were collected by taking randomly ten plants from the plots and the mean of these plants was taken for the plots.

2.5. Statistical Data Analysis

Analysis of variance for the design was carried out using Genstat 15th edition software for the parameters studied following the standard procedures outlined by Gomez and Gomez (1984). The level of significance used in 'F' and 't' test was P =0.05. When the treatment effects were found to be significant, the means were separated using the least significant difference at 5% level of probability.

3. Results and Discussion

3.1. Climatic Conditions

The data on rainfall during the period of experimental year (2015-16) and mean monthly values for the previous four years (2011-2014) as recorded at Fedis Agricultural Research Station are presented in Figure 1.

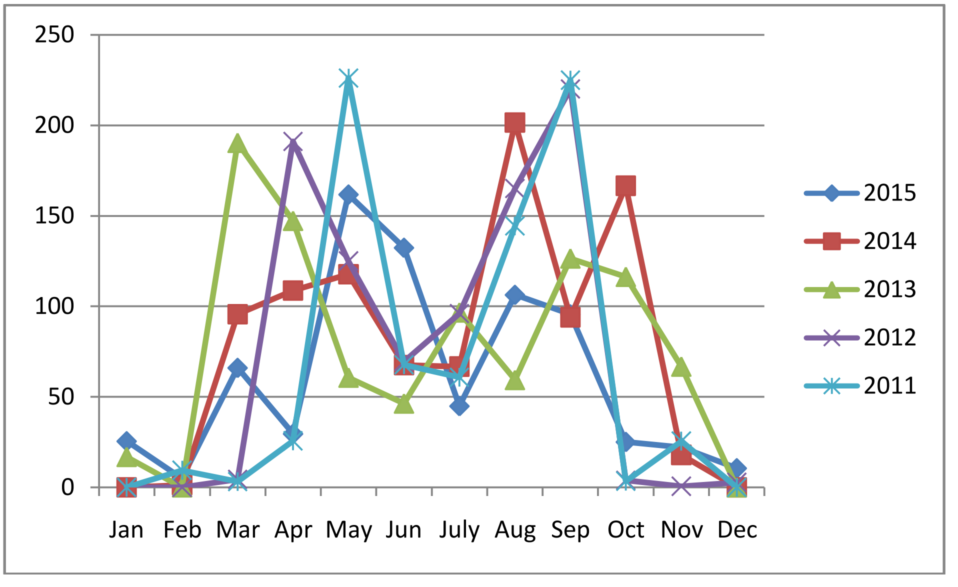

Figure 1. Monthly Rainfall Pattern of Fedis for the Last 5 Years in mm (2011-2015).

During 2015, a total rainfall of 724.5 mm was received, which was 158.625 mm less than the annual average of previous 4 years. During the period of experimentation on average 628.1 mm of rainfall was received, which was 96.4 mm less than the mean of previous four years. However, the period of rainfall during preceding and succeeding crop was 368.5 and 249 mm respectively while this rainfall was less compared to the last four years by 24.7 and 160.025 mm for preceding and succeeding crop respectively. This implies the impact of the rainfall during the experimentation period especially on succeeding crop sorghum. Crop experienced rainfall deficiency in the month of April (29.6 mm), August (106.3 mm), September (95.5mm) and October (25.1mm) compared to the average of last four years, but there was excess rainfall in months of May (161.7mm) and June (132.3mm).

3.2. Preceeding Crop

The objective was to select the best sequential combination for major crop sorghum and the characteristics that are required to be fulfilled is its earliness before time of planting for sorghum for *"kiremt"* from end of June up to mid July. Thus, the majorly considered data were early maturity and yield obtained as it is summarized in Table 1.

Table 1. Mean performance of preceding crops on days to 50% flowering, days to 50% maturity and yield during *"Belg"* season at Fedis and Mieso in 2015.

Treatment	Days to 50% flowering		Days to 50% maturity		YLD(Kg/ha)	
	Fedis	Mieso	Fedis	Mieso	Fedis	Mieso
Lablab	100.67a	100.00a	128.67a	150.0a	NH	NH
76T1#23	67.67b	60.00b	111.00b	106.0bc	BA(9)	433.
Cowpea	65.67b	46.67c	126.67a	107.0b	1647a	345.
Wheat	50.00c	NEAA	78.00f	NEAA	BA(9)	NEAA
Kola1	47.33cd	46.00c	107.7c	103.0d	BA(9)	31.
A/melka	42.33de	47.00c	107.7d	102.0d	1519ab	209.
N-26	38.33ef	33.67e	78.00f	77.0f	1213c	225.
Borada	38.00ef	43.33cd	80.00f	77.0f	1188c	382.
Batu	36.00f	39.33d	83.70e	81.7e	1375bc	197.
B/wheat	25.67g	25.00f	127.33a	105.0c	385d	53.
Local	VS	VS	VS	VS	VS	VS
Fallow	NCAA	NCAA	NCAA	NCAA	NCAA	NCAA
F test	**	**	**	**	**	ns
SE(±)	3.671	2.472	1.652	0.962	114.5	182.2
LSD (0.05)	6.298	4.279	2.834	1.666	208.2	319.1
CV (%)	7.2	5.0	1.6	1.0	9.4	77.7

NEAA= Not Emerged At All, NCAA= No Crop At All, VS= Vegetative Stage, NH= Not Harvested, BA= Bird Attack, LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation; ns= non-significant. Means in column followed by the same letters are not significantly different at 5% level of significance.

As indicated in Table 1, days to 50% flowering and days to 50% maturity were highly significant on both locations while yield has shown highly significant difference only at Fadis. Days to flowering, maturity and yield were not recorded for local variety on both locations and wheat on Mieso, since the local variety was on its vegetative growth stage and wheat didn't emerged at all in Mieso (Table 1).

Days to 50% flowering were earlier (25.67 days in Fedis and 25 Mieso) in buckwheat on both locations, even though, it stays long time before it starts to set seed and mature as it is apiary crop. It is well known that crop require and use high nutrient during flowering thus it is not hidden that buckwheat deplete more nutrients through the process and influence its succeeding crop that require same nutrient. This was seen clearly at Fedis during the succeeding crop sorghum's yield was lowest than the other sequences (Table 3). However, it will be clear after the soil analysis is completed which is currently on process. Other than the local variety which was at vegetative stage, lablab was also late on both locations in starting flowering followed by 76T1#23 and cowpea, while buckwheat was earliest followed by batu and borada on both locations.

As the time approach to *"Kiremt"* season for succeeding crop sorghum (Gubiye) the earliest which was ready to be harvested were mung bean varieties (N-26 and Borada) followed by haricot bean varieties (Batu and Awash melka) on both locations. Overall, Days to maturity were highly significant ($P<0.05$) at Fedis and Mieso during the study.

3.3. Succeeding Crop

During *"Kiremt"* season in July, succeeding crop sorghum variety Gubiye were sown on the plots from which preceding crops were harvested except the plot that occupied with local variety since it takes 7-8 months as it was included as farmers practice. Result of phenological and yield of succeeding crop Gubiye is summarized in Table 2 and 3 for Fedis. Yield was not collected at Mieso but biomass was measured due to drought.

As clearly illustrated in the Table 2, days to 50% emergence were highly significant at $p < (0.05)$ at Fedis on station during the growing season. Days to 50% emergence were earlier for the sequences of B/wheat-Gubiye, Cowpea-Gubiye and Lablab-Gubiye which takes 7.33 days which might be benefited from the remaining moisture in the soil due to the nature of dense canopy by their predecessor crops. Latest days to 50% emergency was local sorghum which took 10 days for the rest it was 8 days including the fallow. Fallow-Gubiye sequence is a practice that is adopted by all early maturing sorghum growers in the area. The same result of 8.22 days were obtained by (Tegene et.al; 2013) in the same place for Gubiye.

Table 2. Mean performance of succeeding crop sorghum on days to 50 % emergence and days to 50 % flowering during *"Kiremt"* season at Fedis 2015.

Treatment	Days to 50% emergence	Days to 50% flowering
Local	10.00^{a}	160.67^{a}
A/melka-Gubiye	8.00^{b}	64.33^{bcd}
Batu-Gubiye	8.00^{b}	63.33^{d}
Borada-Gubiye	8.00^{b}	64.67^{bcd}
Fallow-Gubiye	8.00^{b}	65.00^{bcd}
Kola1-Gubiye	8.00^{b}	65.67^{bcd}
N-26-Gubiye	8.00^{b}	63.33^{d}
Sorghum-Gubiye	8.00^{b}	67.67^{b}
Wheat-Gubiye	8.00^{b}	64.67^{bcd}
B/wheat-Gubiye	7.33^{c}	64.00^{cd}
Cowpea-Gubiye	7.33^{c}	66.00^{bcd}
Lablab-Gubiye	7.33^{c}	67.33^{bc}
F test	**	**
SE(±)	0.2887	2.135
LSD (0.05)	0.4888	3.615
CV (%)	3.6	2.9

LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation. Means in column followed by the same letters are not significantly different at 5% level of significance.

Days to 50% flowering were also highly significant at $p < (0.05)$ and it was not coincidence that this result was recorded because of nature of nutrient utilization of their predecessors was different in which legumes, forages and cereals were included. It was not strange that local sorghum were again late 160.67 days in reaching its 50% flowering. The earliest 50% flowering were recorded in the sequence of N-26-Gubiye and Batu-Gubiye with 63.33 days followed by B/wheat-Gubiye, A/melka-Gubiye, Wheat-Gubiye and Borada-Gubiye with 64, 64.33, 64.67 and 64.67 days respectively, as indicated in table 2. This result vary slightly from that of (Tegene et.al; 2013) which was 59 days in Fedis during 2012 growing season, this might be due to the fact that, this year climate stress which occurred at a country level has direct influence on growth, phenology, yield and yield related parameters.

Days to maturity were highly significant at $p < (0.05)$ however other than local sorghum there was no significant difference between the treatments where Gubiye was used as succeeding crop. This result varies slightly with that of Tegene *et.al,* 2013, which was 111 days for Gubiye. Yield of sorghum were also highly significant at $p < 0.05$ among treatments. Highest yield was obtained from local sorghum (3369 Kg/ha) followed by Batu-Gubiye sequence (2342 Kg/ha). Yield of Gubiye were very low compared to previous seasons and its yield potential as it was also reported by (Tegene *et.al*, 2013) it was about 3478 kg/ha during 2012 cropping season. The drop in yield of Gubiye might directly attribute to the change in climate that manifests itself mainly with decrease of rainfall and temperature increase during the experimentation period, which was also noticed throughout many parts of the country. The rainfall pattern during succeeding crop was 249 mm which was less by 160.025 mm compared to the last four years in the area (see Figure 1). Even this yield might not be obtained if mulching and moisture conservation practice of tie ridging had not been undertaken for the Gubiye. Such practices were used because of harsh and unpredictable climate change encountered during the season; Especially The Change In Rainfall Pattern Was Very High During The Succeeding Crop Time (See Figure 1).

Table 3. Mean performance of succeeding crop sorghum on days to maturity and yield during *"Kiremt"* season at Fedis 2015.

Treatment	Days to Maturity	YIELD(Kg/ha)
Local	221.0[a]	3369[a]
Batu-Gubiye	122.7[bc]	2342[b]
A/melka-Gubiye	122.3[c]	2107[b]
N-26-Gubiye	123.3[bc]	2094[b]
Wheat-Gubiye	124.3[bc]	2052[b]
Lablab-Gubiye	124.0[bc]	2049[b]
Kola1-Gubiye	122.3[c]	1961[bc]
Fallow-Gubiye	125.7[b]	1912[bc]
Borada-Gubiye	123.7[bc]	1826[bc]
Cowpea-Gubiye	122.3[c]	1753[bc]
Sorghum-Gubiye	125.0[bc]	1711[bc]
B/wheat-Gubiye	125.0[bc]	1196[c]
F test	**	**
SE(±)	1.850	460.7
LSD (0.05)	3.132	780.2
CV (%)	1.4	22.7

LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation. Means in column followed by the same letters are not significantly different at 5% level of significance.

4. Summary and Conclusion

The addition of legumes and forages could be a useful strategy for improving the overall farm productivity of sorghum cropping systems in east Hararghe , by delivering a sustainable input of N to soil and providing increased yields of this additional *"meher"* gap crop. As it stands mung bean, haricot bean and cow pea can fit in *"meher"* gap on both locations depending on farmers' preference.

Overall the result was promising and best sequence will be selected after the soil analysis, productivity and monetary value of the system is finalized. Generally, to reach up on good result for recommendation for such dynamic and risky situations the experiment must have to be repeated over years and locations since one year data is not sufficient.

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6. Effect of Iron Fertilization on Nodulation, Yield and Yield Related Traits of Different Maturity Groups of Soybean [*Glycine Max* (L.) Merrill] Varieties Inoculated with Bradyrhizobium at Shinille, Eastern Ethiopia

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Abstract

The availability iron (Fe) is the major constraint soybean cultivation in calcareous soils since it affects symbiotic association of the host plant and the endosymbiont, and eventually the yield of soybean. However, the effectiveness of integrated application of Bradyrhizobium and Fe fertilizer on nodulation, N2 fixation and yield of soybean genotypes has not been studied. Therefore, the objective of this study was to evaluate the effect Fe nutrient on nodulation, yield and yield related traits of Bradyrhizobium inoculated soybean genotypes of different maturity groups. Two experiments were conducted of which the pot experiment consisted of three late maturing (Wogayen, TGx-1336424 and Belsa) and three medium maturing (GIZA, Afgat and Gishame) soybean genotypes. The experiment was arranged in completely randomized design (CRD) with eight treatments that were applied on each genotype grown in pot. The treatments were synthesized by combining three Bradyrhizobium inoculations, with and without Fe fertilizer (0 and 4mg kg-1 soil), and N-treated (20 kg N ha-1) and the control. The Fe nutrient was applied through the foliage and directly to the soil. It was observed significant improvement in most the traits of medium maturing genotypes, but not in late maturing soybean genotypes. Based on the pot experiment result, two promising genotypes, namely GIZA and TGx-1336424, were selected for further field experiment. The field experiment was laid out as split plot in randomized complete block design (RCBD) with three replications where four levels of inoculation factorially combined with three levels of Fe-EDTA were tested. At field experiment, significant increase of nodule number (NN) and nodule dry weight (NDW) were observed due to the increased rates of Fe nutrient application in both genotypes. However, the application of Fe had differential effect on other traits of both genotypes. All traits of TGx-1336424 except NN, NDW and shoot dry matter (SDW) did not improve significantly by Fe application. In contrast, number of pods per plant (NPP), total biomass yield (TBY), grain yield (GY) and plant total nitrogen concentration (PTC) of GIZA genotype were significant improved by the increasing rates of Fe nutrient. The regression analysis indicates different degree of dependence of TBY, NDW, NN and GY of both genotypes with increasing rates of Fe application with different Bradyrhizobium sp. inoculation. Hence, it can be concluded that the effect of Fe application is dependent on maturity groups of soybean genotypes and effectiveness of inoculated Bradyrhizobium sp.

Keywords: Bradyrhizobium sp.; Fe-EDTA; Genotype; Glycine max; Iron; Maturity group

1. Introduction

About six percent of the world's land of agricultural soils in the world are not suitable for crop production due to some kind of salinity (Flowers and Yeo, 1995). Leguminous crop cultivation in the saline soils of semi-arid climates is increasingly advocated as a strategy to amend soil fertility that prevent serious nitrogen (N) deficits and sustaining agricultural production. An essential source of N input into the soil is the biologically-fixed N_2, which is used directly by the plant, and so is less susceptible to volatilization, denitrification, and leaching (Graham, 2008). About 80% of this biologically-fixed N_2 comes from symbiosis involving leguminous plants and various rhizobial species. Of which, soybean [*Glycine max* (L.) Merr.] plays an important role in cycling of agricultural nitrogen (N) by facilitating biological fixation of atmospheric N_2 into plant-available N in the symbiotic process with *Bradyrhizobium* spp. The N_2 fixation potential of soybean varied from 0 to 185 kg N ha^{-1} with an average value of about 84 kg N ha^{-1} (Russelle and Birr, 2004). However, soil stresses, such as soil salinity, can adversely affect N_2 fixation by influencing both the host plant and the symbiotic bacteria (Rai, 1987).

Iron (Fe) deficiency, which results in chlorosis in crops, is a widespread problem in arid and semi-arid regions of the world (Papastylianou, 1990; Rashid and Din, 1992) in soils with a range of pH 7.5 and 8.5 (Guerinot and Yi, 1994; Mengel *et al.,* 2001). This soil pH range often reduces Fe availability below the sufficient threshold level that meets plant needs. Fe is an essential micro-nutrient required by both legumes and root nodulating-bacteria, which is an essential component of nitrogenase, leghaemoglobin and ferredoxins (Evans and Russell, 1971). Deficiency of Fe may affect N_2-fixation by restricting the host plant growth and/or active functioning of *Rhizobium* spp. alone (Andrew, 1962; Rai *et a1*., 1984). Fe deficiency also primarily affects the structure and functioning of the chloroplast (Tognini *et al.,* 1996; Soldatini *et al.,* 2000; Morales *et al.,* 2001) which in turn reduces photosynthesis and carbohydrate synthesis (Miller *et al.,* 1984; Terry and Abadia, 1986; Bienfait, 1989). Consequently, it may restrict N_2-fixation by limiting the host plant growth and the active functioning of the *Rhizobium* spp. (Andrew, 1962; Rai *et al.,* 1984).

Several reports indicate that different soybean genotypes have different degrees of Fe chlorosis (Byron and Lambert, 1983; Halvis *et al.,* 1999). Al-Showk *et al.* (1986). Hartzook (1984) also found that groundnut genotypes displayed different levels of sensitivity to Fe deficiency. This study also indicated that Fe absorption efficient genotypes had equally yielded to other Fe chelate treated genotypes. Rai *et al.* (1984) suggested that genetic make-up of genotypes might be responsible for variation of Fe absorption and transport capacity among lentil genotypes.

It has been found that Fe-EDTA (Ethylenediaminetetraacetic acid) application directly to soils suppressed nodulation in pea plants, mainly due to the effect of the chelate on the formation of lateral roots and the initial processes of nodulation (Lie and Brotonegoro, 1969; Lie and Egerrat, 1988). The hypothesis of the present research was that late maturing genotypes require more nitrogen than medium maturing soybean genotypes. This may results better improvement of nodulation, N_2 fixation and yield of late maturing genotypes by Fe-EDTA application than that of medium maturing genotypes in moderately Fe deficient soils. Therefore, the overall objective of the study was to evaluate the effect of Fe application on nodulation, yield and N_2 fixation of *Bradyrhizobium* spp. inoculated soybean genotypes of different maturity groups.

2. Materials and Methods

2.1. Description of Experimental Site

The field experiment was conducted in 2012 at Shinille Agricultural Demonstration site, Somali region, Ethiopia, which is semi-arid in nature. The experimental field is located at 09°41' N latitude and 41°51' E longitude with an elevation of 1079 m.a.s.l. The soil is dominated by sandy-clay and increases amount of clay further down to lower depth. The site has been used for maize (*Zea mays* L.) and tomato production prior to the experiment. The experimental field did not have a history of inoculation of *Bradyrhizobium* strains and fertilizer application for soybean cultivation.

Rhizobial population sizes were estimated with the most probable number (MPN) method (Vincent, 1970) within 2 weeks of sampling, using a base dilution of 10 and the soybean variety Solitaire as the trap host. Then, no rhizobia were detected by a plant infection technique (Brockwell, 1963) at sowing time. The soil physical and chemical properties and the rhizobial population nodulating soybean is presented in Table 1.

Table 1. pre-sowing soil chemical and physical properties of the experimental site at Shinile.

Soil properties	Shinile soil
pH in H_2O	7.74
EC (mS/cm)	4.12
Organic carbon (%)	2.15
Total nitrogen (%)	0.29
Available P (mg kg^{-1})	25.85
Ca (cmol(+) kg^{-1})	31.10
Mg (cmol(+) kg^{-1})	3.22
Na (cmol(+) kg^{-1})	0.14
K (cmol(+) kg^{-1})	2.22
CEC (cmol(+) kg^{-1})	25.90
Zn (mg kg^{-1})	1.19
Fe (mg kg^{-1})	2.2
B (mg kg^{-1})	0.86
NH_4-N (mg kg^{-1})	26.22
NO_3-N (mg kg^{-1})	23
Clay (g kg^{-1})	27
Silt (g kg^{-1})	50
Sand (g kg^{-1})	23
Textural class	Loam
Number of *Bradyrhizobium* nodulating soybean	None

2.2. Sources of Soybean Seeds and Inocula

The soybean varieties were obtained from Pawe Agricutural Research Center. The three Rhizobial strains were used as inoculants of which *Bradyrhizobium* sp. (UK-Isolate) obtained from Holleta Agricultural Research Center, *Bradyrhizobium japonicum* (TAL-379) and *Bradyrhizobium* sp. (Local isolate) were obtained from National Soil Research Center, Addis Ababa. The local strain had been previously tested for its infectivity under controlled environment in the National Soil Research Center (data not shown).

Sterile fine filter-mud with adjusted pH of 6.7 was used as a carrier. The *Bradyrhizobium* spp. were separately incubated in yeast-extract mannitol (YEM) broth at 30 ^{0}C for 7 days until the number reached 10^9 cells ml^{-1} for inoculant preparation. About 400 ml of *Bradyrhizobium* sp. culture liquid medium was added to one kg. of carrier and mixed thoroughly and packed in plastic bags. Then after, filter-mud-base inoculum was incubated at 26–28 ^{0}C for 15 days.

2.3. Pot Experiment

A plant growth medium containing soil from Shinille agricultural experimental site was prepared based on the absence of indigenous soybean-nodulating *Bradyrhizobium* to facilitate the visual identification of N-deficiency symptoms in plants nodulated by the specific strain. Saline soil, collected (0-20 cm depth) from an area where the field experiment was conducted, was used for the pot experiment. Zero and four mg. Fe kg^{-1} of soil was used in the form of $FeSO_4$ and applied directly to the soil before planting as described by Moosavi and Ronaghi (2011). Nitrogen (i.e. 20 kg ha^{-1}) in the form of urea was applied for N treated pots. Six soybean genotypes, three of which were late maturing (Wogayen, TGx-1336424 and Belsa) and the remaining three (GIZA, Afgat and Gishame) were medium maturing, were inoculated.

The pot experiment was conducted in the semi-controlled greenhouse at Haramaya University, eastern Ethiopia, in 2012. Eight treatments which was synthesized by combining three inoculations factorially with and without Fe fertilizer (0 and 4mg kg^{-1} soil), including N-treated (20 kg N ha^{-1}) and the uninoculated and unfertilized control, were arranged in a completely randomized design (CRD). Seeds were surface-sterilized with ethanol (for 1 min) and sodium hypochlorite (soaked for 5 min) and then washed several times with deionized water and five seeds were sown per pot. The seedlings were thinned to three plants per pot one week after emergence. Pots were regularly watered to 70% water-holding capacity (WHC), avoiding water logging. Rhizobia were cultured to exponential phase in YEM broth, and then 1 ml of culture containing 1 x 10^8 rhizobial cells per milliliter was injected to 7-day-old seedlings using pipettes. At harvesting, when the seedling reached late flowering and early pod setting stages, the seedling were removed from the pots, the roots were thoroughly rinsed with water, blotted dry on filter paper, and nodules were picked and counted. The total plant and nodule dry weights were recorded after oven drying at 70 ^{0}C for 48 hrs.

2.4. Field Experiment

The field experiment was conducted at the experimental farm of Shinille Agricultural Demonstration site in 2012 using well-structured drip irrigation system. The land was prepared by deep ploughing, harrowing and levelling. Then the area was ridged and divided into three metre by three metre plot. The main plot treatments consisted of four levels of inoculants: UK Strain, TAL-379, Local Strain and un-inoculated plot factorially combined with three levels of iron fertilizer (Fe-EDTA) (0, 1, and 2% of Fe). The rate of Fe application was adapted from Moosavi and Ronaghi (2011) and supplied through foliage after three week of sowing. The subplot treatments included two soybean genotypes (Giza and TGx-1336424). The treatments were laid out as split plot in a randomized complete block design (RCBD) with three replications. Each soybean cultivar was planted in spacing of 75cm between rows, 10 cm between plants, 2 m between main plots and 1.5 m between subplots.

Before planting, 20 g of the different *Bradyrhizobium* inoculants were added to different polyethylene bags containing 200 g of soybean seeds. Sugar solution (48%) was added to each bag to enhance proper mixing and adhesion of the *Bradyrhizobium* carrier material on seed coat. Two seeds were sown per hill and then thinned to one seedling per hill. Plots were immediately irrigated after sowing to ensure uniform germination. Subsequently, plots were irrigated by a drip irrigation system at a 7-day interval. Weeds were controlled by hand hoeing over the growth period. A set of five plants from the central three were randomly uprooted at late flowering and early pod setting stage for estimating the nodulation potential (number of nodules per plant and dry weight of nodules) and shoot characteristics (shoot height and shoot dry weight). Dried shoot parts were ground and analyzed for total N using the Kjeldahl digestion method.

At physiological maturity stage, plants were harvested from a central 3 m x 2.25 m net plot (three rows) leaving two guard rows. The plant tops (stalks plus pods) were weighed to determine total dry matter yield before threshing and winnowing to separate the grain and determine the yield. Leaves were not included in the total dry matter yield determinations, as they had already fallen to the ground. Moisture was corrected to 11% when determining grain yield.

2.6. Statistical Data Analysis

Each sample was analyzed in triplicate and the figures were then averaged. Analysis of variance (ANOVA) was conducted using the SAS computer software package. The least significant difference (LSD) was used to separate treatment means at $P < 0.05$ probability level.

3. Results

3.1. Pot experiment

The average nodule number (NN) and nodule dry weight (NDW) were significantly ($P < 0.05$) affected by treatments (T), genotype (G) and T x G interaction (Table 2 and 3). Iron applied in the form of $FeSO_4$ in soil had a significant effect on NN, NDW and shoot dry weight (SDW) for both groups of soybean genotypes. Fe application significantly improved the NN as compared to unfertilized treatment for GIZA and Gishame genotypes. These genotypes revealed significant response in NN for Fe application with both *Bradyrhizobium* inoculations. Fe application integrated with UK-isolate inoculation resulted in significantly higher in NN with Wogayen genotype than UK-isolate inoculated alone. However, the result revealed the non-significant improvement of the average NN due to Fe application as compared to unfertilized plants.

Table 2. Nodule number of soybean genotypes inoculated with exotic and native *Bradyrhizobium* isolates integrated with iron application.

Treatment	Nodule number						
	GIZA	Afgat	Wogayen	TGx-1336424	Gishame	Belsa	Average
Negative control	0.00e	0.00b	0.00e	0.00c	0.00c	0.00c	0.00c
Positive control	0.00e	0.00b	0.00e	0.00c	0.00c	0.00c	0.00c
UK-Isolate	36.33cd	35.00a	48.67b	63.33ab	41.00b	53.33a	46.28a
UK-Isolate + Fe	54.67ab	45.00a	59.67a	44.67ab	43.67b	38.33ab	47.67a
TAL-379	20.00d	10.00b	9.67de	6.67c	9.33c	9.00c	10.78b
TAL-379 + Fe	26.00cd	10.67b	11.67d	7.33c	10.67c	7.33c	12.28b
Local Isolate	38.67bc	40.67a	36.67c	67.33a	39.00b	29.33b	41.94a
Local Isolate + Fe	56.67a	33.33a	32.67c	39.67b	64.67a	39.00ab	44.33a
LSD (0.05)	17.72	12.04	10.86	24.56	15.72	16.40	6.14
CV (%)	21.58	19.50	15.44	30.35	21.35	26.32	23.41
F- value:							
Treatment(T)	36.47^{***}	57.11^{***}	105.17^{***}	32.11^{***}	56.36^{***}	37.47^{***}	235.53^{***}
Genotype(G)							6.56^{***}
T x G							6.31^{***}

****very highly significant at 0.001; Fe- FeSO$_4$; Negative control- neither inoculated nor fertilized; Positive control- Urea treated*

Notes: Means in the same column followed by the same letter are not significantly different at the 5% probability level by Tukey's test

Table 3. Nodule dry weight of soybean genotypes inoculated with exotic and native *Bradyrhizobium* isolates and integrated with iron application.

Treatment	Nodule dry weight						
	GIZA	Afgat	Wogayen	TGx-1336424	Gishame	Belsa	Average
Negative control	0.0000c	0.0000d	0.0000d	0.0000b	0.0000d	0.0000c	0.0000d
Positive control	0.0000c	0.0000d	0.0000d	0.0000b	0.0000d	0.0000c	0.0000d
UK-Isolate	0.2600b	0.2743b	0.3470b	0.4523a	0.4523b	0.3613a	0.3274b
UK-Isolate + Fe	0.6367a	0.3897a	0.4277a	0.3840a	0.3840a	0.3637a	0.4357a
TAL-379	0.4390ab	0.1187c	0.0833c	0.0567b	0.0567c	0.0927c	0.1551c
TAL-379 + Fe	0.3450b	0.0970c	0.1393c	0.0563b	0.0563c	0.0797c	0.1406c
Local Isolate	0.2923b	0.3123ab	0.2833b	0.4467a	0.4467a	0.2260b	0.3207b
Local Isolate + Fe	0.4167ab	0.2433b	0.3130b	0.3883a	0.3883ab	0.2923ab	0.3321b
LSD (0.05)	0.2248	0.0872	0.0796	0.0923	0.0880	0.1019	0.0450
CV (%)	26.62	17.19	14.13	14.64	15.10	20.37	20.38
F- value:							
Treatment(T)	22.36^{***}	67.54^{***}	102.97^{***}	124.83^{***}	81.59^{***}	54.00^{***}	254.06^{***}
Genotype(G)							25.51^{***}
T x G							9.14^{***}

****very highly significant at 0.001; Fe- FeSO$_4$; Negative control- neither inoculated nor fertilized; Positive control- Urea treated.*

Notes: Means in the same column followed by the same letter are not significantly different at the 5% probability level by Tukey's test.

The maximum NN (67.33) was obtained from TGx-1336424 genotype inoculated with local isolate alone. The same genotype also gave the lowest NN (6.67) when inoculated TAL -379 isolate alone. Beside this, a remarkable improvement in NN was obtained in all tested medium maturing soybean genotypes. Of the tested late maturing genotypes, only Wogayen genotype revealed a significant improvement in NN by Fe application integrated with *Bradyrhizobium* inoculation compared to the separate respective inoculation treatments.

There was also a significant improvement in NDW, including the average NDW, in medium maturing soybean genotypes and Wogayen genotype from the tested late maturing genotypes due to Fe application integrated with UK-isolate inoculation as compared to the inoculation alone (Table 6). The highest (0.6367 g) NDW was obtained from GIZA genotype due to UK-isolate inoculation integrated with Fe application. Dual application of TAL-379 and Fe in TGx-1336424 and Gishame soybean genotypes produced the lowest (0.0563 g) NDW. The data also indicated that NDW reduced due to TAL-379 inoculated with Fe application as compared to the TAL-379 inoculation alone in all genotypes except Wogayen genotype.

A significant variation in shoot dry weight (SDW) due to the treatments for all investigated soybean genotypes, except GIZA genotype, was observed at P <0.05 (Table 4). Iron applied with *Bradyrhizobium* inoculation did not significantly improve the SDW as compared to inoculation alone. Generally, the result revealed that UK-isolate and local isolate inoculation resulted in significantly higher SDW in all genotypes, except GIZA genotype, than the control treatment. The highest (9.933 g) SDW was obtained from Wogayen genotype when inoculated UK-isolate, followed by 9.800 g in the same genotype fertilized inorganic N.

Table 4. Shoot dry weight of soybean genotypes inoculated with exotic and native *Bradyrhizobium* isolates integrated with iron application.

Treatment	Shoot dry weight						
	GIZA	Afgat	Wogayen	TGx-1336424	Gishame	Belsa	Average
Negative control	6.367a	4.633b	7.100cd	6.467abc	5.900c	5.367b	5.972d
Positive control	8.600a	8.201a	9.800a	7.900abc	6.467abc	8.367a	8.222ab
UK-Isolate	7.833a	8.233a	9.933a	8.500abc	9.133a	7.667a	8.550a
UK-Isolate + Fe	9.300a	9.033a	8.767abc	7.033bc	8.767ab	8.033a	8.489a
TAL-379	8.767a	7.533a	6.500d	6.033c	6.833abc	7.167ab	7.139c
TAL-379 + Fe	9.300a	6.867ab	8.000bcd	5.533a	6.733abc	7.500a	7.322c
Local Isolate	8.367a	7.533a	9.600ab	9.300ab	6.300bc	8.100a	8.233ab
Local Isolate + Fe	9.533a	7.967a	8.733abc	8.800	8.133abc	8.400a	8.594a
LSD (0.05)	3.9102	2.469	1.728	3.200	2.735	1.963	1.011
CV (%)	16.26	11.61	7.15	15.20	13.29	9.17	12.52
F- value:							
Treatment(T)	1.67^{ns}	6.89^{**}	12.92^{***}	4.47^{**}	4.76^{**}	6.09^{**}	16.20^{***}
Genotype(G)							7.95^{**}
T x G							2.27^{**}

*NS- non significant; **highly significant at 0.01; ***very highly significant at 0.001; Fe- $FeSO_4$; Negative control- neither inoculated nor fertilized; Positive control- Urea treated. Notes: Means in the same column followed by the same letter are not significantly different at the 5% probability level by Tukey's test.*

3.2. Field Experiment

3.2.1. Nodulation

The effects of iron (Fe) and inoculation (I) significantly (P <0.05) affected the NN of both investigated genotypes (Table 5). However, the data indicated non-significant interaction effect of I x Fe on NN of both genotypes. Iron applied at 2% significantly increased NN including its average value for both genotypes. The highest NN (38.67 and 36.83) were scored by TGx-1336424 and GIZA genotypes, respectively, when inoculated local isolate. The unfertilized control produced the lowest NN (25.33 and 29.25) for GIZA and TGx-1336424 genotypes, respectively. Inoculation of TAL-379 performed poorly with regards to improvement of number of nodules per plant, including the average value, in both genotypes.

It was noted that NN of both genotypes had a significant quadratic association trend with increasing rates of Fe (graph not indicated). The coefficient of determination was higher for TGx-1336424 genotype ($Y=1.222x^2 + 5.222x + 33.77$, $R^2=0.278$) than GIZA genotype ($Y=1.166x^2 + 3.944x + 39$, $R^2=0.188$). However, the NN produced in each inoculation treatments had a significant linear association with increasing rates of Fe (Figure 1a and b). The coefficients of determination for GIZA genotype inoculated TAL-379 ($R^2=0.611$) and UK-Isolate ($R^2=0.715$) were higher than that for TGx-1336424 inoculated those respective isolate. The UK-isolate inoculation in TGx-1336424 genotype indicated higher coefficient of determination ($R^2=0.675$) than the coefficient (0.491) of GIZA genotype inoculated the same isolate. The highest coefficient of determination in GIZA genotype was $R^2=0.715$, which was obtained by inoculation of local isolate, while NN of TGx-1336424 genotype showed the highest coefficient of determination ($R^2=0.675$) when inoculated UK-isolate.

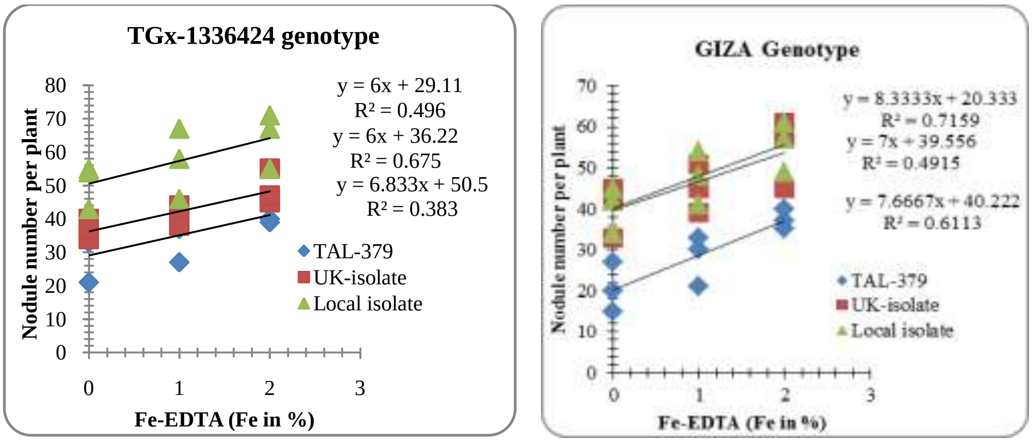

Figure 1. Regression analysis between nodule number and rate of Fe application in a) TGx-1336644, and b) GIZA genotype of soybean under field condition.

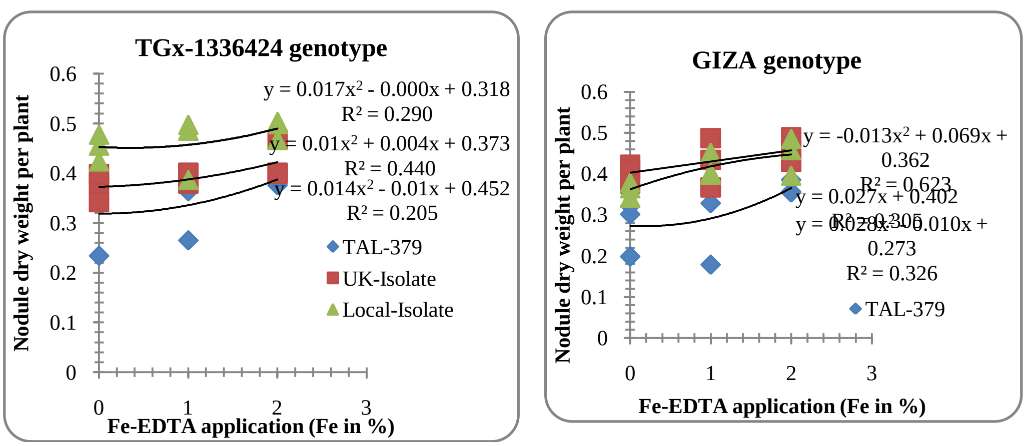

Figure 2. Regression analysis between nodule dry weight and rate of Fe application in a) TGx-1336424, and b) GIZA genotype of soybean under field condition.

The result of this current experiment revealed that Fe application and inoculation alone had significant effect on NDW at $P < 0.05$ (Table 5). Highest rate of Fe (2% Fe) resulted in significantly higher NDW than the unfertilized control. However, the NDW induced at 1 and 2% Fe application showed the non-significant difference for both soybean genotypes. The NDW for TGx-1336424 and GIZA genotypes varied from 0.2861 to 0.3250 g and from 0.2596 to 0.3173 g, respectively. Iron applied at 2% Fe increased the NDW by 13.6 and 22.2% over the unfertilized control for TGx-1336424 and GIZA genotypes, respectively. On top of this, TGx-1336424 inoculated local isolate and GIZA genotype inoculated UK-isolate produced significantly higher NDW than any of other treatments, which induced 0.4666 and 0.4300 g, respectively.

Nodule dry weight of GIZA genotype had a significant quadratic association with Fe rates of application. However, this association for TGx-1336424 genotype was non-significant (graph not indicated). Beside this, NDW produced by both soybean genotypes due to different *Bradyrhizobium* sp. inoculation had a significant ($P < 0.05$) and quadratic association with Fe rates of application, except GIZA genotype inoculated TAL-379, whose association was found to be linear (Figure 2a and b). The highest coefficient of determination was recorded in all inoculated treatments for GIZA as compared to TGx-1336424 genotype inoculated the same isolate. The maximum (R^2=0.623) coefficient of determination was obtained from GIZA genotype inoculated UK-isolate, followed by the coefficient of determination (R^2=0.440) in TGx-1336424 genotype inoculated UK-isolate.

Table 5. Nodulation and shoot dry matter at late flowering and early pod setting stage of two soybean genotypes (TGx-1336424 and GIZA) across different rates of iron and inoculation of exotic and native *Bradyrhizobium* isolates.

Treatment	Nodule Number			Nodule dry weight (g)			Shoot biomass (g)		
	TGx-1336424	GIZA	Average	TGx-1336424	GIZA	Average	TGx-1336424	GIZA	Average
Fe-rate									
F_1	29.25b	25.33b	27.29c	0.2861b	0.2596b	0.2728b	56.74b	56.56a	56.65a
F_2	33.08ab	30.17b	31.63b	0.2951ab	0.2845ab	0.2898b	61.27ab	54.97a	58.12a
F_3	38.67a	36.83a	37.75a	0.3250a	0.3173a	0.3212a	66.81a	48.40b	57.60a
LSD (0.05)	5.74	5.43	3.82	0.0381	0.0447	0.0285	5.90	6.07	4.10
Inoculation									
TAL-379	35.11b	28.67b	31.89c	0.3473b	0.3098b	0.3286b	69.20a	61.42a	65.31a
UK-Isolate	42.22b	46.56a	44.39b	0.3943b	0.4300a	0.4122a	74.41a	50.99b	62.70a
Local isolate	57.33a	47.89a	52.61a	0.4666a	0.4088a	0.4377a	59.79b	48.17b	53.98b
Control	0.00c	0.00c	0.00d	0.0000c	0.0000c	0.0000c	43.02c	52.66b	47.84c
Mean	33.67	30.78	33.22	0.3021	0.2871	0.2946	61.61	53.31	57.46
LSD (0.05)	7.32	6.93	4.86	0.0486	0.0570	0.0362	7.52	7.75	5.21
CV(%)	16.70	17.3	17.0	12.38	15.3	13.83	9.39	11.2	10.22
F-value									
Iron (Fe)	8.50**	14.11***	22.08***	3.56*	5.24*	8.69***	9.12**	6.32**	0.39ns
Inoculation (I)	167.57***	157.98***	320.28***	276.37***	184.37***	441.58***	51.16***	8.29**	33.73***
I x Fe	0.98ns	1.62ns	2.52*	0.49ns	0.84ns	1.20ns	5.88***	3.08*	3.99**

*NS- non significant; * significant at 0.05; **highly significant at 0.01; ***very highly significant at 0.001; F_1- no Fe fertilized; F_2- 1% Fe application ; F_3- 2% Fe application; Notes. Means in the same column followed by the same letter are not significantly different at the 5% probability level by Tukey's test*

3.3. Shoot Dry Weight and Length at Late Flowering and Early Pod Setting Stage

The present finding indicated that *Bradyrhizobium* inoculation (I), Fe rates of application (Fe) and I x Fe interaction had significant (P <0.05) effect on shoot dry weight (SDW) (Table 5). Iron application at 2% significantly increased the SDW in TGx-1336424 genotype as compared to the control. Generally, Fe application in GIZA genotype did not affect significantly the SDW; instead significant reduction of SDW occurred at 2% Fe application as compared to the control. The SDW varied from 48.40 to 56.56 g for GIZA genotype and from 56.74 to 66.81 g for TGx-1336424 genotype. Iron applied at 2% resulted in 17.7% increase in SDW in TGx-1336424 genotype over unfertilized control. While the reduction in SDW for GIZA genotype was estimated at 15.1% as compared to the control. On top of this, the average SDW was significantly increased due to Fe application. Moreover, all *Bradyrhizobium* inoculations significantly enhanced SDW, including the average SDW, in both genotypes. Significantly higher SDW including average SB due to TAL-379 and UK-isolate inoculation over the other treatment in the TGx-1336424 genotype and the was recorded. In GIZA genotype, TAL-379 gave significantly higher SDW than the other treatments.

Iron and I x Fe interaction did not affect significantly (p≤0.05) the shoot height (SH)(Table 6). However, increasing rates of Fe application increased SH of both tested genotypes of soybean. The lowest SH (65.25 cm) for TGx-1336424 genotype was obtained from unfertilized control, while GIZA genotype scored the lowest SH (61.0 cm) at 1% Fe fertilized plants. TAL-379 and UK-isolates inoculation onto TGx-1336424 genotype significantly increased SH than in the uninoculated treatment. The research finding also showed significantly higher SH of GIZA genotype when inoculated TAL-379 isolate than the inoculated treatment. Generally, *Bradyrhizobium* inoculation increased the SH of TGx-1336424 and GIZA genotypes by 19.2 and 11.5%, respectively, over the uninoculated control.

3.4. Number of Pods Per Plant and Number of Seeds Per pod

Iron (Fe), inoculation (I) with *Bradyrhizobium* isolates and I x Fe interaction had significant (P <0.05) effect on number of pods per plant (NPP) of GIZA genotype (Table 6). Only inoculation treatments displayed significant variation in the NPP for TGx-1336424 genotype. Iron application at two percent concentration resulted in significantly higher NPP than that of the unfertilized control in GIZA genotype. Though Fe application did not affect significantly the NPP of TGx-1336424 genotype, the highest NPP was recorded at 2% Fe application. The lowest NPP obtained from TGx-1336424 and GIZA genotypes were 131 and 137, respectively, when treated 1% Fe fertilizer. Significant variation in the NPP was also observed among different inoculation treatments. Inoculations with all *Bradyrhizobium* isolates resulted in significantly higher NPP and its average value for TGx-1336424 than the uninoculated control. However, only TAL-379 inoculation significantly increased the NPP of GIZA genotype.

Table 6. Plant height at late flowering and early pod setting stage, number of pods per plant and number of seeds per pod of two soybean genotypes (TGx-1336424 and GIZA) across different rates of iron and inoculation with exotic and native *Bradyrhizobium* isolates.

Treatment	Plant height at flowering (cm)			Number of pods per plant			Number of seeds per pod		
	TGx-1336424	GIZA	Average	TGx-1336424	GIZA	Average	TGx-1336424	GIZA	Average
Fe-rate									
F_1	66.50a	61.00a	63.75a	138.8a	138.9b	138.9ab	2.4108a	2.5792a	2.4950a
F_2	65.25a	61.67a	63.46a	131.0a	137.4b	137.4b	2.5225a	2.6292a	2.5758a
F_3	68.25a	67.25a	67.75a	139.1a	147.7a	147.7a	2.4142a	2.6075a	2.5108a
LSD (0.05)	6.24	8.411	5.07	15.2	9.5	9.5	0.2106	0.2428	0.1556
Inoculation									
TAL-379	70.67a	71.33a	71.00a	134.7a	176.1a	155.4a	2.6256a	2.7000a	2.6628a
UK-Isolate	73.00a	61.00ab	67.00ab	145.9a	153.3b	149.6a	2.6244a	2.6622ab	2.6433a
Local isolate	61.78b	56.89b	62.61bc	149.8a	153.0b	151.4a	2.3667ab	2.6922a	2.5294a
Control	61.22b	64.00ab	59.33c	115.0b	102.9c	108.9b	2.1800b	2.3667b	2.2733b
Mean	66.67	63.51	64.99	136.3	146.3	141.3	2.4492	2.6054	2.5272
LSD (0.05)	7.96	10.73	6.44	19.4	15.9	12.1	0.2686	0.3096	0.1977
CV(%)	9.18	13.03	11.17	10.92	8.34	9.634	8.43	9.1394	8.819
F-value									
Iron (Fe)	0.73ns	2.08ns	2.62ns	1.14ns	6.84**	4.02*	1.14ns	0.13ns	0.89ns
Inoculation (I)	8.79***	4.91**	8.85***	9.88***	57.78***	45.89***	9.92***	4.06*	11.63***
I x Fe	2.15ns	0.87ns	1.25ns	0.85ns	4.29**	1.67ns	2.01ns	1.44ns	1.68ns

*NS- non significant; * significant at 0.05; **highly significant at 0.01; ***very highly significant at 0.001; F_1- no Fe fertilized; F_2- 1% Fe application ; F_3- 2% Fe application; Notes. Means in the same column followed by the same letter are not significantly different at the 5% probability level by Tukey's test*

The research data indicated the significant (P <0.05) effect of Fe and I x Fe interaction on number of seeds per pod (NSP) (Table 6). Slight improvement of NSP was recorded at 1% Fe application in both genotypes. On top of this, significant variation in NSP due to *Bradyrhizobium* inoculation as compared to uninoculated treatment was observed. TAL-379 inoculation significantly increased NSP in both genotypes over the uninoculated control. The non-significant difference in the NSP among the inoculation treatments. The NSP varied from 2.1800 to 2.6256 and from 2.3667 to 2.7000 for TGx-1336424 and GIZA genotypes, respectively. Generally, *Bradyrhizobium* inoculation improved the NSP up to 20.4 and 14.1% over uninoculated control, for TGx-1336424 and GIZA genotypes respectively.

3.5. Total Biomass Yield

The current research result showed that I x Fe interaction had a significant (P <0.05) effect on total biomass yield (TBY) for both soybean genotypes (Table 7). However, the effect of Fe rates of application on TBY in TGx-1336424 genotype was non-significant. The TBY of this genotype was decreased when increased the Fe rates from 1 to 2%, though 4% slight increase in TBY due to 1% Fe application as compared to the unfertilized plants. The highest (7816.4 kg ha^{-1}) TBY for TGx-1336424 genotype was obtained at one percent Fe application. However, in GIZA genotypes, increase in Fe rates of application resulted in significant improvement of TBY. The highest TBY (7106.5 kg ha^{-1}) for GIZA genotype was obtained from 2% Fe application, which was improved by 18.4% compared to unfertilized control. The non-significant variation of TBY in GIZA genotype was exhibited due to one and two percent Fe applications.

Inoculating local and UK-isolates on TGx-1336424 genotype resulted in a significant increase in TBY over the control. In GIZA genotype, only TAL-379 inoculation produced significantly higher TBY than that of the other inoculation treatments. However, the data revealed the non-significant variation in the average TBY among the inoculation treatments. The highest TBY (9207.8 Kg ha^{-1}) of TGx-1336424 genotype was obtained from UK-isolate inoculation with an average TBY of 7595.2 kg ha^{-1}. Similarly, the highest TBY (8374 kg ha^{-1}) from GIZA genotype was obtained from TAL-379 inoculation with an average TBY of 6687.2 kg ha^{-1}.

Table 7. Total biomass and grain yield and total plant tissue nitrogen of two soybean genotypes (TGx-1336424 and GIZA) across different rates of iron and inoculation with exotic and native *Bradyrhizobium* isolates

Treatment	Total biomass yield (Kg/ha)			Grain yield (Kg/ha)			Total plant tissue nitrogen (%)		
	TGx-1336424	GIZA	Average	TGx-1336424	GIZA	Average	TGx-1336424	GIZA	Average
Fe-rate									
F_1	7500.0a	6003.1b	6751.5b	2226.11a	1961.31b	2071.21b	4.0792a	3.8383b	3.9588a
F_2	7816.4a	6952.2a	7384.3a	2290.76a	1973.09b	2131.92ab	4.0442a	3.8525b	3.9483a
F_3	7469.1a	7106.5a	7287.8a	2247.45a	2196.60a	2222.03a	3.9175a	4.2050a	4.0613a
LSD (0.05)	735.4	744.63	506.78	124.01	153.07	95.39	0.1772	0.1568	0.1146
Inoculation									
TAL-379	6604.9b	8374.5a	7489.7a	2259.14b	1503.89c	1881.51c	4.0267a	4.0311b	4.0289a
UK-Isolate	9207.8a	6913.6b	8060.7a	2518.40a	2205.90a	2766.40a	4.0711a	4.2444a	4.1578a
Local isolate	9032.9a	6049.4bc	7541.2a	2519.18a	2277.33a	2398.25b	4.0544a	4.0200b	4.0372a
Control	5535.0c	5411.5c	5473.3b	1722.39c	1319.05b	1520.72d	3.9022a	3.5656c	3.7339b
Mean	7595.2	6687.2	7141.2	2254.77	1826.53	2141.72	4.0136	3.9653	3.9894
LSD (0.05)	938.1	949.8	644.0	158.17	174.32	121.21	0.2261	0.2	0.1456
CV(%)	9.50	10.92	10.61	5.39	7.40	6.38	4.33	3.88	4.11
F-value									
Iron (Fe)	0.85ns	8.03**	5.29**	0.88ns	11.69***	7.40**	2.87ns	21.89***	3.478
Inoculation (I)	57.03***	27.74***	44.51***	85.75***	142.26***	292.27***	1.74ns	31.08***	21.71***
I x Fe	2.68*	2.00ns	2.08ns	2.42ns	1.15ns	2.52*	2.32ns	8.15***	5.41***

*NS- non significant; * significant at 0.05; **highly significant at 0.01; ***very highly significant at 0.001; F_1- no Fe fertilized; F_2- 1% Fe application ; F_3- 2% Fe application; Notes. Means in the same column followed by the same letter are not significantly different at the 5% probability level by Tukey's test*

3.6. Soybean Grain Yield

The research result revealed that Fe rates application and *Bradyrhizobium* inoculation (I) had a significant effect on grain yield (GY) for GIZA genotype (Table 7). On top of this, the I x Fe interaction had significant effect on the average GY. In this genotype, Fe application at 2% resulted in significantly higher GY production than the unfertilized control. The GY also varied from 1961 to 2196.60 kg ha^{-1}, which produced 12% higher GY at 2% Fe application than that of the unfertilized control. The average GY exhibited significant variation and the highest GY was obtained at 2% Fe application. In contrast, the effect of Fe rates of application was non signficnat on GY of TGx-1336424 genotype.

Inoculations of elite isolate of symbiotic N_2-fixer displayed significant effect on GY of GIZA genotype but not observed on TGx-1336424 genotype. The research data showed that *Bradyrhizobium* isolates inoculation resulted in significant variation in GY of both soybean genotypes. Inoculation with UK and local isolates produced significantly higher GY in both genotypes than that of the uninoculated control. The GY of TGx-1336424 varied from 1722 to 2519.18 kg ha^{-1} with average value of 2254.77 kg ha^{-1}, while the maximum GY of GIZA genotype was 2277.33 kg ha^{-1}, which was 72.7% over the uninoculated control. The UK-isolate inoculation produced significantly higher average value of GY than the other inoculation treatments. The lowest GY in both genotypes, including the average value of GY, was obtained from soybean genotypes inoculated TAL-379 isolate.

The regression analysis indicated the non-significant (P >0.05) association between GY and Fe rates of application in both genotypes (graph not indicated). However, the result showed significant associations when these parameters were analyzed separately in each inoculation treatment, except TGx-1336424 genotype inoculated with TAL-379 (Figure 3a and b). The highest coefficient of determination (R^2=0.728) in TGx-1336424 genotype was obtained from UK-isolate inoculation, followed by the uninoculated control (R^2=0.315). In GIZA genotype, the highest coefficient of determination (R^2=0.676) was obtained in the uninoculated control treatment, followed by that inoculated with local isolate (R^2=0.540).

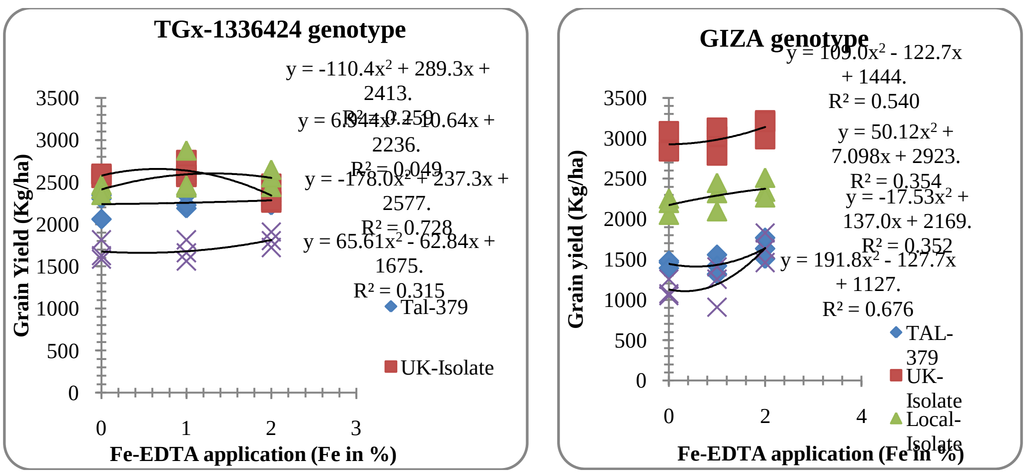

Figure 3. Regression analysis between grain yield and rate of Fe application in GIZA genotype under field condition.

3.7. Total Plant Tissue Nitrogen

The research finding revealed that Fe application, I and their interaction had a significant effect on total plant nitrogen concentration (PTC) in GIZA genotype, but not in TGx-1336424 genotype (Table 7). Iron application at 2% Fe resulted in significantly increased the PTC in GIZA genotype as compared to the unfertilized control. The PTC varied from 3.9175 to 4.0792% for TGx-1336424 genotype and from 3.8383 to 4.2050% for GIZA genotype. In TGx-1336424, the PTC decreased with increasing Fe rates of application. Even though there was no significant variation in the average PTN along the Fe rates, the data generally indicated an increase in PTC along increasing rates of Fe application.

The research data generally indicated that three inoculated *Bradyrhizobium* resulted in higher PTN than the uninoculated control. Inoculating UK-isolate produced significantly higher PTC than the other inoculation treatments in GIZA genotype. The same effect of inoculation treatment on the average value of PTC was noted. The maximum PTC (4.2444%) in GIZA genotype was obtained from UK-isolate inoculation treatment. This value in GIZA genotype was 19% higher than that obtained from the uninoculated control treatment.

4. Discussion

Fe chlorosis is commonly observed in groundnut and soybean crops in Shinille areas, Somali region, Ethiopia. The present study was, therefore, launched to explore whether the soybean genotypes having different maturity groups need different rates of Fe applied through foliage with the intention of obtaining highest yields. Papaslyhanou (1993) found better result when Fe chelate was applied at branching and before flowering stage and the phytotoxicity was found to be moderate. The present work indicated significantly low NN and NDW in Fe unfertilized plants regardless of the genotypes. Similarly, O'Hara *et al.* (1988b) had reported that iron deficiency led to decreased nodule number and mass in peanuts. The current investigation is also in conformity with the finding of Hartzook (1984) who reported that iron chelate treated standard genotype performed equally with that the genotype that had inherently efficient iron absorption. Nevertheless, the present result indicated a significant improvement in NN and NDW due to Fe application in the medium maturing genotypes only, where Fe was applied directly through the soils. The amount of Fe applied directly to soil was sensitive for immobilization and could reduce the availability of Fe for significant improvement of NN and NDW in late maturing soybean genotypes. Differential responses of genotypes to iron application could also be related to genetic make-up of the host, which regulates the absorption, translocation, metabolism, and N_2- fixation (Rai *et al.,* 1984).

The regression analysis indicated that NN in both TGx-1336424 and GIZA genotypes increased linearly with increase in the rates of Fe application. The highest R^2-values of 0.678 and 0.715 were obtained from TGx-1336424 genotype inoculated with UK-isolate and GIZA genotype inoculated with TAL-379 isolate, respectively, indicating that there was better soybean genotype performance due to Fe application integrated with inoculation with different *Bradyrhizobium* strains. Tang *et al.* (1991) have also showed positive interaction between iron concentrations and *Bradyrhizobium* strains on nodulation of peanuts. It is obvious that *Bradyrhizobium* sp. display differently in performance and in nodule formation, N_2-fixation and form symbiotic association with different genotypes (Okereke and Unaegbu, 1992). O'Hara *et al.* (1988a) found that strains of *Bradyrhizobium* sp. differ profoundly in their ability to obtain Fe from their environment for development of their symbiotic systems in peanut. This ability affected the productivity of soybean genotypes differently due to inoculation with different isolates of *Bradyrhizobum* sp. along with rates of Fe application.

The present study indicated that inoculation with UK-isolate in TGx-1336424 genotype resulted in the highest coefficient of determination in NDW, TBY and GY with increase in the rates of Fe application. This suggests that the effectiveness of the *Bradyrhizobium* isolates is the determinant factor or responsible for remarkable effect of Fe-application on the productivity of any late maturing soybean genotype (TGx-1336424). This also implies that late maturing genotypes could need more N from symbiotic fixation in which the BNF requires Fe for various components of nodule function, i.e. nitrogenase biosynthesis, leghaemoglobin production and bacteroid multiplication. However, the highest coefficient of determination between GY and increasing rates of Fe application in GIZA genotype was obtained in the uninoculated control treatment though higher R^2-value was obtained between NN and NDW with increasing rates of Fe application inoculated with TAL-379 isolate and UK-isolate. This could probably be due to the presence of high soil native N which might have determined the final yield of the medium maturing genotypes, thereby hiding the effect of N derived from symbiotic association with *Bradyrhizobium* sp. In contrast, Tang *et al.* (1991) found that higher Fe concentrations in solution were required for maximum growth of plants reliant on symbiotic nitrogen fixation than that of plants receiving inorganic nitrogen fertilizer.

The findings of the current studies also indicated significant improvement in SDW of TGx-1336424 genotype but reduction in SDW in GIZA genotype with increase in rates of Fe application. It is known that iron application usually increases soybean top dry matter yield

(Hodgson *et al.,* 1992; Ghasemi-Fasaei *et al.,* 2002) but higher levels may decrease soybean growth (Roomizadeh and Karimian, 1996). Rai *et al.* (1984) also found that genotypes differed greatly in iron absorption and translocation capacity. High Fe concentration in the plant tissue may reduce the uptake and concentration of Mn in soybean genotypes (Moraghan, 1985), thus lead to poor plant growth (Brand *et al.,* 2000). However, the Fe applied directly to soil enhanced the SDW of medium genotypes, including GIZA genotype, but was not observed in late maturing soybean genotypes. It is obvious that direct soil application of Fe in the form of $FeSO_4$ may not be as effective as application in the form of Fe-chelate as had been previously indicated by Hemantaranjan (1988). Moreover, there might be presence of greater variation in Fe absorption and transport capacity due to difference in genetic make-up among different soybean genotypes (Rai *et al.,* 1984).

The data generated here also indicated that increasing rates of Fe application did not significantly improve the PH, NPP, NSP, TBY, GY and TPC of TGx-1336424 genotypes although Fe application exhibited a significant nodulation enhancement. Beside this, under greenhouse condition, NN, NDW and SDW of late maturing soybean genotypes, including TGx-136424, did not improve with increase in rates of Fe application. A similar finding was reported by Papastylianou (1993) who found that moderately chlorotic peanuts that were fertilized with Fe did not significantly increase in their yield but had bigger nodules than the peanuts that were not fertilized with Fe application. The applied Fe may be also insufficient to get sufficient amount of N from symbiotic N_2-Fixation for significant improvement in the final yield of late maturing peanut genotypes (Robson, 1983; Tang *et al.,* 1991). Tang *et al.* (2006) who also found a similar result in lupin plant reported that the Fe requirement had been very high in lupin, probably due to the fact that it is one of the highest N_2-fixation food legumes, thus requires higher Fe nutrient. Remarkably higher protons production due to need for higher N from symbiotic N_2 fixation may lead to lower rhizosphere pH and, consequently, reduced the availability of some mineral nutrients as well as the effective functioning of rhizobia might be another reason of low response in late maturing genotypes for Fe application (Dakora and Philips, 2002).

The current research data revealed significant improvement in NPP, TBY, GY, and PTC obtained from GIZA genotype with increase in rates of Fe application. This result might be due to the fact that nodulation improvement in GIZA genotype enhances N_2-fixation, which could be sufficient for higher final yield. It is the fact that iron is also a critical micro-nutrient for N_2-fixation due to its essential integral component of nitrogenase, leghemoglobin, and ferrodoxins (Evans and Rossel, 1971). On top of this, it is also important in photosynthesis and carbohydrate synthesis (Miller *et al.,* 1984; Terry and Abadia, 1986; Bienfait, 1989); it might affect N_2-fixation wherever carbohydrates are involved (Atkins, 1984).

The present study revealed a poor soybean growth in Fe-unfertilized plants irrespective of genotypes. Poor nodulation could be the cause of poor growth as has been indicated in Lupin (Tang and Robson, 1995). Tang *et al.* (1992) also found that iron deficiency generally decreases nodule formation, leghaemoglobin production and nitrogenase activity, leading to low nitrogen concentrations in the shoots in some legumes. In such situations, excess malic and citric acids may accumulate in the cells and normal metabolism and N_2-fixation may be disturbed.

5. Conclusions

The unique aspect of this study was the insight into the possibility that there might be an interaction between different rates Fe application and soybean genotypes having different maturity groups (medium and late maturity groups) that would affect the symbiotic N_2-fixation via inoculation with *Bradyrhizobium isolates* when the soil had high soil native N. The results of this experiment revealed that foliar applications of Fe significantly improved the nodulation irrespective of soybean genotypes having different maturity groups. At the later growth stages of soybean, Fe application exhibited different performance between the two tested maturity groups, indicating significant effect on those with medium maturing genotypes. Different performance of *Bradyrhizbium* isolates on different soybean genotypes having different maturity times integrated with different rates of Fe application was also observed. Generally, the generated research results of the pot and field experiments clearly indicated the need for different amounts or rates of Fe application based on the soybean genotype maturity groups and effectiveness of inoculated *Bradyrhizobium* isolates. Further research efforts would be required to maximize yield and reduce the yield gap through investing to alleviate other limited plant and soil resources.

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7. Evidences on Climate Smart Agricultural Practices in Central Rift Valley of Ethiopia

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Abstract
Land degradation is the most chronic problem in Ethiopia. Soil erosion and denudation of vegetation cover are exacerbating land degradation in semi-arid areas. Watershed management is believed to be a holistic approach to create a climate smart landscape that integrates forestry, agriculture, pasture, and soil water management, with an objective of sustainable management of natural resources to improve livelihood. This approach pursues to promote interactions among multiple stakeholders and their interests within and between the upstream and downstream locations of a watershed. Melkassa Agricultural Research Centre (MARC) has been implementing integrated watershed management research project in the Jogo-Gudedo and Adulala watersheds from 2010-2014. Participatory action research (PAR) was implemented on soil and water conservation (SWC), area enclosure, agroforestry (AF), conservation tillage (CT), energy saving stove, and drought resistant crop varieties. Empirical research and action research at plot level and evaluation of introduced technologies with farmers through experimental learning approach and documentation were employed. The participatory evaluation of and collective action on SWC and improved practices brought about high degree of acceptance technologies. This was ratified by the implementation of comprehensive watershed management action research which in turn enabled to taste and exploit benefits of climate-smart agricultural practices (CSA). Eventually, significant reduction in soil loss and fuel wood consumption, improvements in vegetation cover and crop production were quantitatively recorded as good indicators and success. Field visit, meetings, trainings and frequent dialogues between practitioners and communities at watershed level helped in promoting the climate smart agricultural practices and improving productivity that could help to improve the livelihoods of the local people and sustainable watershed resources management.

Keywords: Action research; climate smart agriculture; conservation tillage; watershed management; participatory; soil erosion; stakeholders

1. Introduction

Land degradation is occurring at an alarming rate in Ethiopia (Kidane, 2014; Temesgen *et al.,* 2012), which results in social and economic problems (Moges and Holden, 2008; Kassie *et al.,* 2007; Hurni *et al.,* 2005; Bewket and Sterk, 2002). Poverty and land degradation appear to feed off each other for many years. The excessive dependence of the Ethiopian rural population on natural resources, particularly land, as a means of livelihood has been the underlying cause for land and other natural resources degradation (EPA, 1998). Integrated watershed management approaches are now considered as innovative options for sustaining ecosystems while improving human welfare (Kidane *et al.,* 2015; Alemu and Kidane, 2014; Temesgen *et al.,* 2012). It encompasses the holistic approach to managing watershed resources that integrates forestry, agriculture, pasture and water management which can be broadened to rural development with a strong link to the livelihoods of the local people (Tefera and Sterk, 2010; Yitaferu, 2007; Desta *et al.,* 2005). Similar to most part of the country, low adoption of technology, severe soil erosion, denudation of trees and low productivity of land had been the common features in the Jogo-Gudedo watershed. This report synthesizes experiences and results of climate-smart agricultural practices from action research that have specific relevance to resource management of the Jogo-Gudedo watershed.

2. Methodology

2.1. General Description of the Study Areas

2.1.1. Location of the selected watersheds

Adulala and Jogo-Gudedo watersheds are located in the Central Rift Valley (CRV) of Ethiopia in East Shoa Zone of Oromia State and geographically situated between 80 26.5' to 80 29.5' N and 390 17' to 390 20.5' E and between 80 33' 25" N and 390 12' 29" E respectively (Figure 1). Adulala is 104 km whereas Jogo-Gudedo is 80 km away from the capital, Addis Ababa, in the south east direction.

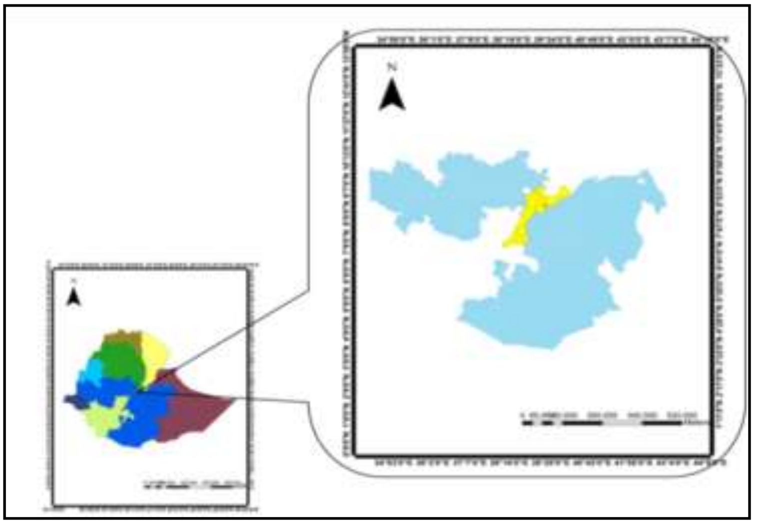

Figure 1. Location of the study watersheds.

2.1.2. Topography

The Digital Elevation Model (DEM) was used to delineate the watersheds, and generate the hill slope information (slope, length, etc) (Figure 2). The DEM was obtained from ASTER Global Digital Elevation (Model METI and NASA, 2009) and clipped to the watersheds' boundary. Based on the DEM, the altitude of the watersheds ranges from 1606 to 1781 m.a.s.l. and from 1807 to 2053 m.a.s.l. respectively for Adulala and Jogo-Gudedo. Based on the DEM of the two watersheds, a number of different methods are available to delineate and generate hill slope information. Two different methods were used for Adulala and Jogo-Gudedo.

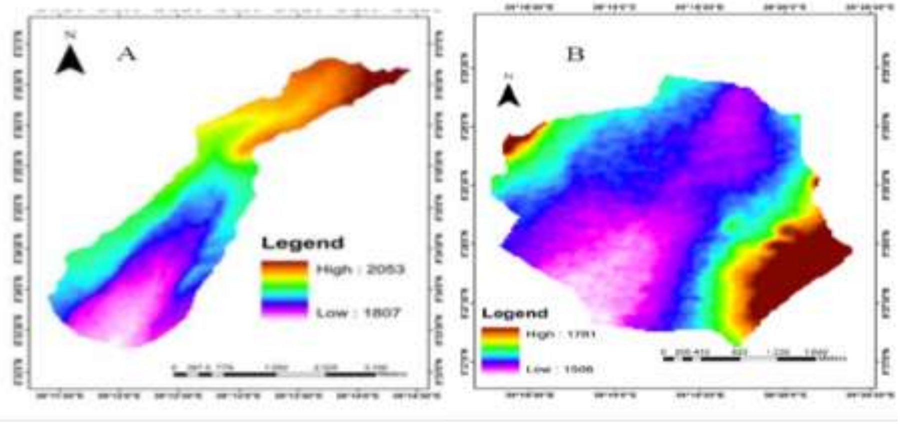

Figure 2. DEM of Jogo-Gudedo (A) and Adulala (B) watersheds.

For Jogo-Gudedo, a model called GeoWEPP was used to generate channel network, determine the sub-catchments of the watersheds and generate the hillslope information (slope, length, etc.). GeoWEPP used topographical analysis software, TOPAZ, to delineate the watershed boundary and channel network of the watershed. TOPAZ requires a Critical Source Area (CSA) and a Minimum Source Channel Length (MSCL) to produce the channel network and it was set 5 ha and 100 m respectively. After the generation of the channel network and selecting the watershed outlet, TOPAZ produced the watershed boundary and sub-catchments areas contributing to the channels. For Adulala watershed, Area based and Point based methods were used for making sub-watershed and main watershed respectively using GIS based hydrologic modeling. GIS based model follows series of steps to delineate watershed using hydrology toolset under spatial analysis tools: Filled DEM (void of depression), Flow Direction (direction water will flow out of each cell of filled elevation), Flow Accumulation (tabulate for each cell, the number of cells that will flow to it), Stream network (producing stream network based on threshold flow accumulation), and Watershed (delineation of watershed using area or point based approach) were done.

2.1.3. Slope

The slope maps of the watersheds were generated from the DEM of the watersheds using ArcGIS slope calculator. The summary of the slope classification is summarized in Table 1. Thereafter the slope map was reclassified into five classes, following the FAO classification (FAO, 2002), namely 0-2% (flat), 2-8% (undulating), 8-16% (rolling), 16-30% (hilly) and > 30% (mountainous). From the result, the slope of Jogo-Gudedo watershed (Figure 3A) ranges from 0% to 39% and out of the total area 6.5, 61.6, 22.7, 8.7 and 0.5% are flat, undulating, rolling, hilly and mountainous whereas for Adulala (Figure 3B) ranges from 0 to 43% and out of the total area 31, 52.3, 12, 4.1 and 0.6% are flat, undulating, rolling, hilly and mountainous. Therefore, the Jogo-Gudedo watershed is classified as undulating to rolling and Adulala as flat to undulating.

Table 1. Slope class of Adulala and Jogo-Gudedo watersheds

Slope class	Adulala Watershed		Jogo-Gudedo Watershed	
	Area (ha)	%	Area (ha)	%
0 - 2	310	31	66	6.5
2 - 8	523	52.3	621	61.6
8 - 15	120	12.0	229	22.7
15 - 30	41	4.1	87	8.7
> 30	6	0.6	5	0.5

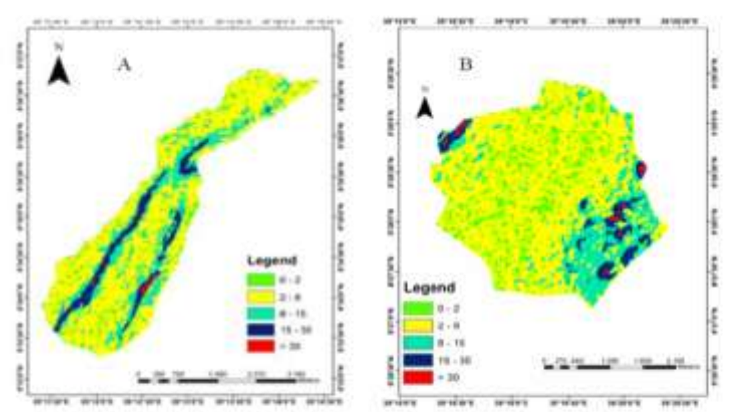

Figure 3. Slope map of Jogo-Gudedo (A) and Adulala (B) watersheds.

2.1.4. Land cover

Both watersheds are a mixture of intensively cultivated land, open bush and shrub land, and rural residential area. Having a witness from loss of soil fertility, the prevalence of large gullies and a decline in agricultural production, the watersheds are currently suffering from severe land degradation. The analysis shows that croplands constitute the majority of the watershed area covering 85.9% of the total land followed by shrub and bush lands constituting 11.7% while the rest was covered by settlement areas. Among the major crops grown by the farmers, cereals such as *Tef* (*Eragrotis tef*) and maize (*Zea mays*) and legumes such as haricot bean (*Phaseolus vulgaris*) in Adulala and *Tef*, barely, wheat, maize and haricot bean are the dominant crops in Jogo-Gudedo. Vegetable crops are not grown because of unavailability of irrigation water and high input requirements for producing these crops. Low crop production and productivity is the main characteristics of the watersheds as compared to the potential productivity of the area. The areas suffer from frequent severe droughts induced by the impacts of enhanced climate variability, poor management of natural resources and agronomic practices, limitations in the use of improved crop varieties and other biotic stresses. As a result, agricultural productivity is very low. There are a number of gullies formed on the farmlands which resulted in shrinking of total croplands.

2.1.5. Climate

The rainfall of Adulala and Jogo-Gudedo watershed follows a bimodal pattern with short rainy season (March to April) and main rainy season (July to September). The average annual rainfall of Jogo-Gudedo and Adulala watershed is around 900 and 798 mm respectively. Jogo-Gudedo watershed is characterized by a maximum annual mean temperature of 28.2 °C and a minimum annual mean temperature of 12.3 °C whereas Adulala is characterized by a maximum annual mean temperature of 28.5 °C and a minimum annual mean temperature of 14.0 °C. In general, the seasonal rainfall in both watersheds is inadequate in amount, poor in distribution (erratic) and intensive mainly during July and August that causes considerable amount of runoff and soil erosion. Runoff and soil loss are severe in the upper reach of the Adulala watershed whereas in the middle of the watershed, owing to the flatness of the area, water logging problem is occurred.

2.1.6. Soil

Based on the information obtained from ETHIO-GIS DATA SETS, the watershed comprises of two major soil units. Adulala watershed is dominantly covered by Mollic Andosols, while Pellic Vertisols are the major soil groups in Jogo-Gudedo watershed. The soil analysis result also revealed that physically, the texture of Adulala soil is loam on the surface grading into clay loam with depth. The organic matter content of the soil is very low and decreases with depth. The pH falls in the slightly acidic (6.6) to moderately alkaline (8.9) range with an increase in pH with soil depth.

2.2. Integrated Watershed Management Research Protocols

Integrated research protocols were developed for each cluster and sub-cluster that require research and development. The research types were empirical and action research. Empirical research is based on experimentation at plot level or observation to test a hypothesis. Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and by joint collaboration at watershed scale. This enabled to taste and exploit benefits of CSA practices.

There has been a tension on the roles of researchers engaging in action research oriented development activities. Action research has been applied by researchers to deal with a variety of educational and social service problems. Researchers used action researches or experiments to merge local and scientific knowledge for the sake of social learning process. Therefore, researchers made an effort to generate and share the knowledge and identify socially acceptable solutions in depth and long term process. Researchers carried out quantitative research techniques such as questionnaire surveys, GIS-based analysis, erosion and runoff measurements and economic valuations in the action research process to validate working group hypotheses.

2.2.1. Approaches in the IWM action research

1. Farmers' participation in IWM Action research

To reduce land degradation, integrated watershed management action research projects were implemented in the Jogo-Gudedo and Adulala watersheds for the last four to five years. Soil and water conservation action researches were based on watershed treatment and integrated agricultural development through Local Level Participatory Approaches (LLPPA), and mobilization. The approach emphasized planning at the watershed level rather than individual farm level. Therefore, it was dominantly characterized by group approach, with no incentives (cash or food) and campaign works. In most cases what was observed as participatory was in fact a bottom-up approach where the extension agents and/or researchers were facilitating farmers to actively engage in development and experiment. Extension personnel and researchers were facilitators to transfer of the technologies.

When farmers proved unwilling to voluntarily adopt the recommended soil conservation technologies, the common practice was that they were governed by means of farmers' "bylaw' developed by themselves. To synergize the process of resource management, communities developed their own rules to administer themselves. It was observed that better organized and effective people's participation assured higher yield benefits and commitment to conserve resources. This enables farmers to have an opportunity to be actively involved in development and decision-making processes inherent in the management of their own areas. In order to enhance active participation, several groups like user groups, self-help groups or common interest groups, watershed committee, and watershed cooperatives were formed. Efforts were made to have due representation of all castes or social groups. The findings revealed that watershed committees actively involved in the SWC action research from the design up to evaluation. These groups were formed carefully and trained well so that the assets created and benefits accrued are sustainable. All resources including private and common property resources were developed, managed and maintained with active involvement of the local community. People's involvement was the key to success, which brings sustainable development and achieved win-win climate change adaptation strategy particularly in the degraded area.

To make sure that women participated in the planning and decision making of watershed development work, a volunteer woman was engaged in each watershed committee. Women's empowerment was carried out by encouraging women to participate in the watershed committee and take a leadership role. Since empowerment is a latent phenomenon and cannot be measured directly so aspects like participation, mobility, voice in decision making in committee, community, and society were taken into consideration for women. In fact, mere presence of women members in the watershed committee has no real impact unless and otherwise they are involved in decision-making process in the committee. It was found that the *kebele* leader and secretary played active role. The watershed association, cooperatives and watershed committee were found to be important at any time for cooperative process. The available evidences confirmed that there existed a positive relationship between people's participation and benefits from IWM research. Similarly, this study showed that the benefits were the highest from the watershed when people's participation was high. Thus, active and voluntary participation of all stakeholders is a guarantee for successful implementation of watershed program.

2. Stakeholder training and awareness creation

Trainings of stakeholders were carried out to impart knowledge and raise awareness among stakeholders on evaluation of SWC technologies and income generating activities. Beneficiaries were given the practical exercises about the measures before starting the physical SWC, sericulture management and beehive construction. These on farm training and extension services were conducted concurrently on beneficiaries' need. Stakeholders were trained on various effective and appropriate measures of soil and water conservation design and implementation. Formal training of farmers included the use of simple survey equipment such as line levels, ranging pole, A-frames and meter tape. Several informal farm visits, seminars, and workshops were also conducted.

3. The role of the researcher in the action research

They had an important role in implementation of applied research or action research merged with local institutions and policy for sustainable benefits. In general, the researches that were conducted in Adulala watershed were initiated with practical and technical work for the sake of catalyzing local participation, with an ultimate focus of shifting from doing to facilitating. Researchers made an effort to make dialogue between local and scientific knowledge in action research processes, by involving a variety of stakeholders.

3. Major Findings on CSA Practices

3.1. Adopted SWC Practices

1. Farm land terraces

The farm land SWC technologies introduced and evaluated in the watershed were predominantly subjective to standard structural SWC technologies. Common terrace practices like soil bund and "*Fanya juu*" structures were done interchangeably on the farm in order to reduce excess runoff, soil loss and the slope gradient, and extend the time span for water to infiltrate into the soil system. Based on the assumption of MMF model prediction, the farm land terraces constructed on crop lands and tree planted on degraded mountainous area reduced soil loss by 15.5%. MMF model estimated that implemented different SWC measures controlled soil erosion by reducing it by more than 42 % arrested soil erosion through doing different SWC using model output. This could be attributed to the fact that there is a linkage with vast enormous km of soil bund and '*Fanya Juus'* conservation tillage and enclosure that have been done in the watershed.

2. Conservation tillage practice

Although conservation tillage has been under demonstration for maize in the watershed before, both farmers and agricultural extension experts did not try the technology for other crop production. Participatory assessment of run-off and soil losses was carried out from the different tillage practices. Experiments were carried out in applied research concept to evaluate the technology at farmer's field (Figures 4 a, b, and c). Result showed that improved tied ridge tillage implementation reduced soil loss by 2.85 ton ha^{-1} and runoff by 863.3 m^{3}ha^{-1} (Figure 4a). It also, increased grain yield of haricot bean by 1110.2 kgha^{-1} compared to conventional tillage (Table 2). Therefore, the economic benefit of haricot bean production through conservation tillage was superior compared to the conventional tillage.

Figure 4. Runoff experimental plot of tillage methods, 2012.

Table 2. Effect of tillage methods on grain yield of haricot bean through on-farm experiment.

Treatments	Grain yield (kg ha^{-1})	Soil loss (t ha^{-1})	Runoff (m^3 ha^{-1})
Tied-ridge	1724	1.32	539.32
Conventional tillage	613.8	4.17	1402.92
Bare land	……	3.83	2419.99

3. Hill side terracing

Identification of economical and appropriate micro-catchment water harvesting systems for the support of early survival of tree seedlings in the watershed was carried out. The design was randomized complete block design. Four types of promising multipurpose trees namely: *Azadirachta indica, Schinusmolle, Acacia saligna* and *Parkinsonia aculeata* were selected and randomly planted in each of the micro-catchment structures after the runoff has been harvested around the structures. The growth (height and diameter) and survival of the trees in each structure were recorded. All treatments were tested at 95% ($P < 0.05$) confidence limits. Hence, tree seedlings require additional moisture to rain water in dry areas for their early survival. Among the micro-catchment micro water harvesting structures used in this study, the highest survival percentages were recorded in semicircular bund (81.7%) and followed by contour-bench terraces (76.7%), whereas infiltration pits performed the least (5%) (Table 3). They had different survival rates. Thus, it led to variation within the same treatment. Semi-circular bunds have also economic advantages that they are easy to construct and are labor efficient. Lower survival percentage was recorded (40%) for the eyebrow terraces, which also have different disadvantages.

Table 3. Effect of micro catchment water harvesting structures on tree seedling survival.

Treatments	Survival Percentage (%)
Semi-circular bund	81.7
Contour-bench terraces	76.7
Eyebrow terraces	40.0
Infiltration pit	5.0
LSD	49.72
SE+	0.28
CV (%)	48.96

4. Area enclosures

Initially there was no any single vegetation cover observed in the degraded hilly areas of the watersheds. However, after the project implementation different grass, shrub and tree species were recorded in the watersheds especially in the enclosure sites. Area enclosure followed by SWC practices and forage and tree seedling planting contributed to emergence and growth of different palatable grass or forage and tree species. Enclosure opens the possibility for regeneration from seed bank of different indigenous Acacia tree species and other tree species (Table 5). This indicated the relevance of area enclosure with various interventions to improve the rehabilitation and development of the degraded hilly land. The plant composition become valuable for bee forage and tree plant in the rehabilitation site. With increased moisture and soil retention in the degraded area enclosure, the duration of bloom period of bee forage plants stayed longer than open areas. This resulted in Apiculture or bee keeping activity to be carried out by beekeepers' associations. This would be one of the main reasons for the substantial increase in honey production.

The overriding concern was to rehabilitate degrade hillside with multipurpose trees in order to conserve biodiversity and/or use tree product, reduce erosion and carbon emission, to adapt and mitigate climate change as triple win strategy. Measurements of above and below ground carbon were conducted (Table 4). For aboveground carbon two carbon pools (herbaceous biomass and tree/shrub growths) were identified and measured. For below ground carbon, soil carbon measurements were done. From the total area of the enclosed hill land, a total of 7.9 ton/ha of carbon was sequestered/stored in the above ground carbon pool just after the area was enclosed (Table 4).

Table 4. Estimated aboveground biomass and carbon stored in area enclosures.

Carbon pool	Biomass (ton)/ha
Herbaceous biomass	5.8
Existing & planted species	10
Total biomass	15.8
Aboveground carbon (total biomass*0.5 conversion factor)	7.9

Table 5. Naturally regenerated and planted species growths (height and diameter), number of stems, frequency and abundance.

Species local name	Scientific name	AverageHeight (cm)	DBH (cm)	No. of stems/ha	Frequency	Abundance
-	*Acacia saligna*	128.85	2.249	6619	15	
Sebesa	*Acacia senegal*	128.27	2.02	105	12	57.14
Tedecha	*Acacia tortilis*	105.57	1.40	543	21	100.00
Hate	*Dichro stachyuscinere*	90.00	0.81	91	7	33.33
Kechachule	*Securinga*	132.07	0.85	143	13	61.90
Baloli	-	117.00	1.25	95	1	4.76
Gora	*Acacia millifera*	116.01	0.78	43	5	23.81
Dodoti	*Acacia gerrardi*	58.50	0.78	19	3	14.29
Kankalcha	*Tephrosia spp*	131.33	1.03	14	4	19.05
Kassale	*Acacia etbaica*	93.60	1.30	24	3	14.29
Badano	*Balanites aegyptic*	158.00	1.28	29	3	14.29
Eka	*Grewia spp.*	*82.60*	*0.86*	*24*	*4*	*19.05*
Gerbi	*Faidherbia albida*	*57.00*	*1.10*	*5*	*1*	*4.76*
Baladi	-	*120.00*	*1.30*	*5*	*1*	*4.76*
-	*Sesbania sesban*	*85.00*	*1.70*	*12*	*5*	

3.2. Agroforestry Practices

Farmers have land use systems where woody perennials (trees, shrubs, and palms) are deliberately used as agricultural crops on the same land management units or home gardens (Figure 5). Agroforestry practices that farmers commonly use for different purposes are described in Table 6. Mostly farmers practiced Agroforestry for income generation, forage and fire wood source.

Figure 5. Agroforestry practices implemented in Jogo-Gudedo watershed.

Table 6. Agroforestry practices and tree species used by farmers in the study areas.

Tree species used for AF practices	AF practices commonly practiced	Common feature	Direct AF trees serve as source of
Acacia albida	-Alley cropping	Tree seedling mortality	Income
A. mellifera			
A. nilotica	Wind breaks		Shelter and shade,
A. seyalstenocarpa	Fencing	Low level AF technology adoption	
A. tortillisraddiana			Forage
Alnusacuminata	Scattered trees		
A.nepalensis		Lack of information on species arrangement for better yield	Fire wood
Anacardiumsenegalensis	Woodlots		
Annonasenegalnsis			
Anogessusleiocarpa			
Azadirachtaindica			
Borassvsaethiopium			
Calliandracalothyrsus			
Cajanuscajan			
Casuarinaequisetifolia			
Carica papaya			
Cedrelaserrata			
Citrus aurantium			
Citrus limon			
Citrus sinensis			
Colophospermummopane			
Leucaenaleucocephala			
Mangiferaindica			
Sesbaniasesban			
Perseaamericana			

3.3. Integrated Soil Fertility Management

Sand was the highest fraction at all depths across all part of the hillside slope enclosure area. Similarly, the silt fraction was relatively higher throughout the depth and watershed positions. On the other hand, the clay constituted a relatively low amount in all depths (Tables 7). Clay content tended to increase while silt content tended to decrease with depth. Moreover, clay content was substantially less in the upper most layers (0-15 cm) as compared to the underlying soil layers. There were slight differences in soil organic matter content in the watershed across depths. There were no significant differences ($P > 0.05$) in nitrogen, phosphorous, and pH across depths and watershed positions. This may be due to the fact that soil property alteration needs long time soil management implementation.

In-line with the gap indicated at household survey and PRA, two farmers were randomly taken to test the ISFM technologies in the watershed on *Tef* and haricot bean fields (Table 8). The result from the experiment showed that use of chemical fertilizers provided high yields in haricot bean. The combined use of half recommended chemical fertilizer and half recommended compost (organic fertilizer), however, showed a comparable yield advantage for haricot bean. The study on haricot bean has convinced farmers that compost can replace the cost they incur for chemical fertilizer by half and enhance organic agriculture. It has also been noted that compost alone did not perform well in yield increment may be due to the slow ability to release nutrients and the advantage is mostly pronounced in the subsequent years.

Table 7. Selected soil properties after two years of intervention at Adulala Watershed

Watershed position (WP)	Depth (cm)	Soil particle size distribution (%)			Textural class	OC (%)	pH	TN (%)	P (mg kg^{-1})
		Sand	Silt	Clay					
Lower	0-15	42±0.23a	39.25±0.17a	18.75±0.11a	Sand-loam	1.178±0.18a	7.58 ±0.12a	0.20±0.12a	4.21±0.19a
Lower	15-30	43±0.09a	38±0.04a	18.66±0.31a	Sand-loam	0.97± 0.21b	7.42±0.22b	0.18±0.23a	4.20±0.17a
Middle	0-15	43.33±0.05a	37.25±0.01a	19.25±0.06a	Sand-loam	1.289±0.15a	7.80±0.24b	0.21±0.15a	5.59±0.16a
Middle	15-30	43.33±0.04a	37.16±0.09a	19.50±0.11a	Sand-loam	0.915±0.20b	7.98±0.51b	0.15±0.11a	5.34±0.19a
Upper	0-15	43.50±0.14a	36.25±0.10a	19.25±0.13a	Silt loam	1.212±0.11a	7.64±0.19b	0.12±0.14b	4.61±0.18a
Upper	15-30	43.6±0..0a	36.25±0.03a	20.12±0.05b	Silt loam	0.895±0.13b	7.62±0.09b	0.16±0.13a	4.39±0.18a
LSD (depth)						0.13	0.211	0.07	2.36
LSD (WP) lower						1.07	7.50	0.19	4.31
Middle						1.10	7.89	0.18	5.47
Upper						1.05	7.63	0.14	4.50

Table 8. Effect of different sources of nutrients on the yield of haricot bean.

Treatments	Grain yield (ton/ha)
Control (with no fertilizer)	0.91
Compost (farmers practice)	0.94
Recommendation compost +1/2 Recommended chemical fertilizer	1.36
Full dose inorganic fertilizer	1.06

3.4. Evaluation of Improved Energy Saving Wood-Burning Stoves in the Jogo-Gudedo Watershed

Performance test of three different stoves was conducted in order to quantitatively determine the efficiency. Evaluation was carried out between two improved energy saving stoves and the conventional one. The test was conducted three times. *Mirte, Gonziye* and traditional open fire stoves were the treatments. Finally, wood consumption, time to cook 10 *'Injera'* and rate of wood consumption of the three selected stoves was evaluated. The result indicated that *Gonziye* stove performed very well compared to the traditional open fire and *Miret*.

Although there was large variability on initial time clod warm or time taken to make *Injera* starting from initial time, Traditional open fire stoves showed a considerably higher fuel-wood and energy consumption compared to *Gonziye* and *Mirte* stoves.

As indicated in Table 9, treatments have statistically significant difference among them on selected parameters. Selection of the best energy saving stove has been completed. Accordingly *'Gonziye'* has been selected over *'Mirt'*.

Table 9. Energy saving stove performance.

Parameters	Unit	Stove types			Statistics	
		Merti	Gonziye	Open fire	P = 0.05	CV
Wood consumed	kg	3.43	2.2	5.6	0.0002	10.21
Time to cook ten injera	min	28	27	34	0.0487	11.86
Wood consumption	kg/min	0.12	0.08	0.25		
Material used		Cement	Mud	Mud		
Cost incurred	Birr	120	60	10		

SD = Standard deviation; CoV = Coefficient of variation; Calorific value (MJ/kg) of Eucalyptus camaldulensis = 29.500MJ/kg (FAO (1993)).

Figure 6. Stove types used in the evaluation of energy saving stoves.

3.5. Drought Resistant Crop Variety Testing and Adaptation

Cereals and pulses are important food and cash crops for farmers and rural households in Ethiopia. Cereal production accounts for roughly 60% of rural employment and 80% of total cultivated land. Households spend an average of 40% of their total food budget on cereals. Pulses occupy 13% of cropland in Ethiopia and are the second most important element in the national diet after cereals. Despite the economic and food security importance of these crops, data and opinion suggest a yield gap: actual smallholder farm yields do not achieve estimated potential yields for wheat, *tef*, maize, haricot beans and barley. Furthermore, cereal prices in Ethiopia fall between import and export parity prices, limiting their international trading prospects. Although there are significant wheat imports, these reflect the influx of food aid and not competitive trade on the international market. The farmers of Adulala and Jogo-Gudedo/Ketchema/ have long been suffering from low production and productivity of crops which could not even satisfy the requirements of their own needs. The low production and productivity of the major crops in the area is highly attributed to lack of improved drought resistant crop varieties which have been worsened by the climatic variability and changes.

According to the baseline information, low soil fertility, soil moisture shortage, pests and diseases, high cost of input and high climate variability were the most important constraints reported to limit crop production both at Adulala and Jogo-Gudedo /Ketchema/ watersheds, but their degree of severity varies among the two watersheds. Except for high climate variability, all are relatively severe at Jogo-Gudedo /Ketchema/ than Adulala watershed. Although agricultural inputs are expensive at Adulala, it is reported that they are highly accessible. Whereas at Jogo-Gudedo/ Ketchema, not only they are expensive, they are not also highly accessibility, only averagely accessible. It can be concluded that highly accessible inputs at Adulala resulted in relatively lower price (i.e. 88%), likewise averagely accessible inputs at Jogo-Gudedo/ Ketchema resulted in relatively higher price (i.e. 92%).

Low soil fertility coupled with high cost of inputs (i.e. particularly fertilizer) is the most important biophysical constraint for crop production in the two watersheds. Like access to inputs, majority of respondents indicated that lack of improved varieties is the major constraint to crop production at Adulala. However, at Jogo-Gudedo/Ketchema/ improved varieties were neither major nor minor constraints to crop production, it is an average constraint. But under the low soil fertility, it is very unlikely that the improved varieties would perform better.

In view of this, the project implemented participatory testing and adaptation of different improved varieties of major crops grown in the watersheds for two consecutive seasons. A mother trial was established on the farmers' fields to demonstrate and compare the performance of the different improved varieties of the major crops that can produce a considerable yield in moisture stress conditions with the local varieties that the farmers are currently growing. The crops include maize (Melkassa II, Melkassa IV, Melkassa VI and the local variety), tef (Tsedey, Gemechis, Qunco, Magna, Dukem, and local variety), wheat (Kekeba, Assasa, Udea, Danfe, qwame and local variety), haricot bean (Nasir, Awash Melka, Dinkinesh, Awash I and local variety) and barley (Sabini, Derbe and local variety). Average yields of the first season variety trials are indicated in the following figures.

The figure clearly illustrates that a huge increment (85% to 246%) in crop yields were observed in crops like haricot bean and maize in Ketchema watershed, while a considerable yield increase (3.5% to 43.8%) was recorded on the other commodities in both watersheds. The second season trials were laid out in 20 farmers' fields per crop. A total of 100 farmers participated in the participatory variety testing and adaptation trials for the major crops.

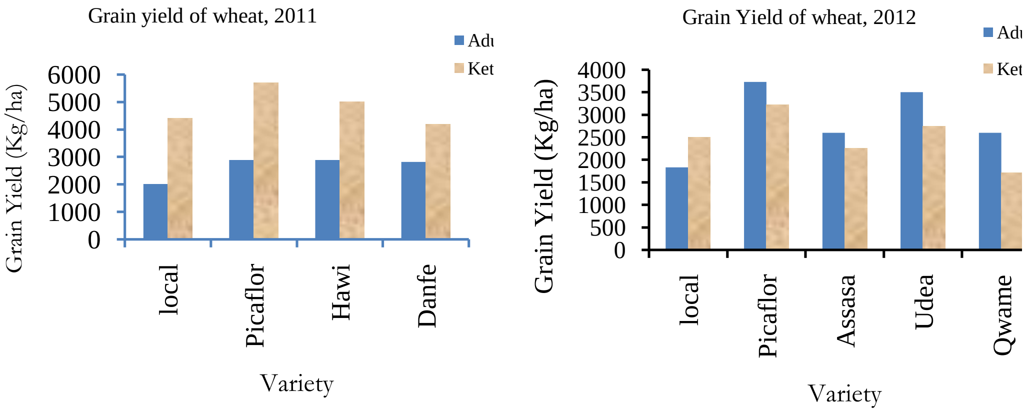

Figure 7. Average grain yields (kg/ha) of wheat varieties tested at Adulala and Jogo-Gudedo/Ketchema/ watersheds in 2011 and 2012 cropping season.

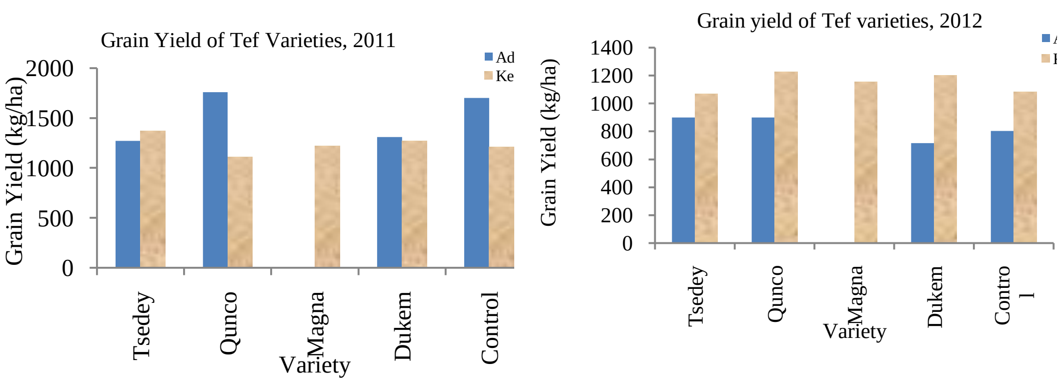

Figure 8. Average grain yields (kg/ha) of Tef varieties tested at Adulala and Jogo-Gudedo /Ketchema/ watersheds in 2011 and 2012 cropping season.

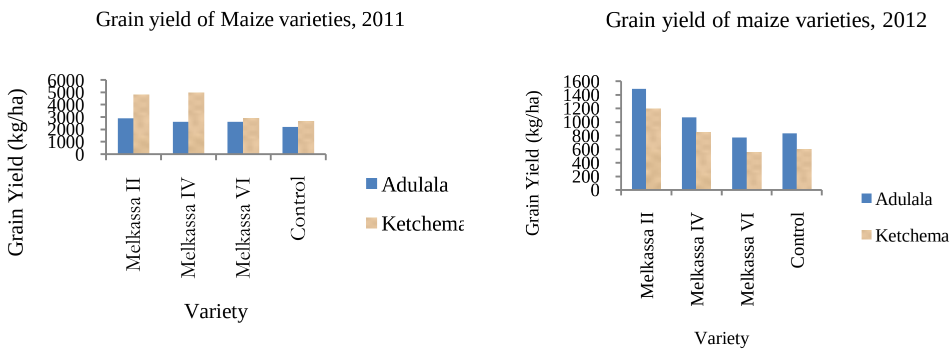

Figure 9. Average grain yields (kg/ha) of Maize varieties tested at Adulala and Jogo-gugedo /Ketchema/ watersheds in 2011 and 2012 cropping season.

The improved crop varieties covered a total area of 25 ha. After demonstration of the performance of drought resistant varieties and water management techniques boost yield in the first year, most farmers in /Jogo-Gudedo/ Ketchema and Adulala showed a great interest to sow the improved varieties of seeds and they exchanged the improved seeds they got from the research with their local seeds to other farmers in a 2:1 ratio because of the demand created after looking at the yield advantages under moisture stress condition. Results of the 2012 growing season are compiled and presented below.

Tef

Five improved varieties of *tef* were tested for its adaptation in the two watersheds. The varieties include Gemechis, Quncho, DZ-cr-37, Tsedey, Magna and local variety. The result showed that the improved varieties showed superior yield advantage to that of the local varieties. Accordingly, Gemechis and Dz-cr-37 gave the highest yield (900 kg/ha) while the local variety gave 545 kg/ha which was by half lower than the improved varieties. On the other hand Quncho gave the highest yield (1225 kg/ha) followed by Gemechis (1209.1 kg/ha). Based on the data as well as farmers' preference, Gemechis and Quncho were widely accepted by the farmers of Adulala and /Jogo-Gudedo/ Ketchema respectively. Figure 10 shows yield obtained from the varieties tested.

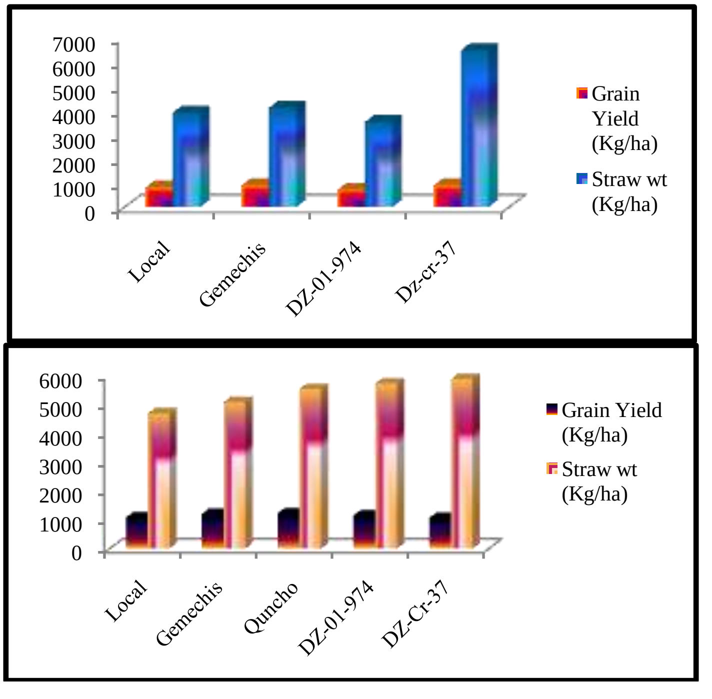

Figure 10. Performance of improved varieties of tef at Adulala (Left) and Ketchema (Right).

Wheat

Four improved varieties of wheat were tested and yield advantage was compared with the farmers' local varieties. Accordingly, *Kekeba* variety was superior in yield performance (3733.3 kg/ha and 3227 kg/ha) at Adulala and /Jogo-Gudedo/ Ketchema respectively. The local variety gave relatively low yield (1333.3 and 2498 kg/ha) at Adulala and /Jogo-Gudedo/ Ketchema respectively as compared to the improved varieties. Demonstration of this activity triggered the farmers and showed a great interest for *Kekeba* variety for the performance it showed for the two consecutive seasons regardless of the rainfall amount they experienced. Consequently, 35 farmers in the first season and 40 farmers in the second season adopted the variety. Figure 11 shows the grain and straw yield of the wheat varieties tested at the two watersheds.

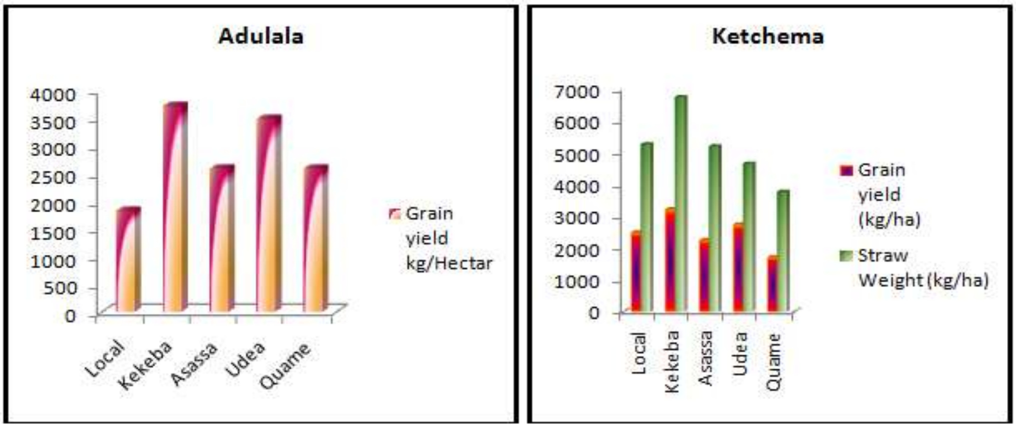

Figure 11. Yield of different varieties of wheat at Adulala and /Jogo-Gudedo/ Ketchema watershed, 2012.

Climate change impacts were numerically tested from the two locations considering the same varieties and farming methods. The result showed that except the local varieties, the improved varieties' yields were low in the low temperature area which can foretell changes in temperature will boost the yield of the tested varieties. The local varieties will possibly be affected by the changing temperature. It has been noted that around 26% yield reduction will be the possible impact of climate change on local varieties of wheat under a 2 ^{o}C increment in temperature in the watersheds. Hence, the improved varieties may be the possible adaptation strategies for the changing climate for wheat.

Haricot bean

Five varieties of haricot bean were tested at Adulala and /Jogo-Gudedo/ Ketchema for its adaptability and yield under present climate condition. The varieties include *Awash I, Awash melka, Nasir, Dinkinesh* and local variety. The result showed that *Nasir* (1652 kg/ha) performed better than the other varieties in Adulala condition, while *Dinkinesh* (1656 kg/ha) followed by *Awash melka* (1551 kg/ha) were superior in yield at Jogo-Gudedo/ Ketchema while the control (1400 kg/ha) showed medium yield. Based on the performance of improved varieties on the farmers' fields, farmers decided to use improved varieties of haricot bean. Accordingly, *Nassir* at Adulala and *Dinkinesh* at Jogo-Gudedo/ Ketchema were selected and used by 40 farmers in the first season (2011) and another 40 farmers in second season (2012). Figure 12 presents the grain and straw yield of the haricot bean varieties tested at the two watersheds.

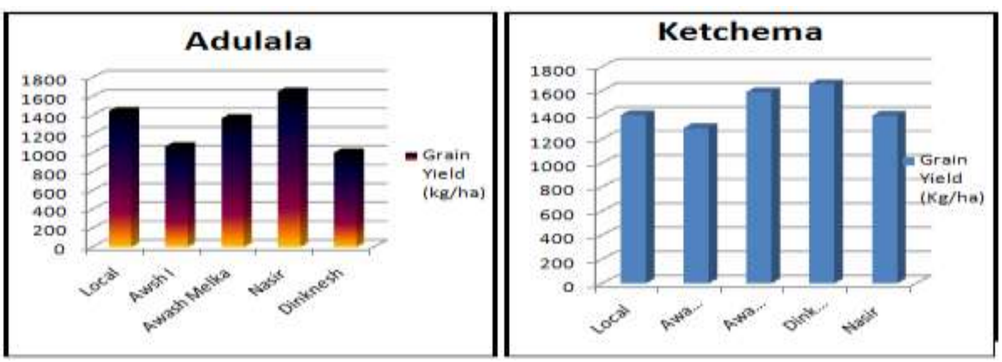

Figure 12. Yield of different varieties of haricot bean at Adulala and /Jogo-Gudedo/ Ketchema, 2012.

Climate change impact on the varieties showed that the yield of the improved varieties will be negatively affected by the changes in temperature. A yield decline of 14% to 39% has been observed within the varieties; however the local variety seems to be not affected by the ongoing increment in temperature. The result implies that strategies should be taken to reduce the impact of climate change.

Maize

Four varieties of maize were tested under the prevailing climatic condition for its yield. The varieties include Melkasa II, Melkassa IV, and Melkassa VI and the farmers' local variety. The results showed that under both site conditions Melkassa II variety (1488 and 1195 kg/ha at Adulala and /Jogo-Gudedo/ Ketchema respectively) provided a considerable yield advantage over the other varieties followed by Melkassa IV (1066 and 866 kg/ha at Adulala and /Jogo-Gudedo/ Ketchema respectively) and Melkassa VI (771 and 556 Kg/ha at Adulala and /Jogo-Gudedo/ Ketchema respectively) at the warmer site (Adulala) and Melkassa IV and Melkassa VI for the corresponding relatively colder site, /Jogo-Gudedo/ Ketchema. The improved varieties responded better than the control at all locations. Figure 13 shows the performance of the tested varieties during 2012 cropping season.

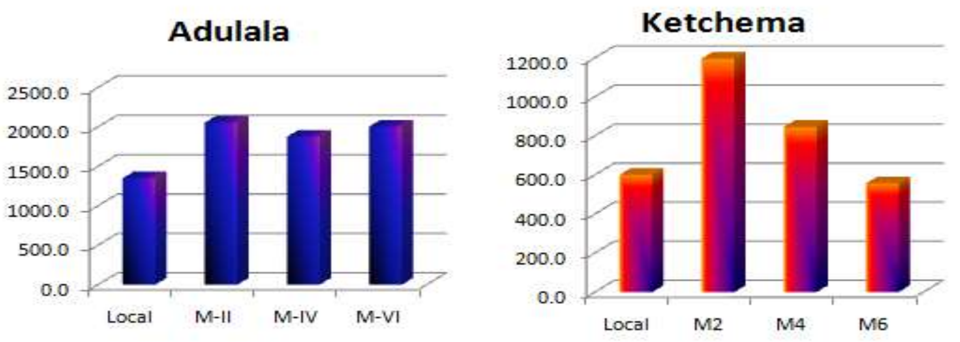

Figure 13. Yield of different varieties of Maize at Adulala and /Jogo-Gudedo/ Ketchema, 2012.

It was observed that the temperature increment has affected maize yields positively and boosted yield. The improved and the local varieties showed a yield increment of 24 to 39% as the temperature increased by 2 ^{0C} in the considered watershed conditions. Improved maize varieties can withstand the prevailing climatic condition.

Barley

Malt barley, Sabini, food barley, and Derbe were tested at Adulala and Ketchema condition and compared for their yield advantage with the farmers' local varieties. The result showed that the improved varieties have a comparable adaptability and yield to that of the locally adapted variety. A considerable yield has been obtained from the malt barley, Sabini, at the lower temperature site, Ketchema, while Derbe performed better for the relatively warmer site, Adulala. Figure 14 shows the performance of the tested barely varieties under conditions of the two watersheds.

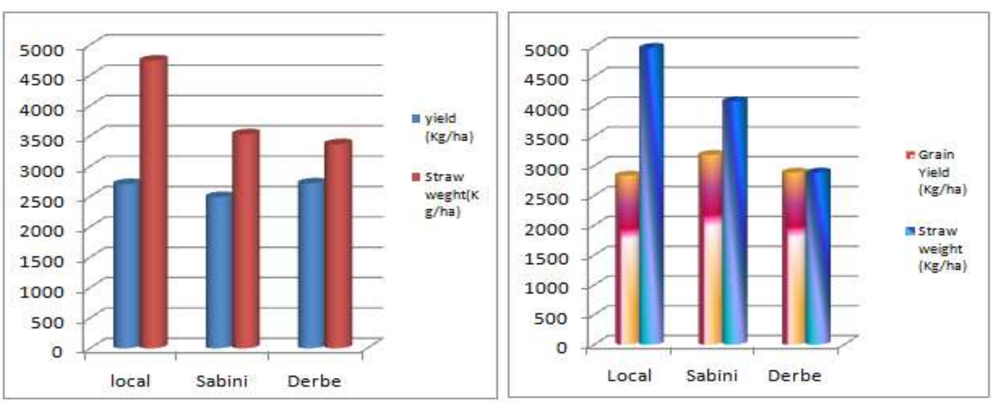

Figure 14. Yield of different varieties of barley at Adulala and /Jogo-Gudedo/ Ketchema, 2012.

Yield of barley has been reduced by increaments of a 2 ^{0}C temperature indicating that as the climate gets warmer barley yields will decline in the tested watersheds. It has been observed that from 4 to 21% yield reduction may occur in barley as the temperature is increasing by two degree celcius.

4. Conclusion and Recommendations

Soil and water conservation action research, through enhancing participation of farmers in planning and adoption of climate-smart soil and water conservation technologies, reduced soil erosion and runoff in the watersheds. Area closures resulted in regeneration of plant species present in the studied watersheds. The agro-forestry systems adopted helped in improving soil fertility as well as reducing labor for women. The integrated soil fertility practices enhanced soil fertility. The energy saving stoves tested resulted in saving of energy coming from consumption of wood. Farmers also adopted crop varieties of *tef*, haricot bean, wheat, barley, and maize that are better adapted to the changing climate based on their performance during the test. Emphasis should be placed on watershed natural resources management as part of local socio-economic development processes in the watershed. By and large, evidences from this approach showed that climate-smart agricultural practices can enhance productivity in areas that are with moisture stress and prone to drought.

From experiences gained from the participatory action research, the following recommendations are forwarded:

- Clear practical strategies for scaling up and extending SWC processes must be developed.
- Partnerships must be built on mutual trust, respect and ownership.
- Conservation measures that are recommended should those that give immediate benefits to the farming communities.
- Local institutions and/or "Bylaw" can have an important role for mass mobilization and technology dissemination and, hence, should be integrated in the government institutions.
- Action research is crucial to strengthen continuum of research and development
- There must be a consensus on the problems to be addressed, and the desired research and development aims.
- Conservation planning should reflect extreme weather events, not just normal weather patterns.

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8 Assessment of the Effects of In-Situ Rain Water Harvesting Techniques on Soil Moisture Conservation and Grain Yield of Maize (*Zea Mays* L.) in Fedis District, Eastern Hararghe, Ethiopia

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Abstract
In the drier farming regions of the world, where crop production is constrained by short growing period, unpredictable and short rainfall with sporadic runoff, in situ rainwater harvesting is vital for successful crop production. In connection to this, a study was conducted in Fedis district of Ormoia region during the main rainy season of 2015 to investigate the effects of selected in situ rainwater harvesting techniques (ridge furrow-RF, contour ridge-CR, and tied ridge-TR) on soil moisture conservation and grain yield of two maize varieties (Melkasa 4 and BH 661). A split-plot design was used and soil moisture content was measured at three stages of the crop (early, mid, and late stages) to a depth of 60 cm with 20 cm interval. The results showed that water harvesting techniques significantly ($P < 0.05$) increased soil moisture conservation compared to the control, which was flat bed preparation. Averaged over the three stages, the CR, TR, and RF treatments increased soil moisture storage by 147.77, 145.31, and 150.50%, respectively, compared to the control. The study also revealed that the in-situ rainwater harvesting techniques, due to the improved soil moisture storage, significantly ($P < 0.05$) affected grain yield of the two maize varieties. The TR, FR, and CR increased the grain yield by 130.55, 126.23, and 123.85%, respectively, over the control treatment for variety Melkasa 4. The corresponding improvements in grain yield for variety BH 661 due to the use of TR, FR, and CR were, respectively, 122.67, 124.29, and 138.31%. Therefore, in drier environments, such as Fedis, in situ rainwater harvesting techniques can be recommended for better moisture conservation and subsequent improvement in crop production.

Keywords: In situ rainwater harvesting; soil moisture; contour ridge; tied ridge; ridge furrow

1. Introduction

Agriculture is the major economic activity for Sub-Saharan countries, and it is strongly considered as the backbone of these countries' economic development and their people's wellbeing in the future (Giller *et al.,* 2009). Rapid population growth occurs in developing countries with a significant proportion still depending on a predominantly rainfed agriculture based economy. Unfortunately, in several regions, including Africa, rain fed agriculture has generally been associated to low yield levels, and high on-farm water losses. As a result, the majority of the people are not able to ensure their food security. Low crop productivity, food insecurity and malnutrition characterize the smallholder subsistence agriculture based community (Bekele, 1998).

From the 41% of semi-arid region of Sub-Saharan Africa farming land, only about 2% of the arable lands are irrigated, that is, rain fed agriculture is the dominant crop production system to meet the food demand (Zougmoré *et al.,* 2002). However, the unreliability in rainfall and recurrent droughts often lead to subsequent production failures and puts great pressure on the food self-sufficiency of the region. The low soil water retention capacity or the high potential evapotranspiration rate is the major problem.

Among the environmental problems people in eastern lowlands of Ethiopia are vulnerable to, soil moisture stress problem and the consequent notable droughts are the major ones constraining crop production (Gebre-Michael and Kifle, 2009; Tadesse *et al.,* 2008; UNEP, 2006). Some studies have been done on the effectiveness of micro-basin tillage to improve soil moisture in different parts of the semiarid areas in highlands of Ethiopia (Aklilu and Mekiso, 2015; Gebreyesus, 2012; McHugh *et al.,* 2007; Heluf, 2003). Except, Aklilu and Mekiso (2015), all of the studies were at the highlands. However, the same problem (soil moisture stress) is happening in low lands of eastern Hararghe. This indicates that there were less or no studies done to identify suitable in-situ rainwater harvesting techniques to solve crop production problem. Hence, this study was carried out in Fedis district, East Hararghe zone of Oromia regional state, Ethiopia. The objective of this study was to determine the effect of selected *in situ* rainwater harvesting techniques on soil moisture conservation and grain yield of maize.

2. Materials and Methods

2.1. Description of the Study Area

The field experiment was conducted during the main rainy season (May to December) of 2015 in eastern Ethiopia, at Fedis research sub- station of Haramaya University. Fedis is one of the *woreda's* of eastern Hararghe Zone in the semi-arid belt of the eastern low lands in the Oromia regional state. The station is located west of Boko town in the semi-arid area of Fedis *woreda*. Climatically, the district is classified into *woinadega* (15%) and *kola* (85%) agro climatic zones. The area is characterized by bimodal rainfall distribution locally called "*Belg*" and *Meher*. The "*Belg*" season is between March and May, and the main rainy season, *Meher*, extends from July to October (Fedis Woreda Office of Agriculture). The site is situated at $9^{0}07'$N and $42^{0}4'$E with an altitude of 1702 meters above sea level (GPS measurement). In the study area, the mean annual maximum and minimum temperature is 27.8 and 8.8 ^{0}C, respectively, and the area annual rainfall of the cropping season was 714.3 mm (Fedis Agricultural Research Centre).

2.2. Treatments and Experimental Design

The experiment was conducted by using spilt-plot design with three replications. Treatments tested on the main-plot were two maize varieties (Melkasa 4 and BH 661), and the sub plots consisted of contour ridge (CR), tied ridge (TR), ridge furrow (RF) and Fat bed planting (FBP), which is control. Recommended rates of N and P fertilizers were used. Buffer zones were left between plots and around the experiment area to facilitate crop management operations. Each plot was consists of six (6) rows spaced 75 cm between rows with row length of five meter. The spacing between plants within the row was 30 cm. Ridges with 20-30 cm height; in CR, TR and RF treatments of 0.75 m spacing was constructed using a ridger implement. Cross earth ties in TR, 8-12 cm in height, was manually constructed with hoes at 1.5 m apart. Sowing was done in the furrow.

2.3. Data Collection and Statistical Analysis

The soil moisture content data was collected from three depths (0-20, 20-40 and 40-60 cm) at three periods (viz. early, mid, and late vegetative growth stages) during the growing season, and expressed in equivalent depth of water (mm) per 0.6 meter soil depth (assumed to be the depth of the root zone). The soil water stored (%) in each 0.2 m incremental depth down to 0.6 m was determined gravimetrically. It was then converted to water depth (mm) by multiplying the gravimettric water content by the specific bulk density value measured by the core sampler method from the respective depths as described by Blake (1965). Grain yield and all other desirable data and samples were collected from the three central rows of each plot.

Statistical analysis was conducted for the collected data with the help of SAS software version 9.1. ANOVA was computed and mean differences were made by using least significant difference (LSD) at P=0.05. The results were presented by using tables, figures and text.

3. Results and Discussion

3.1. The Effect of *in Situ* Rainwater Harvesting Techniques on Soil Moisture Conservation

The effects of the treatments on SMC are presented in Table 1 below. In all measurement depths at the three vegetative growth stages, the results obtained showed significant (P>0.05) difference in SMC between *in-situ* water harvesting treatments and FBP. Accordingly, *in-situ* water harvesting treatments (RF, TR and CR) recorded SMC values that were higher than the FBP in all the depths. This result was in agreement with the findings of Ibrahim (2008), Mohammed (2009), Li *et al.* (2000), Tian *et al.* (2003), and McHugh *et al.* (2007).

In this area, using of the conventional tillage method (FBP) may not help to conserve enough water for crop production, mainly due to the erratic rainfall that induces runoff. High intensity rain showers also enhance water losses through runoff. Crop growth conditions may further be hampered by a number of climatic factors such as, low and erratic rainfall, low humidity levels and high temperature during growing season (Botha *et al*,. 2003).

The water harvested was retained and was far from the evaporative effects but within reach of plant roots. This is because of the presence of heavy textured soil at 40-60 cm depth (sandy clay) than top 0-20 cm (sandy clay loam). Lateral flow through which water harvested in the channels could benefit crops can only take place theoretically in the presence of a flow impeding layer at depth. This means water harvested in the channels feeds the soil until it reaches the impervious layer and starts flowing laterally or rising, thereby providing a reservoir of water to the crop at depth which on clays or heavy textured soils, rises by capillarity during dry spells and ensure the crop benefits.

Table 1. Treatment means for soil moisture storage (mm/depth) at three vegetative growth stages from three depths.

	Vegetative growth stages								
	Early			Mid			Late		
	Depth (cm)								
Treatments	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
TR	37.54[a]	39.55[a]	38.70[a]	37.00[a]	39.29[a]	34.41[a]	30.59[a]	31.56[a]	31.94[a]
FR	35.39[b]	35.49[b]	34.36[b]	33.31[b]	35.45[b]	32.66[a]	29.62[b]	31.19[a]	31.37[a]
CR	34.87[b]	35.26[b]	37.66[a]	35.18[b]	38.02[a]	34.97[a]	28.87[b]	30.23[a]	30.93[a]
FBP	26.40[c]	26.82[c]	26.28[c]	24.67[c]	24.43[c]	22.39[b]	21.56[c]	23.19[b]	21.23[b]
LSD	1.62	2.98	2.45	2.14	1.86	2.85	0.94	2.17	3.70

LSD0.05 = least significant difference at 5% level and means in a column followed by the same letter are not significantly different at P =0.05.

3.2. The Effect of *in Situ* Rainwater Harvesting Techniques on Grain Yield Of Maize

The *in situ* rainwater harvesting techniques affected grain yield of maize significantly ($P < 0.05$). For Mekassa 4 variety, all the rainwater harvesting treatments gave a significantly higher grain yield as compared to the control treatment. Accordingly, grain yield improvement of 130.55, 126.23, and 123.85%, respectively, over the control was recorded due to the use of TR, FR, and CR treatments. On BH 661 maize variety only the CR treatment resulted in significantly higher grain yield as compared to the control (Table 2). Nevertheless, improvements in grain yield amounting to 122.67, 124.29, and 138.31% over the control were recorded due to the use of TR, FR, and CR respectively.

All the *in situ* rainwater harvesting treatments performed much better than the control treatment for both varieties. This might be due to the fact that the harvesting structures stored rainwater *in situ* and enhanced infiltration, which provides a reservoir of water to the crop at a depth where fine textured soils (sandy clay) are found and rises by capillarity during dry spells and ensure crop benefits. This result is in agreement with the finding by Gebreyesus (2012) that tied-ridge and fertilizer, and its interaction significantly influenced the yield and yield components of sorghum and resulted in up to 48% increment. Tied ridges found to be very efficient in storing the rain water, which has resulted in substantial grain yield increase in some of the major dryland crops such as sorghum, maize, wheat, and mung beans in Ethiopia (Georgis and Takele 2000). The average grain yield increase (under tied ridges) ranged from 50 to over 100 percent when compared with the traditional practice. This increase, however, will vary according to the soil type, slope, rainfall and the crop grown.

In the current result, the yield of maize was affected by all the *in situ* rainwater harvesting treatments. The work of Heluf (2003) also supports this finding by the fact that the yield response to water conservation treatments was higher both under fertilized and unfertilized conditions than the control treatments.

Table 2. The effect of in-situ rainwater harvesting techniques on grain yield of maize (quintal/he).

Treatments	Grain yield (Quintal/ha)			
	Melkasa 4		BH 661	
	Mean	SD	Mean	SD
TR	43.89[a]	5.43	37.98[ab]	3.15
FR	42.44[a]	4.10	38.48[ab]	8.22
CR	41.64[a]	2.64	42.82[a]	6.55
FBP	33.62[b]	1.74	30.96[b]	1.41
CV (%)	9.28		14.73	
LSD0.05	7.06		10.42	

LSD0.05 = least significant difference at 5% level and means in a column followed by the same letter are not significantly different at P =0.05.

4. Conclusion and Recommendations

In areas where the rainfall distribution is uneven and erratic, rainwater harvesting using structures, such as furrow ridge, tied ridge, and contour ridge, can significantly improve soil moisture storage and serve to meet crop water requirements at a later stage when the rains stop. The differences in soil moisture storage were translated into grain yield of two maize varieties. Accordingly, significant improvements in grain yield were recorded due to the use of the rainwater harvesting techniques as compared to flat bed planting. Nevertheless, varietal difference in response to *in situ* rainwater harvesting was also noted, suggesting that variety selection for better response is also vital.

Since this experiment is conducted for a single season and one soil type, repeating the experiment for another season is required to make comprehensive recommendation for Fedis area. Furthermore, the experiment should be conducted on different soil types and also crops to come to recommendation for wider areas and crop types.

5. Acknowledgments

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9. Effects of In-Situ Rainwater Harvesting Techniques on Yield and Yield Components of Field Crops Grown in Babile, Eastern Ethiopia

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Abstract

Moisture stress is one of the crop production constraints that cause significant yield and quality reduction. Therefore, a field experiment was conducted in 2008 cropping season at Babile Research Station of Haramaya University in Eastern Ethiopia to select in-situ rainwater harvesting techniques which increase agricultural water productivity by comparing the effect of in-situ rainwater harvesting treatments on the yield and yield component of sorghum (Sorghum bicolor L. Moench), maize (Zea mays L.), and common bean (Phaseolus vulgaris L.). The treatments comprised of in-situ rainwater harvesting techniques with a runoff strip width of 1 m (IRWH1), 1.5 m (IRWH1.5) and 2 m (IRWH2), closed end tied ridge (TR) and conventional tillage (CT). The experiments were laid out in a Randomized Complete Block Design (RCBD) with three replications for each crop. In-situ rainwater harvesting treatments stored the highest amount of water whereas the CT treatment stored the lowest amount of water during most of the measurement periods. Yield per plant of sorghum was significantly ($P<0.05$) affected by the treatment effects. Furthermore, compared to the CT treatment, the IRWH1, IRWH1.5, IRWH2 and TR treatments increased grain yield per plant by 117, 104, 130 and 65%, respectively. Grain yield per plant of maize was not significantly affected by the treatment. However, compared to the CT, the IRWH1, IRWH1.5, IRWH2 and TR treatments improved grain yield per plant by 43, 34, 32 and 33%, respectively. Seed yield per meter square of common bean was significantly affected ($P<0.05$) by the treatments. Compared to the CT, the IRWH1, IRWH1.5, IRWH2 and TR treatments increased seed yield per meter square by 71, 56, 33 and 29%, respectively. In general, the IRWH treatments have a potential to increase the grain yield of crops.

Keywords: Conventional tillage; drought; in-field rainwater harvesting; yield per plant

1. Introduction

The majority of rural people in Ethiopia depend entirely on rainfed agriculture for their livelihoods. The country's food insecurity is the result of the cumulative effects of the various factors that have increased in magnitude over many years. Some of the major factors contributing to food insecurity include extended gap between level of food production and rapid population growth, degradation of the natural resource-base, dominance of crop farming, which is mainly dependent on rainfed cultivation, erratic and unreliable rainfall pattern that lead to poor agricultural production (Hune, 2004). The high risk of crop failure due to erratic and unreliable rainfall pattern makes rainfed agriculture a risky business.

Rainfall distribution in the arid and semi-arid regions of Ethiopia is erratic and low in amount resulting in soil water deficits at some critical stages of crop growth (MoA, 2000). This leads to lower crop yields and sometimes total crop failure. It is, therefore, necessary to seek for suitable water conservation techniques that could combat the low soil water storage problem and improve rainwater productivity (RWP). These strategies are particularly important for critical crop growth stages, as well as for the whole growing period.

Sorghum (*Sorghum bicolor* L. Moench), maize (*Zea mays* L.) and common beans (*Phaseolus vulgaris* L.) are the major food crops grown in the Hararghe region. In East Hararghe zone, sorghum, maize and common beans cover an area of 104,934.29, 62,368.59 and 11,194.24 ha, respectively (CSA, 2007). However, drought causes a great deal of instability and uncertainty in crop production in this zone (Shemelis *et al.,* 1990; Storck *et al.,* 1991). Therefore, improved resource management system that allows effective conservation and utilization of the meager rainfall that ensures sustainable production is required.

According to Reddy and Kidane (1993), the most efficient and cheapest way of conserving rainfall is to hold it *in-situ*. There are wide ranges of *in-situ* water harvesting techniques known throughout the arid and semi-arid regions of the world (Critchley and Reij, 1989; FAO, 1994). One of such techniques is the in-field rainwater harvesting (IRWH) technique. According to Oweis and Hachum (2006), in-field rainwater harvesting is defined as the process of concentrating precipitation through runoff and storing it for beneficial use. The IRWH systems are micro-catchments using sheet flow from short slopes within the cultivated fields. The systems maximize infiltration of rainfall by concentrating the runoff from in-field strips (micro-catchments) to a cultivated crop. The IRWH technique reduces runoff from field to zero by converting it to stored soil water, and hence lead to increased yields (Hensley *et al.,* 2000). The technique is simple because it can be done with locally available tools and easy to farmers to perform.

The IRWH technique showed good potential in the semi-arid areas of South Africa (Hensley *et al.,* 2000). The objective of this technique is to maximize rainwater productivity (RWP) and hence known as mini-catchment runoff farming (Owies *et al.,* 1999). According to van Rensburg *et al.* (2003), the surface layout of the technique is based on runoff strip followed by wide basin in which crops are planted in the basin area while the runoff area is kept as a no-till/no-plant area. The aim of this structure is to collect runoff from runoff strip, so that crops planted in the basin can benefit from the collected water. The width of runoff strip can vary depending on soil, rainfall and crop conditions.

In-field rainwater harvesting technique is a sustainable crop production tool that has the ability to empower people in rural villages and enable them to fight food insecurity (Botha *et al.,* 2003). Hensley *et al.* (2000) and Botha *et al.* (2003) reported a significant yield increase of maize, sunflower and sorghum grown using the IRWH technique.

To alleviate the serious problem of food scarcity and to get benefit from the vast area of the drylands of Ethiopia, which accounts for more than 66% of the total land mass (Kidane *et al.,* 2001), crop yield should be increased by using appropriate crop production technologies. In eastern Ethiopia, there is population pressure, land shortage, soil erosion, and periodically occurring drought (Dechassa, 2001). To solve these problems, the scarce land and moisture resources should be exploited properly so that the sustainability of crop production is ensured. This calls for the selection and evaluation of a range of *in-situ* rainwater harvesting techniques for their appropriateness to the area. One of these techniques, which has been found to be very promising in the arid and semi-arid areas of South Africa, is the in-field rainwater harvesting (IRWH). The IRWH contains a runoff strip for runoff generation and a basin for collection and storage of the generated runoff. The runoff strips serve as a micro-catchment. As, a result the amount of runoff volume generated depends on the size (width) of the runoff strips.

The research conducted in Ethiopia and South Africa showed that, IRWH with 2 m runoff strip width in combination with different mulching materials in the basin and runoff strip area increased grain and above ground biomass yield compared with conventional tillage. However, so far, the IRWH with runoff strip width 1, 1.5 and 2 m, respectively without mulching materials have not been tested against the tied ridge, which was found to be effective in different parts of Africa. Therefore, evaluation of the suitability of the in-field rainwater harvesting technique with respect to the width of its runoff strips and other *in-situ* rainwater harvesting techniques in Babile area where there is moisture scarcity is a priority. Thus, the objective of this experiment was to compare the effects of *in-situ* rainwater harvesting techniques on the yield and yield components of sorghum, maize and common bean crops grown in Babile.

2. Materials and Methods

2.1. Site Description

Babile is situated at 9˚13´ N and 42˚19´ E, with altitude ranging between 1644 to 1655 m.a.s.l. and slope of 5-10% (Bobe, 2004). The area is characterized by bimodal rainfall with the first rainy season (*belg*) extending from March to mid-May and the main rainy season extending from July to September. The long-term (12 years) annual average rainfall is 719.2 mm. The 12 years mean minimum and maximum temperatures were 15.4 and 28.3 ˚C, respectively with an average temperature of 21.9 ˚C. The major crops grown in the area include khat (*Catha edulis* L.), groundnut (*Arachis hypogaea* L.) and sorghum (*Sorghum bicolor* L. Moench) (Bobe, 2004).

2.2. Experimental Materials

This study consisted of sorghum, maize, and common bean, which are adapted to the dryland area. The detailed description of the three crop varieties is given in Table 1.

Table 2. Description of the crop varieties used for the experiment.

Crops	Varieties	Adaptation area Altitude (m.a.s.l)	Rainfall (mm)	Days to Maturity	Year of release
Sorghum	76TI#23	Less than 1600	600	90-120	1979
Common Bean	Melka Awash-98 (PAN-182)	Low land, hot region		95-100	1998/99
Maize	Katumani	1000-1600	600-800	110	1974

Source: (NSIA, 1998; Mandefro et al., 2001; MoARD, 2007).

2.3. Treatments and Experimental Design

The treatments comprised of five *in-situ* water harvesting techniques and three field crops (sorghum, maize and common bean). The five water harvesting treatments were:

1. In-field Rainwater harvesting with 1 m wide runoff strip (IRWH1),
2. In-field Rainwater harvesting with 1.5 m wide runoff strip (IRWH1.5),
3. In-field Rainwater harvesting with 2 m wide runoff strip (IRWH2),
4. Closed-end tied ridge (TR), and
5. Conventional (flatbed) tillage (CT).

The treatments were laid out in randomized complete block design (RCBD) with three replications and randomly assigned in each of the replications. The spacing between plots and blocks were 1m and 2 m, respectively. For maize and sorghum crops, plot sizes of 100, 125 and 150 m^2 were used for the IRWH1, IRWH1.5 and IRWH2 treatments, respectively, while a plot size of 75 m^2 was used for the tied ridge and conventional tillage treatments. For the common bean crop, the corresponding plot sizes for the IRWH1, IRWH1.5 and IRWH2 treatments were 75, 100 and 125 m^2, respectively, whereas a plot size of 40 m^2 was used for the tied ridge and conventional tillage treatments.

A basin, one m. wide and 0.30 m. deep, was prepared to store the water coming from the respective runoff strips in sorghum and maize fields. The corresponding dimension of the basin for the common bean crop was 0.5m wide and 0.2m deep. To ensure uniform distribution of water throughout the length of the IRWH and TR treatments` fields, the basins of the IRWH treatments and the furrows of the TR were tied in the middle along the length of the basins and ridges, respectively. The respective runoff strips of the IRWH treatments were compacted by human feet to discourage infiltration of water into the runoff strip fields and thereby encourage runoff.

The spacing used between rows and plants was, 75 cm x 20 cm for sorghum, 75 cm x 30 cm for maize, and 40 cm x 10 cm for common bean, in the IRWH and tied ridge treatments while seeds were broadcasted in the conventional tillage treatment.

The seeds of sorghum, maize and common bean were planted on June 9, May 18 and July 21 2008, respectively. Seeds of sorghum and maize were planted in the basin by preparing two rows within a basin by leaving 12.5 cm at each border, for IRWH treatments. In case of the TR treatment of sorghum and maize, rows were prepared within tied ridge at spacing of 75 cm between rows. The sowing of common bean was done by preparing 2 rows within a basin by leaving 5 cm at each border of a basin, then the spacing between rows was 40 cm. In tied ridges of common bean, rows were prepared in the tied ridge with spacing of 40 cm between rows. In case of IRWH treatments, the two rows of crop, which were found in the basin, were watered by the water, harvested from the respective runoff strip area.

The recommended seed rate of 10, 25 and 90 kg/ha were used for sorghum, maize and common bean, respectively (MoARD, 2006; MoARD, 2007). Recommended rates of fertilizers 46 kg/ha P_2O_5 and 64 kg/ha N for sorghum (MoARD, 2007) and 46 kg/ha P_2O_5 and 92 kg/ha N for maize (MoARD, 2006) were used. However, the common bean experimental plot did not receive any fertilization. Thinning was done after emergence to have optimum plant population per plot. All the plots were weeded manually during the cropping season.

Each plot had 10 rows except the conventional tillage plots. Data were collected from the middle six rows out of 10 rows of plant population per plot by excluding the border two plants at each end of rows. The data of tied ridge and conventional tillage treatments were collected from a net plot area of 41.85 m^2, 43.20 m^2 and 23.52 m^2 for maize, sorghum and common bean, respectively.

2.4. Data Collection and Experimental Procedure

2.4.1. Soil sampling and analysis

Disturbed (from 0-30 cm depth) and undisturbed (0-30, 31-60 and 61-90 cm depths) soil samples were collected from across the experimental field before planting. The disturbed samples were then mixed thoroughly to form one composite sample. The composite sample was air dried and ground to pass through a two mm diameter sieve in the laboratory. The disturbed sample prepared in this way was used for analysis of particle size distribution, soil pH, available phosphorus, organic carbon, whereas for the determination of total nitrogen the soil samples were passed through 0.5 mm sieve.

Particle size distribution was determined using the pipette method (Ranst *et al.,* 1999); Soil pH was measured using pH meter (Chopra and Kanwan, 1976). Organic carbon was determined using the wet digestion method (Walkely and Black, 1934). The total nitrogen was determined following the Kjeldahl procedure (Bremner, 1965) and the available phosphorus was determined using the Olsen II method (Olsen *et al.,* 1954).

The undisturbed samples were collected using soil cores fitted into core sampler and determined by the core method. The equilibrium water content at -33 and -1500 kPa was determined gravimetrically. The available water holding capacity of the soil was calculated as the difference in water content at field capacity and permanent wilting point. Infiltration rate was determined in the field using the double ring infiltrometer.

The rainfall and temperature data of the experimental site were collected during the cropping season from the nearby Babile meteorological station.

2.4.2. Data collected on crops

2.4.2.1. Yield and seed weight of sorghum and maize

Grain yield per net harvest plot area was recorded as the total grain weight obtained from net plot area after adjusting the yield to 12.5% moisture content by using seed moisture tester, then after converted to grain yield per m^2. Grain yield per plant was determined by taking the average grain weight of 5 randomly taken plants at maturity from the net plot area. Thousand grain weight was determined by taking 1000 sample grains randomly from the harvested grain.

2.4.2.2. Yield and seed weight of common bean

Seed yield per net harvest plot area was recorded as the total grain weight obtained from net plot area after adjusting the yield to 10% moisture content by using seed moisture tester, then after converted to seed yield per m^2. Hundred seed weight was determined by taking 100 sample seeds randomly from the net plot area after harvest.

2.5. Soil Water Changes

The soil water content was measured gravimetrically on samples collected every seven days when soil sampling was possible. Samples were collected from the 0-30 and 31-60 cm depths for common bean and maize fields while the 61-90 cm depth was included for sorghum fields. The gravimetrically determined water contents were converted into volumetric water contents by using bulk density values determined for the respective depths. Furthermore, the volumetric water contents were converted into equivalent depths, expressed in mm, by multiplying the values by the respective depths. The total soil water storage in the entire sampling depth of each crop's field was then expressed in mm/m using the following relationship:

$$\left[\text{Storage(mm/m)} = \frac{\text{Storage in the i}^{\text{th}}\text{ layer(mm)}}{\text{Thickness of the i}^{\text{th}}\text{ layer(mm)}} \times \frac{1000\,\text{mm}}{\text{m}} \right]$$

2.6. Data Analysis

Data were subjected to analysis of variance following a procedure appropriate to the design of the experiment (Gomez and Gomez, 1984) using statistical software SAS version 9.0. Least significant difference (LSD), test was used for treatment mean separation where significant differences exist (Gomez and Gomez, 1984).

3. Results and Discussion

3.1. Meteorological Condition During the Experimental Period

The seasonal monthly rainfall distribution and the minimum and maximum temperatures of the experimental site are presented in Figure 1. The total rainfall (765.5 mm) recorded over the period of the cropping season was generally above the 12 years average for the area and could be seen as optimum for crop growth.

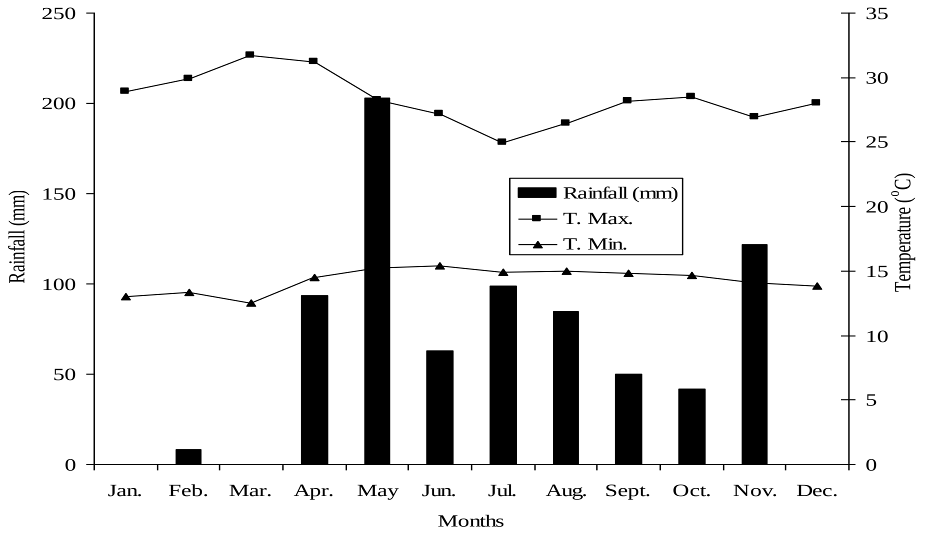

Figure 1. Rainfall (mm), minimum and maximum temperatures (oC) recorded during the cropping year (Source Babile Meteorological Station).

The seasonal rainfall of the cropping season started early and ceased later than the average onset and offset of the historical means. Accordingly, the length of the growing period was more than four months, which is enough for long season crops, such as sorghum. Due to uneven distribution of rainfall, frequent dry spells were common in between rainfall events.

3.2. Soil physical and Chemical Properties

The soil analyses results are presented in Table 2. The textural class of the soil is sandy clay loam. The average bulk density of the 0-90 cm soil depth was 1.77 g/cm^3. Although coarse-textured soils generally have high bulk density values compared to the fine-textured ones, this value seems too high, which indicates the existence of soil compaction.

According to soil pH rating of Tekalign (1991), the soil was moderately alkaline. The organic carbon content of the soil was 1.71% and was moderate according to the rating established by Berhanu (1980). Similarly, according to the rating of Berhanu (1980) and Landon (1991) total nitrogen, of the soil was very low. The Olsen P measured was 1.28 ppm. This value lies below the critical soil test value for crops for the Olsen extractable P (8.5 ppm) established by Tekalign and Haque (1991) for some Ethiopian soils. In general, the results of the soil analysis mentioned above indicate that the soil is relatively poor in its natural fertility.

Table 3. Selected soil physical and chemical properties of the soil at the experimental site.

soil property	Result
TEXTURAL CLASS	*SANDY CLAY LOAM*
BULK DENSITY (G/CM^3)	1.77
ORGANIC CARBON (%)	1.71
PH (H_2O)	7.6
Total Nitrogen (%)	0.01
Olsen P (ppm)	1.28
INFILTRATION RATE (CM/HR)	9.32
Water content at (%v/v)	
FIELD CAPACITY	25.84
PERMANENT WILTING POINT	21.24
AVAILABLE WATER HOLDING CAPACITY (%V/V)	4.60

3.3. Influence of Rainwater Harvesting Treatments on the Soil Water Storage Changes, and Yield of Sorghum

3.3.1. Soil water storage changes

The soil water storage changes of the sorghum fields for the entire sampling depth (0-90 cm) for the crop growing cycle are presented in Figure 2. The results indicated that all the treatments stored the maximum amount of water, which ranged from 337 mm/m in CT to 477 mm/m in IRWH1, 29 days after planting whereas the minimum amount of water, which ranged from 87 mm/m in CT to 115 mm/m in IRWH1, was stored 56 days after planting (Figure 2). These relatively high soil water storages were the cumulative effects of the relatively high rainfall which occurred in the months of May and mid-June (Figure 1). The relatively higher soil water storage towards the end of the crop cycle was the result of the high amount of rainfall that occurred during the month of November (Figure 1). By and large, the differences in soil water storage among the treatments, as can be seen from the Figure 2, were not distinct during much of the growing season albeit some differences. This could be due to the relatively high amount of rainfall during the growing season. Although none of the treatments stored consistently high or low amount of water during all the measurement periods, the IRWH1 treatment stored the highest amount of water whereas the CT treatment stored the lowest amount of water during most of the measurement periods. Naturally, *in-situ* water conservation technologies retain better amount of moisture during periods with low rainfall amount.

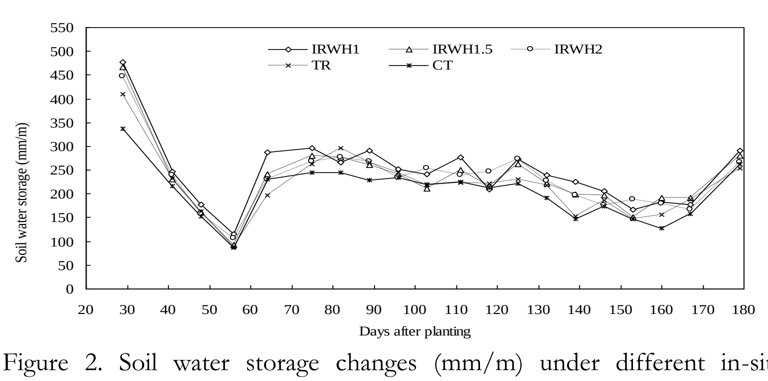

Figure 2. Soil water storage changes (mm/m) under different in-situ rainwater harvesting treatments during the growing season for sorghum field.

3.3.2. Yield and seed weight of sorghum

3.3.2.1. Grain yield per plant and per meter square

Grain yield per plant was significantly ($P<0.05$) affected by the treatments applied but grain yield per meter square was not significantly affected (Table 3). The CT treatment gave significantly lower grain yield per plant while all IRWH and the TR treatments had the same grain yield per plant. The TR treatment also was not significantly different from the CT treatment. This indicates that the IRWH treatments were superior to the CT in producing grain yield on individual plant bases. Furthermore, compared to the CT treatment, the IRWH1, IRWH1.5, IRWH2 and TR treatments increased grain yield per plant by 117, 104, 130 and 65%, respectively.

Table 3. Grain yield per plant, grain yield per meter square and thousand grain weight of sorghum as influenced by in-situ rainwater harvesting treatments.

Treatments	Grain yield per plant (g)	Grain yield per meter square (kg)	Thousand grain weight
IRWH1	50[a]	0.124	35[a]
IRWH1.5	47[a]	0.123	35[a]
IRWH2	53[a]	0.116	35[a]
TR	38[ab]	0.119	34[ab]
CT	23[b]	0.083	31[b]
LSD (5%)	23	*ns*	3.1
CV (%)	19.1	7.4	3.2

IRWH 1, 1.5 and 2 = In-field rainwater harvesting with 1, 1.5 and 2 m wide runoff strip, respectively; TR = Tie ridge; CT = Conventional tillage; LSD = Least significant difference; CV = Coefficient of variation; ns = Non significant.

3.3.2.2. Thousand grain weight

Thousand grain weight was significantly ($P<0.05$) affected by the treatment effects (Table 3). There was a significant difference in thousand grain weight between all the IRWH and the CT treatments. However, the IRWH treatments did not give significantly different thousand grain weight than the TR treatment.

The lowest thousand grain weight in the CT treatment could be due to the relatively low soil moisture storage in CT treatment compared to the IRWH and TR treatments during most of the growth period (Figure 2). The effect of moisture availability on thousand grain weight had been established (Manjarrez-Sandoval *et al.,* 1989). Sorghum grain weight reflects the growing conditions experienced by the crop during the grain filling period. One of the desired characteristic of sorghum is its ability to compensate for the effects of early low soil moisture by producing large grain size upon withdrawal of rainfall (Blum *et al.,* 1989). Relatively low soil moisture at flowering affects grain number while stress during grain filling affects grain size. In the current study, therefore, the treatments that supplied enough water during flowering and grain filling stages gave higher thousand grain weight than those treatments which conserved less water. The thousand grain weight of the treatments was within a range of 31-35 g. This range is within a range of values given for the variety, which is 30-70 gram (NSIA, 1998). Individual grain size is the function of translocation of assimilates stored in temporary sink (mainly stem) and the level and duration of current assimilates particularly from the flag leaf (Huda *et al.,* 1987; Palaniswamy *et al.,* 1986). In line with this experiment, Gebreyesus *et al.* (2006) reported lower hundred grain weight in the flat planting compared with tied ridge planting. Moreover, Dechassa (2005) reported that thousand grain weight of sorghum was significantly affected by moisture conservation treatments in Miesso with total rainfall amount 713 mm. On the other hand, Tesfaye (2006) reported that *in-situ* water harvesting treatments had no effect on 500 g weights of sorghum even though marked differences were observed in available soil water due to the *in-situ* water harvesting treatments in Ebinat with total rainfall amount 712.1 mm.

3.4. Influence of Rainwater Harvesting Treatments on the Soil Water Storage Changes and Yield of Maize.

3.4.1. Soil water storage changes

The soil water storage changes for the entire depth (0-60 cm) are depicted in (Figure 3). The results indicated that all the treatments stored the lowest amount of water, which ranged from 45 mm/m in TR to 69 mm/m in IRWH1 treatments, 48 days after planting. This time corresponds to the period when there was no rainfall. However, the highest amount of water stored by each treatment occurred at different periods. Except at 48, 64 and 111 days after planting, the conventional tillage treatment field stored relatively low amount of water compared to the other treatments. Similar to the trends observed for the sorghum fields, the soil water storage change in maize fields also followed the rainfall pattern. In addition, except on some measurement days, the differences in soil water storage among the treatments were not distinct, indicating the effect the relatively high seasonal rainfall at Babile had on soil water storage.

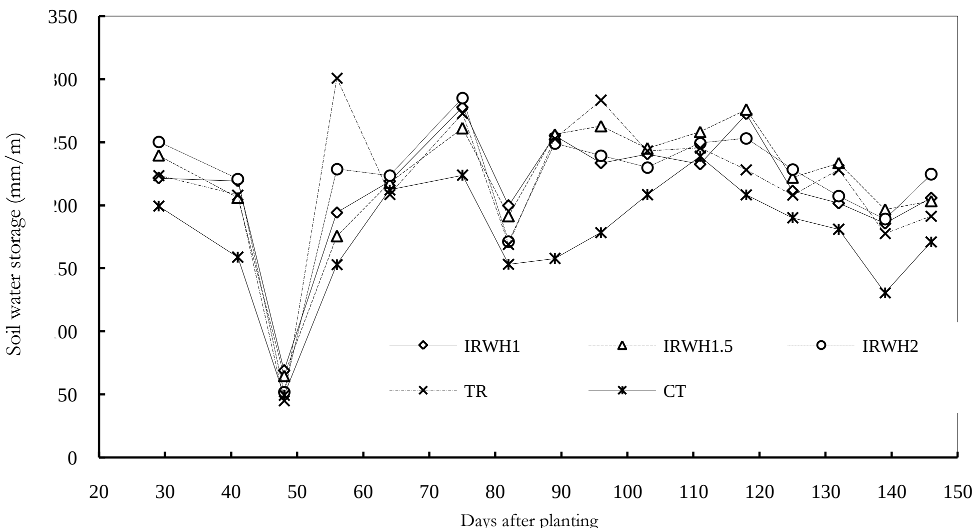

Figure 3. Soil water storage changes (mm/m) under different in-situ rainwater harvesting treatments during the growing season for maize field.

3.4.2. Yield per plant, yield per meter square and thousand grain weight of maize

3.4.2.1. Yield per plant and yield per meter square

Grain yield per plant and grain yield per meter square are presented in Table 4. The results indicated that grain yield per plant of maize was not significantly (P>0.05) affected by the treatment effects. Nonetheless, the grain yield per plant values in Table 4 indicated that the *in-situ* water harvesting treatments gave relatively better grain yield per plant. As a result, compared to the CT, the IRWH1, IRWH1.5, IRWH2 and TR treatments improved grain yield per plant by 43, 34, 32 and 33%, respectively.

Unlike grain yield per plant, grain yield per meter square was significantly (P<0.05) affected by the treatment effects (Table 4). Consequently, the CT treatment gave significantly lower grain yield per meter square than the rest of the treatments, which gave the same grain yield per meter square (Table 4). This indicates that the relatively better moisture storage and, hence, availability in the *in-situ* water harvesting treatments had helped the plants to produce better grain yield than the CT. As a result, the increment in grain yield per meter square due to the *in-situ* water harvesting treatments ranged from 48% (TR) to 62% (IRWH1).

Table 4. Grain yield per plant, grain yield per meter square and thousand grain weight of maize as influenced by in-situ rainwater harvesting treatments.

Treatments	Grain yield per plant (g)	Grain yield per meter square (kg)	Thousand grain weight (g)
IRWH1	113	0.34[a]	340
IRWH1.5	106	0.34[a]	337
IRWH2	104	0.32[a]	325
TR	105	0.31[a]	313
CT	79	0.21[b]	300
LSD (5%)	*Ns*	0.04	*ns*
CV (%)	12.1	7.4	5.0

IRWH 1, 1.5 and 2 = In-field rainwater harvesting with 1, 1.5 and 2 m wide runoff strip, respectively; TR = Tie ridge; CT = Conventional tillage; LSD = Least significant difference; CV = Coefficient of variation; ns = Non significant

3.4.2.2. Thousand grain weight of maize

The thousand grain weight of the maize crop is presented in Table 4. The results in Table 4 indicated that the treatments did not have any significant effect on the thousand grain weight of maize. This shows that the differences observed in soil moisture content among the treatments did not influence the grain weight considerably. Although the differences were not significant, the IRWH1, IRWH1.5, IRWH2 and TR treatments did increase, compared to the CT, the thousand grain weight by 13, 12, 8 and 4%, respectively.

3.5. Influence of Rainwater Harvesting Treatments on the Soil Water Storage Changes, and Yield of common bean

3.5.1. Soil water storage changes

The soil water storage changes for the entire measurement depth (0-60 cm) are shown in Figure 4. As indicated in the Figure, except during the early periods, in all the treatments relatively high amount of water was stored. In addition, though not consistently, the differences in the amounts of water stored in the different treatments were more distinct than the ones observed in sorghum and maize fields. Moreover, between 46 to 81 days after planting, the TR and CT treatments stored relatively low amount of water compared to the IRWH treatments. Except at 18, 25, 95 and 102 days after planting, the IRWH1.5 treatment field stored relatively high amount of water compared to the other treatments. The relatively high amount of water stored in the common bean field could be due to the high rainfall after planting (July 21[st]).

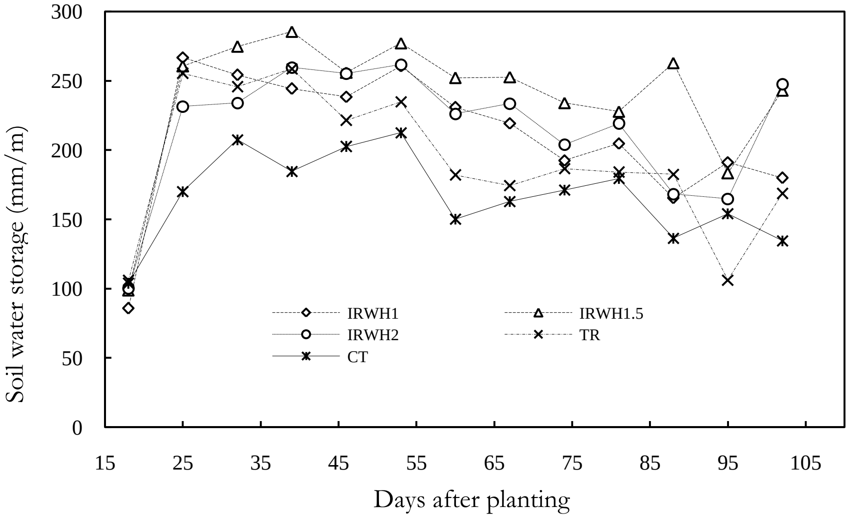

Figure 4. Soil water storage changes (mm/m) under different in-situ rainwater harvesting treatments during the growing season for common bean field.

3.5.2. Yield per meter square and hundred seed weight of common bean

3.5.2.1. Seed yield per meter square

Seed yield per meter square of common bean was significantly ($P<0.05$) affected by the treatment effects (Table 5). Plants grown under IRWH1 treatment gave significantly higher seed yield per meter square than those plants grown under TR and CT treatments while plants grown under the IRWH1, IRWH1.5 and IRWH2 treatments had the same seed yield per meter square (Table 5). Therefore, the IRWH treatments were superior to CT and TR treatments.

Table 5. Seed yield per meter square and hundred seed weight of common bean as influenced by in-situ rainwater harvesting treatments.

	Treatments						
Parameters	IRWH1	IRWH1.5	IRWH2	TR	CT	LSD (5%)	CV (%)
SYPM (kg)	77^{a}	70^{ab}	60^{abc}	58^{cb}	45^{c}	17	14.9
HSW (g)	16	15	15	15	14	*ns*	2.4

HSW = Hundred seed weight; SYPM = Seed yield per meter square; IRWH 1, 1.5 and 2 = In-field rainwater harvesting with 1, 1.5 and 2 m wide runoff strip, respectively; TR = Tie ridge; CT = Conventional tillage; LSD = Least significant difference; CV = Coefficient of variation; ns = Non significant

Compared to the CT, the IRWH1, IRWH1.5, IRWH2 and TR treatments increased seed yield per meter square by 71, 56, 33 and 29%, respectively. This revealed that the IRWH treatments were superior in producing yield per meter square compared with CT treatment.

In line with the findings of the current experiment, Hailu and Kidane (1988) reported that growing crops on tied ridge increased grain yields of mungbean by 105% compared to planting on a flat seedbed at Kobo. Nevertheless, in this experiment TR is not significantly different from the CT treatment concerning yield per meter square. Furthermore, experiment conducted in the semi-arid high altitudes of northern Ethiopia revealed the favourable effect of TR on soil water availability compared with the CT. As reported by Gebreyesus and Wortmannb (2008), grain yield was the highest in the tied ridge treatment with grain yield increase of 79, 31, and 96% for faba bean, lentil, and field pea, respectively, compared with flat bed planting.

3.5.2.2. Hundred seed weight

Hundred seed weight of common bean plants was not significantly ($P>0.05$) affected by the treatment effects (Table 5). The soil moisture storage difference during the growing season did not bring any significant change on hundred seed weight. Similar to this, growth analysis by Hidalgo (1977) indicated that seed size was found to be little affected by relatively low soil moisture. In line with this experiment, moisture conservation method had no effect on hundred seed weight (Dechassa, 2005).

Contrary to this, results reported by House (1979) and FAO (1980) on the effects of relatively low soil moisture on seed weight indicated that, due to relatively low soil moisture caused by different moisture conservation activities, the seed size was reduced resulting in lower hundred seed weight.

4. Conclusion

Among the *in-situ* water harvesting treatments evaluated, IRWH treatments stored the highest amount of water whereas the CT treatment stored the lowest amount of water during most of the measurement periods. IRWH treatments increased seed yield per plant, seed yield per meter square thousand or hundred seed weight (in case of common bean) of sorghum, maize and common bean as compared to the CT. The use of IRWH1 is advisable for proper utilization of land resource since there was no significant difference among the IRWH treatments this might be due to the above average rainfall amount during the cropping season. The locally accustomed practice, which is TR, gave comparable yield advantage with IRWH practices in sorghum, maize and common bean except it is significantly different from IRWH with 1 m runoff strip in common bean.

As can be seen from higher yield per plant, per meter square and seed weight record, the IRWH treatments have a potential to maintain the grain yield of crops when the seasonal rainfall is below normal and/or its distribution is erratic. The benefit of *in-situ* water harvesting techniques is associated with rainfall and the area allocated for *in-situ* water harvesting.

5. Acknoledgements

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10. Innovative Watershed Management and Water Harvesting Practices in Northern Ethiopia: The Cases of Erob Sand Storage Checkdam, Abraha We Atsbeha Watershed Management, and Raya Valley Spate Irrigation in Tigray Region

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Abstract
Drylands account for about 70% of Ethiopia's land area. The country in general and the northern Ethiopia of the Tigray region in particular have been experiencing crop failures followed by chronic food shortage as water scarcity and food insecurity are the prominent interrelated problems. Yet, there exist specific localities in the Tigray region known for their innovative practices geared towards addressing water scarcity. These local innovations include Erob sand storage checkdam, Abraha we Atsbeha watershed intervention and Raya valley spate irrigation based practices, where various soil and water conservation and flood diversion structures are constructed for enhancement of water and land productivity. It has been reported that these innovations do contribute to availability of water for various domestic and agricultural purposes at local scale even though these localities have some limitations related to field level water management and demand for improvement. Thus, such local innovation practices need to be communicated to the national and international community for the sake of experience sharing as well as attracting their attention in research and development interventions pertinent to water and land management gaps these localities have.

Keywords: drylands; innovative practices; watershed management; water harvesting; water and land productivity; food security

1. Introduction

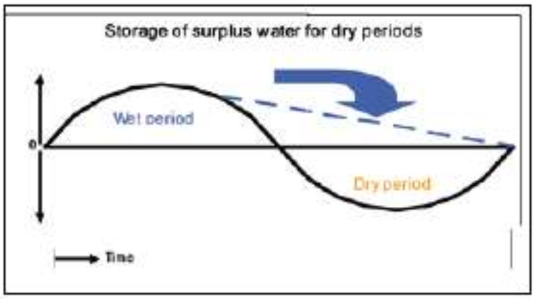
The rainfall variability and drought occurrences affect productivity of rain-fed agricultural systemsin significant areas of Ethiopia and this directly affects the country's economy (World Bank, 2006). In Ethiopia, dry lands account for over 70% of the land mass and 40% of the arable land (Yihun *et al.,* 2013). Moisture stress remains to be a determinant factor for the performance of agricultural systems in those areas. The rampant land degradation and frequent dry spells often lead to crop failure especially in the semi-arid and dry sub-humid areas (Awulachew *et al.,* 2010).

Considering these problems, extensive landscape restoration efforts under the name of "Soil and Water Conservation" have been carried out in Ethiopia in general and Tigray in particular since 1970s to address the progressive land degradation where the interventions included planting trees and construction of terraces, deep trenches, percolation ponds, etc (Lulseged etal., 2014). The past soil and water conservation efforts had largely failed due to various reasons, which include: poor planning, poor design of structures, lack of community participation, poor linkages between intervention and agricultural productivity, resource management (Temesgen, 2015). Considering the critical moisture problem and limitations of past soil and water conservation efforts, water harvesting and watershed management concepts have got due focus since 1980s (ibid).

The objective of this review is to present innovative practices related to watershed management and water harvesting being undertaken in Tigray region. Watershed management and water harvesting activities have contributed to availability of water for domestic and agricultural purposes.

1.1. Water Harvesting and Watershed Management: Basic Concepts

Water harvesting can simply be described as collecting water during short wet periods for using it during dry periods, as described in Figure 1.



Source: NWP (2007)

Figure 1. Schematic representation of storage of surplus water for use during dry periods.

In implementing the concept of water harvesting starting from storage to use, various technologies are employed. In developing the water harvesting techniques, availability of construction materials, equipment and skills at local level are quite crucial. Besides, understanding the water balance at various scales of watershed and field levels and subsequent conservation and utilization would be paramount important to enhancing agricultural water productivity.

Watershed management is described as "the integrated use of land, vegetation, and water in a geographically discrete drainage area for the benefit of its residents, with the objective of protecting or conserving the hydrologic services the watershed provides and of reducing or avoiding negative downstream or groundwater impacts" (Darghouth *et al.,* 2008 in Temsgen, 2015).

1.2. Linkage between Water Harvesting and Watershed Management towards Enhancing Agricultural Water Productivity

There is an agreement in the literature that water harvesting and its utilization can be taken as one of the major components of watershed management interventions and can be considered as an adaption strategy. Water harvesting can be realized through various ways, which include (a) in-situ rain water harvesting measures, (b) surface water development measures, such as ponds, earthen reservoirs, small harvesting tanks, gully control structures (c) sub-surface or ground water development measures such as percolation tanks, ponds, sub-surface dams (d) roof top collection and runoff water, cistern and, (e) improved water management practices including micro-irrigation and on-farm water management.

To this effect, there is a clear connection between watershed interventions and water harvesting and its utilization. Watershed interventions comprising various physical and biological measures contribute to retaining of surface water resource in place through encouraging infiltration within the watershed area. Consequently, gradual release of water from the catchment in the form of springs and river flow as well as increase in groundwater recharge and levels are evident. The enhancement of water availability at watershed level creates favorable conditions for water harvesting and utilization for domestic and agricultural purposes.

According to Sharda (ud.), in order to make successful implementation of integrated watershed intervention and realize water harvesting practices, it is necessary to carry out a survey prior to selecting sites for watershed interventions and promotion of water harvesting practices. In the initial survey, various data (that include: climatic records- rainfall and evaporation rates; topographical maps including drainage networks and ephemeral streams; distribution of rock types, especially surface features; recognition of recharge, discharge areas and the flow direction of the groundwater) need to be collected. Besides, it is very important to involve the local community in all stages of the watershed management and construction of water harvesting schemes within the watershed as community involvement would ensure sustainability of the system.

2. Water Harvesting and Watershed Management Related Innovative Practices in Tigray Region

In most parts of the Tigray region of Ethiopia, moisture stress is the major limiting factor for crop production as the rain fall is inadequate and erratic in distribution.

In the absence of dependable water supply for meeting various needs such as for crop cultivation and domestic water supply, some rural communities have developed their own innovative water harvesting practices that contribute to availability of water as an adaptation to local conditions. These farmer innovations include the Erob sand storage checkdam, the Abraha we Atsbeha watershed intervention, and the Raya valley spate irrigation based water harvesting practices (Figure 2).

Figure 2. Locations of Erob, Abraha we Atsbeha, and Raya valley water harvesting practices.

Generally, the linkage between watershed interventions and water harvesting practices in the region can be described as in Figure 3.

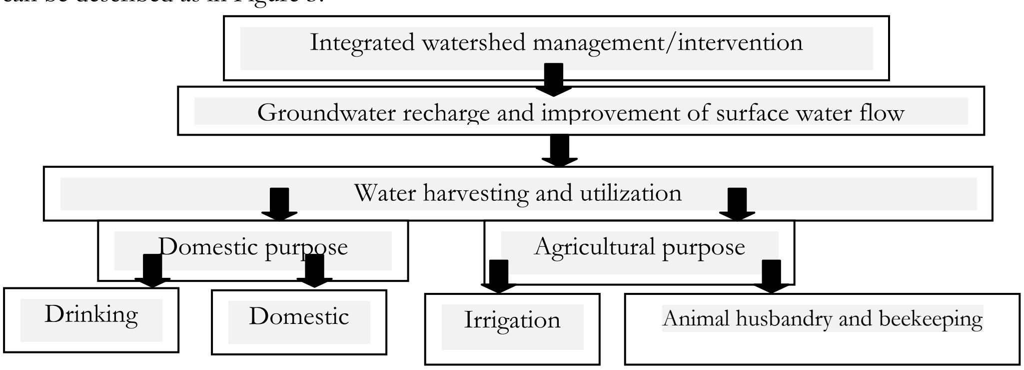


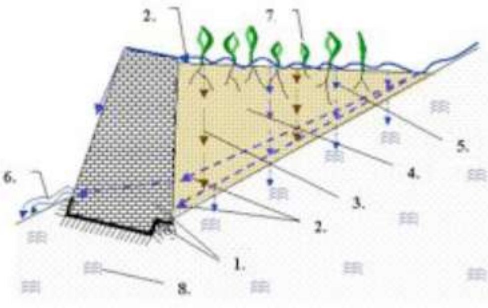
Figure 3. Link between watershed intervention and water harvesting in Tigray region.

2.1 The Erob Sand Storage Checkdam Based Water Harvesting Practices

2.1.1 General description

Erob woreda (district) is located in the north east tip of the Tigray region bordering with Eritrea. This area is dominated by gorges, rugged and undulating topography where availability of plane lands for crop cultivation is almost impossible. It has an average altitude of 2000 masl, an average temperature of 19.2 °C and rainfall of app. 400 mm per year (Fabienne, 2003).

The continued demographic pressure over land and the cuttings of forest trees for firewood and grazing livestock caused an extreme land overuse followed by intense soil erosion, which is one of the main problems of Erob (ibid).
As a counter measure towards the ongoing soil erosion problem as well as critical water shortage, construction of sand storage check-dams (locally called "daldal") along the gorges were initiated by local farmers around 1953 and this local initiative has been supported by ADDA (Adigrat Diocesan Development Action) since 1975.
Following the construction of such check dams along the gorges, availability of water has increased while fertile soils are deposited behind each check-dam creating a new land for crop production as described in Figure 4.



1. construction of foundation and check dam wall
2. dam up of the watercourse and diminishing of the flood energy
3. sedimentation of soil particles
4. up-silting behind the check dam and soil reclamation
5. water infiltration
6. spring at the check dam's bottom
7. crop cultivation
8. aquifer in sediments and nearby rock faces

Source: Fabienne (2003).
Figure 4. Cross section of a sand storage dam and its importance.

The common crops cultivated on the newly created check-dam lands are maize, barley and sorghum, which contribute to the farmer's self-sufficiency (ibid).
As a result of check-dam based interventions in such undulating topography, the valley above and below the dam turned into a green strip amidst the dry and rocky landscape as shown in Figure 5. It opens up new opportunities for food security and water supply of the people in this district.

Source: Fabienne (2003).
Figure 5. Green cover above and below sand storage check dam.

Depending on the rainfall amount of each preceding year, spring water persists for a minimum of five months to a maximum of a whole year. The inhabitants of the area thus enjoy the availability of water for various domestic and animal watering purposes (Figure 6).

Source: Fabienne (2003).
Figure 6. Check dam for spring water serving as drinking water for people and livestock grazing

Another positive effect of check dams based water harvesting is the favorable condition being created for biodiversity (appearance of fauna and flora). Plants and animals start to appear following the storage and gradual flow of water in the gorges. Typical example is the appearance of trees like acacia tree surrounding the check dam area (Figure 7)).

Source: Fabienne (2003).
Figure 7. Acacia grown around the checkdam.

2.1.2. Construction specificities of Erob sand storage checkdam

The local community has accumulated technical experience in constructing the sand storage check dams with some specifications:
i) The height of a dam is gradually increased every year following the deposition of sediments behind the check dam. Such innovative practice helps mainly to avoid total collapse of the dam from big floods coming from the mountains.
ii) Check-dams are also constructed in sequence (Figure 8) to increase availability of water by slowing the velocity of the surface runoff down slope and create wider area for cultivation.

Source: Fabienne (2003).
Figure 8. Construction of checkdams in sequence.

2.1.3 Interventions of ADDA towards expansion of sand storage checkdams
According to Kevin and Paula (2008), ADDA's interventions had been lead by Dr. Bruno Strebel (a project coordinator from Switzerland), who had directed the various soil and water conservation activities undertaken in the district. In 1991, the accomplishments included construction of 32 hand dug wells as deep as 25 m; 385 check dams varying from 3 to 15 m in height; 4.5 hectares of hillside terracing; 10 hectares of fruit and vegetable gardens and 4700 m long wall along the side of the river. As a result, about 60,000 people benefited from the interventions.

Since the interventions of ADDA in 1975, the Checkdams have been constructed using masonry, cement, gabions as shown in Figure 9

Source: Fabienne (2003).
Figure 9: Types of checkdams depending on construction material .

There were various dimensions (LxWxH) of the various checkdams constructed by ADDA. These included: 26 x 3.2 x 6.5, 83x 3.2 x 9, 15x 2.5x 5, 50 x2.5 x5, 23x 7x 7, 25x 2.5x 4.5, 58x 5x 10, 55x 3x 7, 27x 2x 3, 13.5x 2x 3.5 while the size of the newly created cultivable land ranged from 7500 - 12,000m^2.

The construction approach applied by ADDA is more or less community based approach that considers locally available material and technique. Figure 10 depicts women involvement in the construction

Source: Fabienne (2003).

Figure 10. Community involvement in construction of checkdams.

The ownership of the newly created land behind such checkdam is communal and it is entitled to each village involved in the construction through the support of the ADDA. Every year, group of farmers get the right to cultivate the checkdam land based on some criteria (being female headed household, being landless, etc) or based on lottery as this land is believed to belong to all of the nearby village inhabitants.

Table 1. Number of farmers sharing the cultivated land in 2003.

Visited checkk dam	Village	No of female headed families	No of male header families	Totla No of Poeple
Alakalo	Awo	10	27	37
Dasamo Gade	Dawhan	3	13	16
Dogogola	Upper-Daya	3	5	8
Intigade	Bobo	5	10	15
Tikibta	Down-Daya	6	10	16

Source: Fabienne (2003).

The number of the farmers sharing each check-dam in 2003 varied from 8 to 37 with average number of 18. The main reason is believed to be the size of the new land created behind the check-dam. Each group of farmers cultivates each check-dam and share the harvest.
The quantity of maize harvest obtained from the fields of the various check-dams in good and bad years based on farmers' interview are shown in Table 2.2. It is demonstrated that the farmers in this locality managed to harvest maize yield of up to 3000 kg out of 7500 m2 area.

Table 2. Quantity of maize harvest in kilograms in good and bad years.

Visited checkk dam	Village	No of female headed families	No of male header families	Crop sort	Totla No of Poeple
Alakalo	Awo	1'000	0	Maize	3'500
Dasamo Gade	Dawhan	1'400	200	Maize	2'500
Dogogola	Upper-Daya	3'000	0	Maize	7'500
Intigade	Bobo	200	0	Maize	750
Tikibta	Down-Daya	1'500	0	Maize	12'000

Source: Fabienne (2003)

2.2. The Abraha we Atsbeha Watershed Management Based Water Harvesting

2.2.1. General description

Abreha we Atsebha is geographically located at 13⁰51'50"lat. N and 39⁰33'40" lon. E and at a distance of about 64 Km north from Mekelle (capital of Tigray region). Initially, the conditions in Abreha we Atsebha were so bad that the community was to be resettled. However, with some external assistance and through hard work, the community transformed their catchments (Tony, 2010).

Integrated and community based catchment treatments and construction of water harvesting structures were done for irrigation and other purposes since 2003. The catchment treatment activities included: construction of different soil and water conservation measures like check-dams, chains of percolation ponds for 'water banking', deep trenches, stone/soil bunds etc.; area closures; and afforestation at upstream areas of the watershed. Consequently, upstream soil and water conservation measures have recharged the groundwater systems and the local communities have constructed a number of alternative water harvesting structures at downstream areas, mainly hand-dug wells for water supply as well for irrigation purposes. More than 270 ponds and over 500 hand dug wells have been constructed over the years and are being used for irrigation, domestic and livestock watering purposes (Lulseged *et.al.*, 2014).

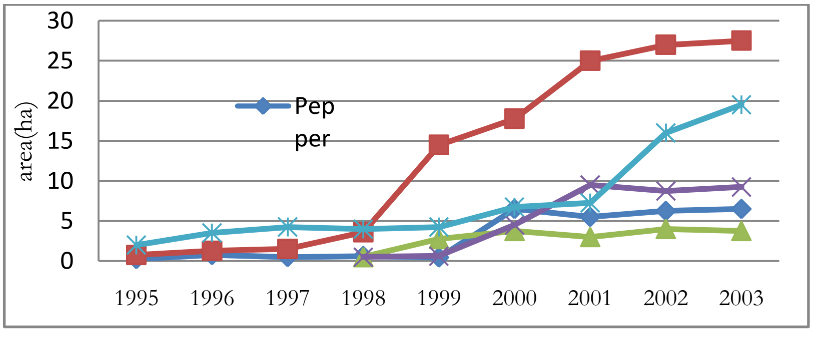
As a result of integrated catchment treatments, at least 50% of the rainwater being trapped to recharge ground water stores (Tony, 2010). Through such integrated watershed intervention, the community has enhanced its water resources within the catchments and utilized for various purposes (drinking, washing, irrigation, watering animals).

This area has been considered as one of the models and demonstration site in the region as far as integrated watershed management, expansion of water harvesting, irrigation and agronomic practices are concerned. It is has become an internationally recognized community based watershed interventions with UNDP Equator prize Award of 2012 in Rio de Janeiro.(Link: https://www.wfp.org/stories/ethiopian-village-recognized-rio20-innovative-hunger-solution).

Most of the wells are open, equipped with pulley and treadle pump. The construction type is mainly of dry brick or stone lining and few are with masonry lining. The shape of the wells include trapezoidal, circular, rectangular, and irregular. Diameter of wells for the circular type ranges from 1.9 to 8.8 m, while the rectangular wells are about 4 by 6m. The depth, static water level and the yield of the wells ranged from 1.7 to 10 m, 0.8 to 5.2 m and 1 to 3 l/s, respectively. Diesel pump, treadle pump, and buckets are used to lift water from those wells to the field.

2.2.2 Contributions of the innovation practices

As a result of promotion of wells in the study area, not only irrigation practice has been introduced but also the frequency of production has increased to two to three times a year. In the cultivated land wheat, maize and potato have been the dominant crops. Recently, the farmers are shifting to vegetables, such as cabbage, tomato, chills and onion. According to the development agent responsible to Mindae catchment of Abreha we Atsebha, about a total of 65 ha is so far developed out of which 46 ha is for vegetables (tomato, cabbage, onion) and fruits (95,000 guava, orange, mango, avocado trees) and 19ha for cereals. The expanding trend of fruits and vegetables along years is presented in Figure 11.



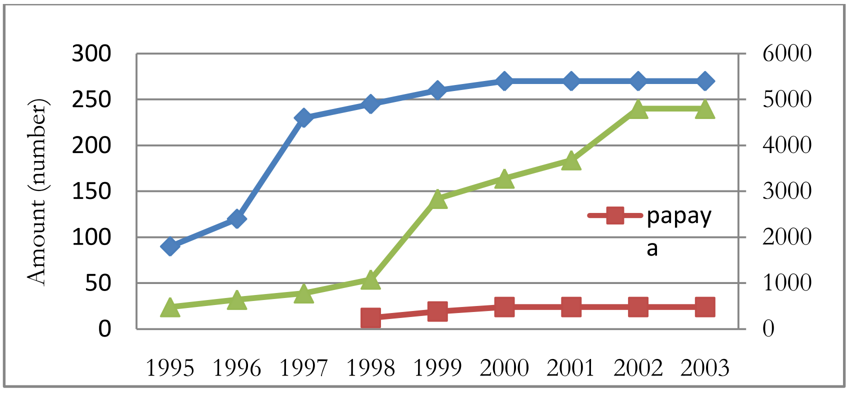


Figure 11. Vegetable and fruit tree expansion along years at Mindae, Abraha we Atbeha.

Following the watershed intervention and increased availability of water for irrigation, the number of farmers practicing irrigation in this specific area has been increasing over years, and drastic increase is marked particularly since 2004 (1996EC) as shown in figure 12.

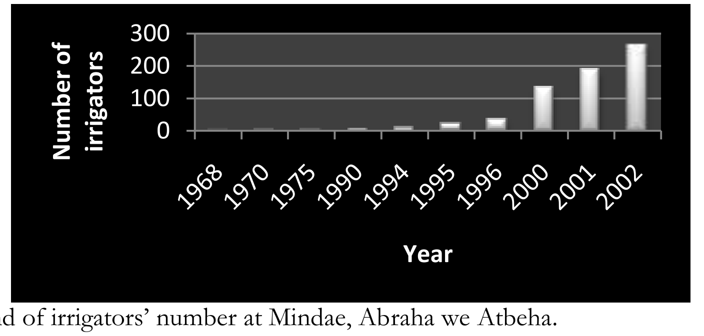


Figure 12. Trend of irrigators' number at Mindae, Abraha we Atbeha.

The dominant irrigation methods practiced in the area are furrow irrigation for vegetables and micro basin for fruit trees (Fig.ure 13).

Figure 13. Furrow irrigation for onion and micro basin for guava.

From the perspectives of optimization of available water resource utilization, the downstream farmers dig shallow wells here and there without any restricted well spacing. This practice may lead to depletion of the ground water resource due to excessive and uncontrolled ground water abstraction exceeding the recharge rate.

Besides, the irrigation water application at field level is regarded as unscientific and simply decided by observing to crop and soil moisture status. There is a mismatch between scientific crop water requirement and farmers' water application. The farmers apply constant irrigation depth (amount) in every irrigation interval and application time throughout the crop growth season regardless of crop type, crop growth sage, and crop root depth. Besides, irrigation depth varied among farmers while they grow same crop under similar soil type. Consequently, the field level water application efficiency is low (poor). Thus, the field level irrigation water application need to be guided by crop water requirement based application and there is a need for introducing more efficient irrigation methods such as drip and pitcher irrigation..

2.3. The Raya Valley Spate Irrigation Based Water Harvesting Practices

2.3.1. General description

Raya valley is found within in the districts of Raya Azebo and Alamata in the Southern Zone of the Tigray National Regional State. It is located between 12°16' and 12°55' N latitudes and 39°22' and 39°53' E longitudes (Figure 14) at a distance of 180 Kilometers south of Mekelle.

Source: Hintsa (2014).
Figure 14. Raya Valley.

The area gets a bimodal rainfall during "Belg" (short rainy season from February to March) and "Kiremt" (a long rainy season from June to September). The other months of the year are generally dry. The rainfall pattern in the valley is relatively erratic and unpredictable generally characterized by semi-arid climate.

In the Valley, there are no perennial rivers and streams and it mainly depends on surface water resources coming from the adjacent highland areas. Thus, the farmers in the southern part of the Tigray region mainly found along the foothills of the Raya valley practice long spate irrigation for generations. Spate irrigation is "an ancient irrigation practice that involves the diversion of flashy spate floods running off from mountainous catchments where flood flows, usually flowing for only a few hours with appreciable discharges and with recession flows lasting for only one to a few days, are channeled through short steep canals to bunded basins, which are flooded to a certain depth" (UNDP and FAO, 1987).

The coverage of irrigated area through spate in the valley so far is about 21,000 ha. There is still a potential of 80,000 ha of land to be irrigated by a total runoff of about 170 Mm^3yr^{-1} generated from the highland catchments (Spate irrigation Network, ud). These lowland areas do receive not only flood water but also fertile sediments for agriculture from the surrounding highland catchments.

2.3.2. Types of spate irrigation practices in Raya valley

According to Spate irrigation Network (ud), there are two common methods of spate irrigation. These are traditional and modern types.

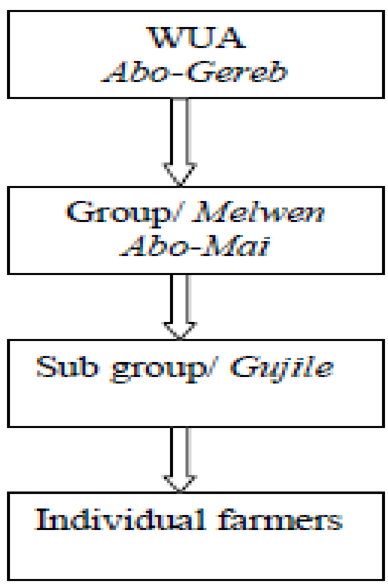
i)Traditional systems

This type of spate irrigation practice have been transferred from generation to generation. The farmers themselves have bigger stake in the continuity of this practice for years as. This system:

- depends fully on indigenous skills and local materials;

Figure 15. Traditional system

- the farmers are organized under their own Water Users' Associations (WUA) to manage the spate irrigation systems guided by rules and regulations (locally called "Sirit"). Based on the Sirit, the elected leaders (locally called "Abo-Gereb" and "Abo-mai") enforce the fair distribution of spate water and regulate any offence against the smooth running of the system.



Source: Haile (2009).

Figure 16. The organo-gram of traditional spate irrigation management

ii) Modern systems

The modern systems are recently introduced systems by other stakeholders with the aim of tackling the short comings of the traditional systems. One of the design concepts embedded in modern systems is to divert significant amount of flood and serve farm lands of a larger command area using robust structures, mainly cement masonry and/or concrete structures.

Modern spate structures include weir, intake, sluice gate, retaining wall and main canals (Fig 17).

Figure 17. Modern spate diversion

Most of the constructed modern spate diversions in the valley are however not performing well due to various reasons such as over sedimentation in diversion and canal, failure of structures due to impact of flood and big boulders coming with energy from the highlands, inappropriate design and poor participation of farmers during design and construction.
According to Hintsa (2014), 13 out of 17 modern systems constructed in Raya valley have failed and currently are non functional (Fig 18).

Source: Hintsa (2014).
Figure 18: Collapsed and non functional modern diversions

Traditional systems in Raya valley can thus be regarded as local innovations that persisted for generations and outperformed the modern systems. This is because local farmers have knowledge and practical skills that they have accumulated as a result of centuries old fight to harness the flood and use it for productive purposes. Moreover, traditional systems are flexible to fit to changing bed levels and river meandering; lesser conflicts occur between upstream and downstream users as they give priority to equitable sharing of water at many diversion points; and such systems have ability in avoiding sedimentation in cases of large floods.

Yet, traditional systems have limitations in that they require excessive labor every season for re-construction and maintenance of the diversion and canal structures; have negative environmental impact as they require local materials such as woods, bushes and shrubs for construction; they are limited to lower head diversions and it is almost impossible to construct such systems in deeper wadis.

It is thus essential to combine the strong aspects of these two systems to get a hybrid that can perform best. As an attempt to blend the advantages of these two systems, the woreda level experts together with the farmers have tried to modify the design and alignment of the diversion as shown in Fig 19. Its alignment across the river resembles to that of the traditional system, which is deviated from the perpendicular cross-sectional alignment of modern systems while industrial materials are used instead of tree materials as that of modern system.

Figure 19. Hybrid spate diversion

2.3.3 Contributions of spate irrigation practice to crop yield

Spate irrigation practice has clear advantages as compared to rainfed cultivation in that the former can create opportunities of growing various types of crops while enabling to harvest more yield from a given unit of land. There are also cases that crop production may totally collapse in rainfed fields due to lack of rainfall in the valley despite that some fields within the spate irrigation system can give yield for instance during Belg season. Table 2.3 shows yields and cultivation of various crop types in spate as compared to rainfed.

Table 3. Average yield of major crops during 2009-2011.

	Average YieldYield(Qt/ha)							
	Spate Irrigation				Rainfed production			
Crop type	2009	2010	2011	Average	2009	2010	2011	Average
Maize	21.3	17.3	22.0	20.2	-	-	-	
Onion	27.7	29.3	33.9	30.3	-	-	-	
Sorghum	19.5	20.3	20.5	20.1	16.3	15.8	16.2	16.1
Teff	9.9	10.3	11.6	10.6	7.8	8.1	7.4	7.8
Moisture	3.8	3.7	4.0	3.8	2.7	2.7	2.9	2.8

Source: Spate irrigation Network (ud).

3. Concluding Remarks and Recommendations

3.1. Concluding Remarks

Generally, it is evident that, in response to critical water shortage, the locally practiced community based interventions and innovations have indeed contributed to increased water resources retention at catchment and ultimately improved water availability for domestic and agricultural purposes at downstream fields.

The initiatives of Governmental and Nongovernmental organizations towards modernizing the local practices in these areas deserve appreciation. Nevertheless, there remain gaps in attaining the required results or improvements due to less focus that has been given to amalgamate local innovations with modern ones as well as improving limitations of local practices.

Field water application in the areas is less efficient that is based on simple observations of soil and plant status; and hence needs to be guided by crop water requirement based application. The current practice leads to water wastage due to mismatches between crop water requirement & application of constant amount throughout the crop growth stages.

3.2. Recommendations

The following recommendations are forwarded based on the reviewed literature as well as own field observations:

i. The attempts of modernizing community practices need to be founded on maximum community participation and inclusion of well performing community innovations.
ii. Available local community innovations in water harvesting and watershed management deserve recognition. The local innovations need to be conserved by conducting inventories through mapping and building digital database for each site elucidating the strength and limitations of these innovations.
iii. Linking catchment treatment from the top of the watershed with the water harvesting practices at downstream (as in the case at Abrah we Atsebeha) is necessary in order to be more effective in water management though challenges are expected in handling larger catchments.
iv. Restricting water abstraction level based on specific catchment's recharge capacity (through the application of water balance approach) need to be practiced at each catchment for optimizing and sustaining water resource utilization.
v. Development agents and farmers in each area need to be trained on efficient field level water application in order to be able to match crop water requirement and irrigation application.
vi. Access to data acquisition (through establishment of local metrology stations, and soil moistures sensors and water measuring devices) is required at the localities in order to make irrigation water application scientific.
vii. Detail and further research need to be carried out at these localities
    - to evaluate the effectiveness of the existing innovative practices,
    - to minimizing losses out of harvested water through evaporation, deep percolation and other forms,
    - to evaluate and introduce efficient irrigation methods such as drip and pitcher irrigation, and
    - to conduct socio economic impact and sustainability of these innovations.

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11. Climate Change Related Hazards, Early Warning Indicators, and User Requirements of Climate Forecast Information in Pastoral Areas of Ethiopia

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Abstract

Access to climate change information, particularly actionable and timely weather and climate forecast information is critical to build the adaptive capacity of rural communities. Pastoralists, agro-pastoralists, farmers, local government, and businessmen need climate information to plan and make informed livelihood decisions. The major climatic hazards indicated across the regions are drought, disease, heat stress, erratic rain fall, flood and conflict. Heavy rainfall, fire out beak and strong wind has also been mentioned in few areas. To mitigate effect of climate change or adapt to the change, the community need information on climate elements and early warning advisory. Ethiopian National Meteorology Agency, in this regard, can assist both crop and livestock producers through provisions of climate forecast information. The effort exerted by NMA in providing climate forecast information and early warning advisory services to the pastoral areas of Afar, Oromia (Borana) and Somali regions was assessed with the present study and found that so far there was no information disseminated by NMA to the community level. In the absence of scientific climate forecast information from NMA, the pastoral and agro pastoral communities and local business organizations depends on traditional climate forecast information. The traditional indicators are based on star, starting date of the year, wind direction, change in animal behavior, animal intestine, flowering of trees, etc. However, accuracy of traditional indicator is declining as the rapid change in weather challenged the forecasting ability of forecasters and religious discouragement of traditional forecast (star as indicator) threats the sustainability of this forecasting method. As a result the community vowed their willingness to pay for scientific climate forecast information provided the information from NMA reaches them with location specific, timely and accurately. Types of climate information expected from NMA are drought/rainfall onset, set off and its volume, heat stress, disease outbreak, erratic rainfall, flood, etc within time frame of up to two months ahead and maximum of four months in advance in most cases. They have indicated for what purpose they need such forecast information in detail. Among kind of decisions with respect to different climatic hazards forecast information they opt for option as adaptation or mitigation strategies such as migrate to highland and watering point areas when heat stress is high, move to feed and water available areas and destock animals when drought is high, prepare agricultural land and cultivate adaptive varieties when information on rainfall pattern and volume is promised, etc. In general the community forwarded what is expected from them, the government and NMA. The responsibility of the community is to utilize available climate forecast information and early warnings efficiently and create awareness to the remaining community members. The government responsibility is suggested to facilitate dissemination of the forecast information on right time for the specific area with advisory services and follow up its implementation is expected. The responsibility of NMA is to

use best/modern technologies available and predict climate information that suits for every village/grazing areas not to the main town and cities alone and be delivered on time so that they make use of it and be benefited from it.

1. Introduction

It is inevitable that climate change caused challenges to livelihood of major Africans, who depend on natural resources for their livelihood activities. Pastoral, agro-pastoral, and farming livelihoods are climate sensitive as climate is one of the major inputs for the production and productivity of livestock and crops. Agro-pastoral and pastoralism are the major livelihood system in lowlands of Ethiopia, where temperature is already high.

Slight increase in temperature has huge consequences in such areas as it contributes to climate change related hazards such as drought, pest and disease, water shortage, and imperfect hydrological cycle. Pastoralists have been applying different kind of coping and adaptation strategies which are born out of necessity to counteract the impacts of climate change. However, most of the strategies are not effective as there is no well define ways of its application, and they are also applied once the hazards caused huge damage. Limited efforts exist in preventive /mitigation/ measures in the area, ought to lack of early warning provisions for the pastoralist communities. EWS are monitoring devises designed to avoid or minimise the impact imposed by a threat on life, property, environment or livelihoods (Cetina & Nadime, 2008)

According to Teshome (2012), scientific early warning systems do not adequately exist in Ethiopia, or are ineffective, or break down at critical points – risking devastation, death, and destitution. The existing scientific warning has been criticized for being too complex and resource intensive that requires skilled staff at all levels and requires efficient communication channels, which is lacking in most parts of Ethiopia; not suitable for pastoral and agro-pastoral areas in Ethiopia; and lack of baseline (contextual) information. Early warning information is widely recognized as worthwhile and necessary in improving resilience to natural and man-made hazards and protecting economic assets and development gains. It helps society adapt to and defend against the uncertainties of climate change mainly if it is developed taking the available resources into account.

PRIME is working to enhance pastoralist's adaptation to climate change through improving this ill-functioning early warning information system. As part of the strategy, PRIME intends to work with NMA (Ethiopian National Meteorology Agency) to try to improve local weather and climate forecasting capacity and delivery forecast services to local producers and businesses in PRIME operational areas. In order to tailor the production of climate/weather forecasts to the information needs of communities and businesses, PRIME intends to support the NMA forecast validation process with user-based assessment of major climate and weather related extreme events, community and resource vulnerabilities, early warning and disaster information needs. The user-based assessment gives a true reflection of the forecast and warning information end-users perception of products and services provided by the NMA, as well as qualitative information on desired products and services. Haramaya University (HU), one of the consortia of PRIME, conducted study on the user-based NMA climate/weather forecasts and warnings needs in Oromia, Somalia, and Afar pastoral areas.

PRIME intends to work with NMA (Ethiopian National Meteorology Agency) so as to try

1. To improve local weather and climate forecasting capacity;
2. To delivery forecast services to local producers and businesses people in PRIME operational areas

Given the objective of *PRIME,* this study was proposed to:

1. Identify major climate related hazards in the PRIME target areas; and
2. Analyze user-based NMA's climate/weather forecasts requirements and warning needed in PRIME operational areas.

2. Methodology

HU together with CARE (climate change and natural resource management lead institute in PRIME) selected a total of eleven districts (*woredas*), namely, Afdem, Mullo, Kebribeya, and Harshine from Somalia region; Moyale, Teletele, and Dire from Oromia region; and Awash

Fentale, Amibara, and Awash from Afar region for the assessment. However, the team cancelled Liben *woreda* in consultation with the concerned bodies from the target since the area was not secured enough during the survey period. The assessment was conducted by disaggregating the community based on three livelihoods (pastoral, agro-pastoral, and local business) taking gender into account. It was also tried to capture the climate information needs of government sectorial offices such as Disaster Prevention and Preparedness bureau (DPP), Water bureau, Pastoral Development Bureau (PDO), Information and Communication Bureau, and Agricultural and Rural Development Bureau (ARD). The data was collected from focus group discussion with pastoral and agro pastoral livelihood leading communities at kebele level for each selected *woredas*, Key Informant Interview (KII) with *woreda* experts and local business groups, and Dialogue with *woreda* higher officials such as head of local administration, agricultural and rural development office, water Bureau, Women affairs, communication office, and community elders. There were three dialogue workshops conducted at Dire *woreda*, Awash Fentel *woreda*, and Afdem *woreda* are presenting , Southern, Northern (Afar), and Eastern Clusters respectively. A total of 20 focus group discussion was conducted each group containing from 10- 12 participants. The FGD was evenly disaggregated among gender, and livelihood (pastoral and agro-pastoral) to explore the different information needs. Efforts were also made to represent different age groups (18-60) in the discussion. Key informant interview conducted with experts and local business persons. The dialogue has three major purposes which are awareness rising about early warning information, collective validation of the NMA services if there is any, and a good platform for gathering climate information needs. The team conducted an extensive literature review on existing documents related with early warning information, climate hazards and trends (including reviewing PRIME CVCA reports), communities livelihood strategies, resource management practices and response strategies in pastoral areas of Ethiopia.

3. Results and Discussion

3.1. Climate Change Related Hazards

The community has been affected by a various climate change hazards, namely, Heat, Drought, Flood, Erratic rainfall, Pest and Disease, Heavy rainfall, Conflict, and Wind. Drought, and Pest and disease were identified to be their first and second priority problems; respectively. These hazards have the highest magnitude of impacts on community's livelihood resources, and occur very frequently. For instance, in most cases Drought is responsible for 75 % livelihood asset loss whereas pest and disease brings 50% loss. They are commonly happening at least once in two years of time. On the other hand, Wind, Heavy rainfall, conflict, and flood were identified as hazards occurring very rarely in few places and hence, their impact is not pronounced as such. The hazards have similar incidences and impacts regardless of livelihood type, gender, and region. However, a few hazards such as heat stress, pest and disease, conflict, and flood have impact differences. For instance, Heat stress is reported to have more serious impact for the agro-pastoralists than the pastoralists. One of the main reasons could be agro-pastoralists sedentary way of life which restrict their movement to other areas in case of strong heat weave incidences. Pest and disease are also reported to be very serious in agro-pastoralists than pastoralists. This may be related to lack of experience to manage crop disease and pests as agro-pastoralism is a very recently introduced livelihood activity in the pastoralist areas. Disease and pest are also reported to happen every year in Dire and Moyale *woredas* of Oromia whereas in Mullo of Somalia it is perceived to occur once in more than three years. Conflict which is mainly caused by natural resource competition is a very serious issue happening at least every year in Moyale *woreda* of Oromia, Afdem *woreda* of Somalia, and Amibara *woreda* of Afar, and it's responsible for human killings, asset distraction, and lootings. In Moyale there is a conflict between Borena and Gebera Oromo clans. This conflict was even going on during this survey period. There is also a long waited conflict between Afar and Isa clan of Somalia.

The community perceived that there will be more hazard impacts in the future unless appropriate intervention is made. They also believed that heat intensity, number of hot days and erratic rainfall will increase and rainfall volume will decrease in the future reinforcing the climate change related hazards more.

District experts' perception on past extreme events and current climate hazards ranked drought first (70%) followed by disease and pest (40%). Conflict is mentioned as third priority problem followed by flood. While invasive weed species (*Prosopis juliflora*), and wind erosion are mentioned as being a threat.

3.2. Effectiveness of Traditional Indicators for Predicting Hazards

In response to absence of scientific information forecasting, the community has developed early warning system which bases traditional knowledge to forecast potential hazards and counteract their impacts. Traditional knowledge is generally defined as the "Knowledge of a people of a particular area based on their interactions and experiences within the area, tradition, and their incorporation of knowledge emanating from elsewhere into their production and economic systems" (Boef *et al.,* 1993). This knowledge and skills has accumulated overtime and handed down from generation to generation orally. The knowledge is evolved by locally defined conditions and needs. The community knows a wide range of traditional indicators some of which follows certain universal principles or logics, others base correlation, and majority base on local experience without scientific bases. The indicators with level of accuracy are indicated on Table 1.

Table 1. Traditional indicators with their accuracy level.

Traditional indicators	No of FGDs using the indicator	No of FGDS not using the indicator	Average Accuracy (%)
Astronomical observation	17	3	52
Wind direction	8	12	84
Animal Behavior	8	12	72.7
Animal Intestine	5	15	54.6
Starting date of a year	5	15	92
Termite infestation	1	19	98
Tortoise leaving its hole	1	19	97.8
Stone count	2	18	91
Witchcraft	1	19	100
Analog year	1	19	0
Cloud pattern	1	19	95
Flowering of acacia plant	2	18	96
Ground water	1	19	0
Spider net	1	19	0
Night weather	1	19	98
Earth crack	1	19	94
Tracking of crop growth	1	19	0

3.3. Integrating Traditional and Scientific Forecasting

Traditional forecasting has major flaws such as low accuracy, less trust, less coverage, unsustainable, and less communicated. Scientific forecasting has drawbacks such as too aggregated to be relevant, resource intensive, and time taking. For getting combined benefit bridging the knowledge systems should be done through intensive dialogue between scientific knowledge providers and user groups. SWOT analysis of traditional indicators depicted on Table 2.

Table 2. SWOT analysis of traditional indicators of climate forecasts.

Strength	Weakness	Opportunity	Threat
Locally available o Doesn't cost too much o Hazard specific o Area specific o Not limited to climate change related hazards only. Used to predict death, security, marriage fate, and others etc.,	Very low accuracy o knowledge and skills of prediction is highly restricted. o Not sustainable	CARE is involved in Southern & Afar clusters in assisting traditional forecasting. o Government offices are taking training on traditional early warning system.	-Climate change: frequent hazard occurrence confused the traditional forecasters -Religion..only Allah knows -Conflict and natural death -Restricted knowledge and skills transfer: blood line

3.4. National Meteorology Agency Services Requirements

Information on rainfall onset, amount and set off with required accuracy and timely provision is highly demanded by pastoral and agro-pastoral in all clusters of PRIME targeted areas. Drought information, though it is the reflection of rainfall, is highly needed. Information on disease and pest occurrence/prevalence, heat stress and erratic rainfall are more needed by agro-pastoralists. Information on the incidents of heavy rainfall information is wanted only by Harshin and Afdem districts of Somali regional states.

The major climate information required by business persons firms are on drought, rainfall pattern& volume, and disease and pest with percentage of 89, 78 and 56, respectively.

Decision to be taken by community based on reliable and timely information from NMA

The community in the study area stated what they could do if they get accurate forecasts about the future climatic conditions. They mentioned as they first pray to God for better situation. If bad scenario is forecasted destocking, mobility, diversification, variety selection and food aid request will be considered while during better scenario expansion of agricultural land and purchasing animals for better production will be sought.

If accurate forecast and early warning information is provided, pastoralists and agro pastoralist are ready to exercise destocking and other above indicated strategies. In addition, different types of decisions can be made for resilience improvement to climate change/variability; such as water harvesting, storing available pasture, water rationing, migration, moving animals to hill areas, etc.

The district officers have suggested training of trainers for district experts by regional meteorology so as to provide right information with good advisory service to the community. Local business owners have also suggested mainstreaming of climate information into their business plan so as to make their business climate smart and sustain.

So far, Bureau of disaster preparedness and preparation and early warning at district level intervene to pastoralists' area not based on weather or climate information, rather based on filled information on checklist sent from regional office, every month visit of pastoral area by district higher officials and finally rectified by experts from federal level when potential hazard is reported. The role of DPPB and EW office is limited to intervention and do not have role on pre-emptive action in minimizing occurrence of climate related hazards.

3.5. Information Delivery Time, System and Accuracy

District experts provide advisories for the communities, solely based on their previous experiences on how the seasons turned out to be. It is imperative to build the capacity of the district sectorial experts to understand, demand, and use climate information and services. Hence, awareness and training for experts is needed to coordinate among relevant sectorial departments, for better exchange of climate information, should be looked into.

More than half of the respondents in Afar and Oromia requires at least before two months of the hit occurrence. The climate information delivery system preferred is through extension agents in addition to other means (radio, TV, sirens, workshop, etc). The accuracy level of weather or climate forecast required is minimum of 80% accurate in Oromia and 60% accurate for Somali and Afar and maximum accuracy level required by majority of respondents for high use value is 100% that would require higher efficiency from NMA side.

So far there is no climate information disseminated to pastoralists' area from NMA; except information they might hear sometimes about larger cities forecast which cannot be understandable and has less use value for pastoralists. Hence, if timely, accurate and understandable climate information that is tailored to their specific grazing areas needs to be disseminated by NMA; the pastorals and agro-pastoral communities are willing to pay for the information received.

NMA forecast based on three main seasons namely; Bega (October to January), Belg (February to May) and Kiremet (June to September) (NMA, 2015). The seasons of pastoralists are four, which is different from NMA's season of forecasting. Hence, adjustment of seasonal forecast based on pastoralists' season will help the pastoralist to adjust their decision as per the forecast. Seasons for Pastoralists is depicted in Table 3.

Table 3. Seasons of pastoralists in the study area.

Afar (Awash Fentale)			Somali (Afdem *Woreda*)			Oromia (Dire)		
Seasons	Type of season	Period	Seasons	Types of seasons	Period	Seasons	Type of season	Period
Karma	Main rain	July and August	*Keren*	Main rain	August – October'15	*Gena*	Main rain	March 20 to May 20
Jilal	Long dry	Sept…to February	*Jilal*	Long dry	Oct'15-March'15	*Adolesa*	Short dry	May 20 to Sept 20
Shugum	Short rain	March & April	*Drea*	Short rain	March'15-May	*Hagay*	Short rain	Sept 20 to Nov'15
Hagay	Short dry	May & June	*Hagay*	Short dry	June & July	*Bona Hagaya*	Long dry	Nov'15 Mar. 20

Higher officials of three representative districts of the three PRIME targeted clusters and community representatives discussed on what to be done in short and long term decisions and type of advisory services required; if NMA provides seasonal forecasts (Table 4).

Table 4. Local governmental bureaus' decisions and advisories for potential below and above normal rainfall seasonal forecast.

Woreda	Seasonal Forecast	Short term decisions	Long term decisions	Advisories
Dire	Below Normal Rainfall	o Water rationing o Marketing awareness o Mobilizing resources o Conservation of pasture and water	o Water harvesting o Area enclosure (for dry season) o Training o Re-settlement o Saving and credit o Technology utilization o Sedenterazation	o Sow drought resistant crops o Irrigation o Destocking o Moving animals to green areas o Diversity livelihood o Differentiate pond for animal and for human
	Above normal rainfall	Dike preparation or dam construction in case flood is a threat.		o Breed your animals
Awash Fetale	Below Normal Rainfall: *Afar community say that " pasture land is lost from failure of Sugum rain and People is lost from failure of Government*	o Informing the problem to the concerned body o Preparing feed o Informing or warning the community o Exploring areas with adequate pasture and water using " Edo" system o Special follow up for children and pregnant women as they are affected much by scarcity of water	o Settling conflicts between different clan groups so that the buffer zones will be used in case of hazards o Starting the DRR and emergency program o Resettlement o Strengthening social networks	o Selling animals with good price and sterile ones and purchasing feed for the rest of the animals o Killing newly born animals o Moving animals expect those pregnant and lactating o Saving and credit o Storage
	Above normal rainfall	o Informing the community about the hazard so that they will harvest and store their crops in a good place o Implement emergency activities such as dam construction for flood prevention. o Providing professional support to victims very closely.	o providing sustainable seasonal climate forecast for the community o providing training on prevention measures for key hazards like flood o implementing soil and water conservation	o Harvest their crops o Resettling to areas (peak places) where flood doesn't reach Moving animals to reen areas

Afdem	Below NRF (Jilale season)	o Water tracking o Emergency (food, feed , medicine and drug provision, digging well, distribution of contingency ratio, giving geo-memberane, vaccination, agricultural tools, and drug etc)	o Conflict resolution o Re-settlement o Nutrition o Early warning o Environmental conservation (afforestation, rehabilitation) o Resource saving o Awareness cration regarding EWI and prevention measures
	Above Normal RF (Kerema)	Awareness Mobilization o Resettlement to peak areas	o Soil and water conservation o Water harvesting (Bonds, and Birka)

5. Summary, Conclusions and Recommendations

The study revealed that climate change related hazards are common in the lowland of PRIME target areas. The pastoral, agro-pastoral and local business persons in the study area are suffering from climate related disasters. There is no climate information disseminated in user friendly way to communities in the lowlands of Ethiopia. Pastoralists use forecast information from traditional forecasters which is not as such accurate and communicated. NMA provides climate information referring on major cities; which do not help the pastoralists located far away from major cities in the country.

Hence, to strengthen the NMA service in the pastoral communities of Afar, Somali, and Oromia regional states;

- NMA should provide seasonal climate forecast information for pastoral areas tailored to their local seasons and specific villages/grazing areas
- Establish climate desk center at district level that give forecast and early warning information on time, training on awareness creation and interpretation of forecast information and that give advisory service to the ultimate user of the climate information
- The community, government offices and NMA should effectively make their contribution for eradicating poverty in pastoral areas through devising appropriate climate change mitigation and adaptation strategies.
- User-driven services and products: increasing the quantity and quality of meteorological products and services, focusing on the real needs of the users; facilitating dialogue and feedback information with the communities, allowing product improvement and usefulness of the products and information
- Enhanced capacity of the staffs of the regional branch offices of NMA: improving the skills of the professional and technical staff of the branch offices in pastoral areas, to design and implement continuous improvement of products and services and incorporating quality assurances in the process;
- Strengthening the operational observing and monitoring capacity of the NMA: establish more automatic weather stations in pastoralist areas, combining and using the ground-based data with satellite data, and conducting further studies on traditional indicators commonly used and perceived to have better accuracy

- A major recommendation was the implementation of a Public Weather Services Unit, to act as the interface between the meteorological service providers and users for the development and implementation of user specified products and services of high impact.

In nuts shell, for the NMA services and products to have an impact on pastoral livelihoods, responsibilities cannot stay solely in the hands of the NMA, there needs to be cross-sectoral communication and development that links the impact of the climate forecast and warning across the various sectors.

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12. Policy and Practice in Land Use and Administration in Pastoral Areas: Analysis of Implication on Development Intervention

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Abstract

This research is the examination of gap between the policy and practice and the implication the gap will have on interventions in Afar and Ethiopia Somali Regional State in particular. The FDRE constitution recognizes firm land use right on grazing for the pastoral community. As per Art.40 (5) of Ethiopian constitution, pastoralists have the rights to get land for free and not to be displaced from their grazing lands. Considering the communal grazing land as no man's land is, therefore, prohibited in Ethiopia. The researchers used key informant interview, household survey and document analysis in addition to literature review. As the findings revealed, grazers themselves were the major violators of the major land use type, grazing. Similarly, crop producers, clan leaders and the state violated land use rights. The majority of the respondents(about 59%) felt unsecured in their land use right due to the absence of private holdings; absence of land certificate; failure to implement the land law and policy; unfair distribution of land; absence of legally divided land; fear of dispossession; and absence of formal land use system. That was why the majority of respondents (about 79%) were very much interested in certification of their land use right. Failure to implement the land laws and policies due to lack of commitment; budget, experts and proper office adjustment; escalating feeling of insecurity, discrimination, fear of dispossession; and failure of the formal and customary institutions to cooperate for the betterment of the livelihood of the pastoral community were the problems related to the land use right while doing away with the challenges, amending the Afar land laws; enacting regulations, directives and guidelines in Ethiopian Somali Region; clearly identifying the land use rights of the pastoralists; preparing proper land use plan; and exploiting the potential cooperative areas of formal and customary institutions were recommendations forwarded for proper implementation of the land use right of the pastoral community under study.

Keywords: Agro-pastoralists; Pastoralists; Land rights, Security; Tenure; Investment

1.Introduction

Land is the most important resource from which owners or possessors drive lots of benefits including but not limited to livelihood source. That is why issues related to it are attracting different interested groups. Customary and formal institutions are highly involved in management and administration of the land resources in rural Ethiopia in general and that of the pastoral community in particular. Such dual functioning may, however, result in uncertainties and counter actions and may hamper intervention in pastoral areas if they are not done in cooperative environment.

Land, including that of pastoralist area, is the common property of the Nations, Nationalities and Peoples of Ethiopia and will not be subject to sell; the possessors have only the right to use and collect fruit from it. The constitution has also specifically dealt with pastoralists. Pastoralists have the right to get land free and not to be displaced from their grazing lands. Even if there is such constitutionally guaranteed land use rights of the pastoral community of Ethiopia; tenure insecurity, conflict and discrimination against women are still problem challenging them. There are, of course, beginnings in adopting pastoral specific land laws and policies in regional states such as Afar and Ethiopian Somali National Regional States. Such policies and laws are, however, put on shelf without being implemented. This research is, therefore, aimed at studying factors hindering implementation and implication of the same in the two regional states taking in to account PRIME project areas with the title *Policy and Practice in Land Administration and Use in Pastoral Areas: Analysis of Implication on Development Intervention*.

2. Methodology

The researchers used qualitative and quantitative research approaches and for that purpose employed key informant interview, household survey and document analysis. Key informant interview was conducted with formal and customary institutions; emphasis given to the local levels. Twenty-five (25) key informant interviews were conducted both federal and regional level from the formal institutions while nine (9) key informant interviews were conducted from the customary institutions. Questionnaire having both close ended and open-ended questions was prepared and distributed. For this purpose, eight kebeles were selected purposely: four from each region. Documents used to support the data collected from the field. The findings of the study are presented in the form of descriptively analysis. For the purpose of Household Survey, the researchers used purposive sampling techniques.

3. Land use Laws and Policy Related to Pastoralists

3.1. Land Use Laws and Policy at Federal Level

A. *Laws dealing with land policy*

The land policy of Ethiopia starts from article 40 of the 1995 Federal Constitution that declares state ownership of land. Land including that of pastoral area is, therefore, the common property of the state and the people of Ethiopia and will not be subject to sell.[9] The possessors have only the right to use and collect fruit from it. The constitution has also specifically dealt with pastoralists. They have the right to get land for free and not to be displaced from their grazing lands.[10] The pastoralists have, therefore, constitutional guarantee for the land they hold not to be considered as no man's land. The constitution, however, empower the government to expropriate any land for public interest upon payment of compensations for the losers.[11] A rural landholder, including pastoralist, whose holding is expropriated has the right to get compensation for displacement; property situated on the land; and permanent improvements made based on the valuation to be done by certified private or public institutions.[12] The absence of proper valuation method for communal property, however, make the regional governments in pastoral community disregard compensation when communal lands are used for various purposes.[13] This shows as to how compensation and valuation are and will be serious problem in the pastoral community unless pastoral specific scheme is followed.

The Federal Rural Land Administration Proclamation No. 456/2005 which is expected to be detailed and implemented by regional governments also confirm land use rights of the pastoral communities.[14] As per this proclamation, every citizen of 18 years old who wants to make living from agriculture will have free access to land.[15] The proclamation also defined communal land holding as a land which is given to the community by the state.[16] This may result in recognizing a small portion of the communal grazing land and preserving the other portion for different purposes and, ultimately displace the pastoralists from their own lands.

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[9]See the cumulative reading of Art.40(3) and 40(5) Proclamation No.1/1995(Constitution of the Federal Democratic Republic of Ethiopia), Federal Negarit Gazetta, No. 1, 21stAugust, 1995

[10]Ibid Art 40(5)

[11]Ibid, cumulative reading of Art.40(6) and Art.40(8)

[12]See the cumulative reading of Art. 7 and Art.8 of Proclamation No.455/2005(Expropriation of Landholdings for Public Purposes and Payment of Compensation Proclamation Federal Negarit Gazetta-No. 43, 15th July, 2005

[13]Abebe Mulatu, et al (2015), An Approach to Securing Pastoral Land Use right in Ethiopia(Paper presented at 2015 world Bank Conference on Land and poverty), P.5, Available at https://www.conftool.com/landandpoverty2015/.../Woldegiorgis-365-36

[14]See Art. 6(3) proclamation No. 456/2005 Federal Rural Land Administration Proclamation)Proclamation, Federal Negarit Gazetta 11th Year, No. 44,15 July, 2005

[15]Ibid Art.5(1)B

[16]Ibid Art 2(12)

There is argument that effective pastoral land tenure should give a place for communal holding.[17] Recognized and certified communal grazing land not only protects the right of pastoral communities but also minimize degradation of grazing lands.[18] There is, however, disagreement among different interested groups as to how and for whom the certificate is to be given. Unlike the farming community, the pastoral community of Ethiopia has not been certified[19]except in agro-pastoral and settlement areas.[20] Compensation, certification, conflict, and gender empowerment in land use, which are the burning issues of the pastoral community, remain unsolved till today.[21] Tenure[22] security is, therefore, very much weak in the pastoral community of Ethiopia.

B. Policy documents dealing with land resource

Agricultural Development Lead Industrialization (ADLI), Rural Development Policy and Strategy (RDPS); and the Growth and Transformation Plan (GTP) are the policy documents dealing with the agricultural policy in general and that of the land policy in particular. The RDPS clearly states that provision of water only will not solve the problem of the pastoralists and, therefore, it required to improve, protect and manage pastureland. This intern requires rehabilitating degraded pasture; using them economically; building on the traditional knowledge; and training development agents, experts and extension workers. The policy is aimed at settling the pastoralists in selected areas so that they could lead settled life and get proper public serves regularly.[23] The GTP is also aimed at enhancing livestock productivity by increasing access to water and pasture in addition to sustaining the settlement program.[24] Such programs are, however, poorly implemented to bring land tenure security in pastoral areas. The absence of certification and clear-cut tenure system, on the other hand, facilitated encroachment of pastoral lands by different interested groups.

Mobility, which is one of the four elements of pastoralism, as claimed by customary institutions, fasilitates resource access among neighboring pastoral groups without being restricted by geographical boundaries. It is a dryland strategy practiced by pastoralists allowing them to exploite the avilable resource economically.[25] Such best coping strategy is, however, facing challenges due to resouce scarcity and is charactorised by conflicts due to overlap of claims.[26] Furthermore, increasing population, enclosures and state interventions are challenging such cooperative tradition of the pastoral community.[27] The long term goal of the government as clearly stipulated in policy documents is to settle the pastoralists in areas where they could get sufficient pasture and water.[28] The land Use and Administration Proclamations of the Afar and Ethiopian Somali

[17]Mohammed Abdulahi (2007)The Legal Status of the Communal Land Holding System in Ethiopia: The Case of Pastoral Communities, in International Journal on Minority and Group Rights 14 (2007)8 5-125,Koninklijke Brill *NV,* Leiden), p.122,Available at https://chilot.files.wordpress.com/2011/04/the-legal-status-of-the-communal-land-holding-system1.pdf

[18]PFE, IIRR and DF (2010) Pastoralism and Land: Land Tenure, Administration and Use in Pastoral Areas of Ethiopia, p.54 Available at https://chilot.files.wordpress.com/2011/04/the-legal-status-of-the-communal-land-holding-system1.pdf

[19]Certificate here implies a document that is given for the possessor of the land witnessing his possession either on individual or group basis. It indicates the type, size and borders of the land.

[20]Interview with the director of the Land Administration Directorate of the Ministry of Agriculture and Rural Development on18 February,2014

[21]See Supra note 10, p.29

[22]Land tenure is defined as the method by which individuals or groups acquire, hold and transfer property in land

[23]FDRE (2003)Rural Development Policy and Strategy (RDPS), Ministry of Finance and Economic Development, Economic Policy and Planning Department Addis Ababa, p. 58, Available http://gafspfund.org/sites/gafspfund.org/files/Documents/Ethiopia_4_of_6_ARD%20policy.pdf

[24]FDER(2010) Growth and Transformation Plan (GTP) Ministry of Finance and Economic Development (MoFED), p. 24 Available at http://www.afdb.org/fileadmin/uploads/afdb/Documents/PolicyDocuments/Plan_for_Accelerated_and_Sustained(PASDEP)_final_July_2007_Volume_I_3.pdf

[25]See supra note 10. p. 6

[26] Ibid, P.9

[27]Fekadu Beyene et al(2015) Assessment of the Customary Land Administration and Natural Resource Management in the Pastoral Areas of the Oromia Regional State(unpublished),p.72

[28]See Supra note 15, p. 58

National Regional States, for example, encourages and give incentive for those who voluntary settle[29] and encourages crop cultivations[30] over livestock raising.

3.2. The Legal and Policy Framework at Regional States Level

The Regional State of Afar has somewhat comprehensive land related policy and laws in relation to the pastoral community supported by separate land policy document, proclamation, regulation and directives. Ensuring land use rights of the pastoralists; avoiding land use related conflicts; establish government land administration and use institutions; and creating awareness among the people with respect to land administration and use policy of the region are some of the objectives of the policy.[31] The Land Policy of the Ethiopian Somali National Regional State has, however, only land policy document and proclamations; the regulations, directive and guidelines are yet to be enacted.

I. Land use right of the pastoralists and agro- pastoralists

Pursuant to the land use and administration proclamation of Afar and Somali National Regional States, pastoralists of the regions have lifelong right to use their grazing land if and only if they have the certificate witnessing their possessory right.[32] Communal grazing land in both regional states is not certified so far and may, therefore, be considered as no man's land. The right to get certificate is ensured both by policy and the proclamations in both Regional States. As per the proclamations communal lands should be measured and registered under the name of the users. The certificate of registration will be placed in the hands of the community's representative.[33] The Directive issued to implement the Afar Regional State Land Use Proclamation and regulation clearly indicate that pastoralists and agro- pastoralists will have the right to use land if and only if they are members in the registered and certified grazing systems whose members are clearly known and registered at woreda level.[34] Certification of the pastoral land use right of the pastoralists remain, however, on paper except for those who have farming lands and settled. As per the proclamations of both regional states, it is prohibited to enclose for private use and investing on communal grazing lands. The government can, however, decide in making communal grazing land for investment based on the interest of the community concerned after changing it into private holding.[35] As the experience of other countries shows, changing communal land into the private holding is disastrous unless it is supported by communal grazing schemes.

A pastoralist who is 18 years old and above and who want to practices sedentary farming has the right to request land as of right in the two regional states.[36] This may, however, result in unfair distribution of land in that it only requires interest and no other option than that of crop production. Agro pastoralists seem to be favored more than pure pastoralists in the two regional states. A pastoralist or agro-pastoralist can, for example, ask land as of right if he or she is of 18 years old and want to practice crop production.[37] Investors, governmental and non-governmental organizations residing in the two regional states have also a right to get rural land on the basis and in line with the development plans of the regional governments.[38] In addition, compensation is kept silent in the provision dealing with the land use right of pastoralists unlike that of agro-pastoralists.[39] The communal grazing land may, therefore, be considered as no man's land in the two regional states. Women have also equal rights with men on grazing lands.[40] If they want to engage in raising animals, crop farming and natural resource development they have the right to

[29]See Art.5 (6) of the Afar Regional State Land Use and Administration Proclamation and Art 5 (7) Somali Regional State Land Use and Administration Proclamation.

[30]See Art 5 (5)& of the Afar Regional State Land Use and Administration Proclamation and Art 5 (6) Somali Regional State Land Use and Administration Proclamation

[31]See section 3.3 of the 2008 Afar National Regional State land Use and Administration Policy

[32]See the cumulative reading of Art. 5 (1) and Art.16 (5) *Dinkara Gazetta* of Afar National Regional State(proclamation No. 49/2009(The Afar National Regional State Land Administration and Use Proclamation) and section 4.2 land use directive. See also the cumulative reading of Art. 5 (1) and Art.15 (5) of *Dhool Gazetta*, proclamation No.128/2013, The Ethiopian Somali National Regional State Rural Land Administration and Use Proclamation

[33]Ibid art.6

[34]See section 4.3.4 of Afar National Regional State Land Use and Administration Directive

[35]See supra note 24, the land Proclamations, cumulative reading of Art. 5 (9) &Art.7 (Afar) and Art 5 (10) (Somali)

[36]Ibid, Art.5 (5) for Afar and Art.5 (6) for Somali

[37]Art 9 of the respective regional states' land administration and use proclamations

[38]Ibid, Art.16 (Afar) and Art.15 (Somali)

[39]Ibid, Art. 19 (17) for Afar and Art.19 (14)for Somali

[40]See the respective regional States Land Proclamations Art 5(2)

get farm and grazing lands free of charges.[41] Husband and wife will have equal right of use on their holdings.[42] Orphans have also the right to use their land through their guardians until they attain the age of 18.[43] The right of elderly, the handicapped and infirmed persons to access the rural lands is guaranteed by the two regional state land proclamations.[44]

Community participation in the process of land administration and use is also recognized. Land related dispute is to be solved by local elders in the first place. If the parties are not satisfied with the decision of the elders, they can bring their grievance to the formal courts.[45] The local community is also empowered to participate in the land administration and use in the form of Kebele Land Administration Committee composed of elders, women and representative of the youth.[46] There is, therefore, a legal and policy framework for the participation as well as integration of the customary institutions. Surprisingly, the name of clan leaders is not mentioned as member of the committee even if they are in control of the land resources. Elders are mentioned there, but an elder may not necessarily be a clan leader.

II. Transfer of land use right through rent, other agreements and to beneficiaries

Landholders who have holding in the communal grazing could bequeath their individual land holding to their children or other legal hears.[47] This may, however, result in private enclosure of the communal grazing land in the absence of proper follow up. Agro-pastoralists with land holding certificate (both private and communal) may rent out as much as half of their holding to other agro-pastoralists or investors in a way that will not displace them. The lease term is five years when it is for fellow agro-pastoralist and up to 20 years for other users. Such arrangements should be made based on consents of all right holders.[48] The Land Administration and Use Proclamations of the two regions stated about expropriation of the agro-pastoral land by paying compensation. The proclamations, however, make reference to the federal compensation laws. The latter may not, however, be effective in the pastoral areas because of the fact that it was enacted in the context of urban and farming community.

III. Redistribution, allocation, minimum and maximum size of land

As per the Afar Land Proclamation, holdings beyond the maximum allowable size and irrigation schemes developed by the government funding and common grazing areas could be allocated for the landless if there is no another alternative solutions.[49] Redistribution and allocation are poorly mentioned in the land proclamation of the Somali Regional States in Art 12(1).The landless could get land from communal or state holdings.[50] Minimum agricultural holding is half hectare for irrigation and one hectare for rain fed agricultural lands in Afar Regional State.[51] Minimum holding is one hectare for irrigated land and three hectares for rain fed agriculture in the Ethiopia Somali National Regional State.[52] The maximum size of a land to be distributed after the enactment of the current proclamations of the two regional states will be decided in the future. The maximum allowable size for holdings before the enactment of the current proclamation is 5 hectare for irrigated land and 10 hectare for rain fed areas in the Afar Regional State.[53] Such holdings are recognized regardless of the maximum and minimum size in the Somali Regional State.[54]

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[41]Ibid, Art. 9 (5)
[42]Ibid, Art. 9 (7)
[43]Ibid, Art. 9 (10) for Afar and Art. 9 (9) for Somali
[44]Ibid Art. 9 (15)(Afar) and Art.5 (8) (Somali)
[45]Ibid, Art.15 for Afar and Art.14 for Somali
[46]Ibid,Art.22 (Afar) and Art.20 (5)(Somali
[47]Ibid, Art. 5 (4) for Afar and Art.5 (5) for Somali
[48]See Art. 11 of the respective regional state Land use and Administration proclamations
[49]Ibid, Art.12 of the respective regional state Land use and Administration proclamation
[50]Ibid, Art 13 for Afar and Art 12 for Somali
[51]See Art.13 Afar regional state Land use and Administration proclamation
[52]See Art. 12 of Somali regional state Land use and Administration proclamation
[53]See the cumulative reading of Article 12 (2) of the Afar Land use Proclamation and section 9.1.1 of the Afar National regional state land use and administration directive No. 4/2012
[54]See Art. 12 (1) of Somali regional state Land use and Administration proclamation

3.3. The Role of Customary Institutions in Land Administration and Use

Most of the pastoral communities apply their customary institutions in governing their routine activities including natural resource administration.[55] The land use system among Afar community is, for example, based on communalism and controlled by clans and[56] governed by customary rules to the extent of allowing neighbors to use the resource.[57] In Somali community, rangelands are common resource regulated through clan allegiance by determining who could exploit a given resource and how. Recently, however, many pastoral communities are no longer able to apply most of their traditional rangeland management practices because of both inside and outside factors.[58] Previous studies indicated that the government policies have their share in weakening of the traditional institutions.[59] Surprisingly, such customary institutions are in control of the resources in Afar and Ethiopian Somali Regional States.

3.4. The Problems in Customary and Formal institutions

Both customary and formal institutions have their own strong and week sides. Privious studies indicated that leaders of customary institutions and individuals in Afar Region, for example, are involved in diverting the common grazing areas for their personal benefit.[60] These change in land use in Afar community resulted in loss of communal grazing land and conflict between crop producers and neighboring community.[61] Private enclosure in the communal land in unauthorized way in many pastoral community of Ethiopia also resulted in privatization of the communal land and restricted the mobility tradition of the pastoral community.[62] Previous studies indicated that authorized and organized enclosure in which all interested groups participated are recommended particularly in the pastoral areas where land holding is communal.[63] Enclosure, if done privately, may also result in conflicts because of clash of interests among crop cultivators, livestock producers and other interested groups.

Conflicts of interest and lack of trust among local communities and the government is also frequent in many part of the pastoral community of Ethiopia. The case of the Arero forest, over which different interested groups fight over it use, is the best example as to the existence of such conflict and mismanagement of the same.[64] There is also such conflict of interest between the government and local people in Middle Awash Basing in that the government wants to use the land for investment, parks and modern agriculture while the pastoralists want the same for dry season grazing areas.[65] There is also argument that the investment strategy of the government, which encourages investment in dry season grazing areas, is unconstitutional.[66] Such arguments seem, however, flawed in that the constitution is clear in that regard.[67] The problem is, however, considering the land in the pastoral community as no man's land.

The top down approach of natural resource management in disregard of the local resource management institutions is also reflected in pastoral communities of Ethiopia.[68] This resulted in loss of social ties and less functionality of the customary institutions and increment of poverty in the pastoral community.[69] The experiences of countries such as Namibia, Mali, Morocco and

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[55]See Supra note 9 P.91

[56]Bekele Hunde, Property Rights Among Afar Pastoralists of Northeastern Ethiopia: Forms, Changes and Conflicts P.3 available http://www.saga.cornell.edu/saga/ilri0606/35hundie.pdf

[57]See Supra note 10 , p.55

[58]Ridgewell et al, 2007 Gender & Pastoralism: Rangeland & Resource Management in Ethiopia p. 56 Available at http://www.sahel.org.uk/pdf/Gender%20&%20Pastoralism%20Vol%201%20-%20ebook.pdf

[59]See supra note 5, P.5

[60]Getachew Kassa, 'Resource Conflicts Among the Afar of the North-East Ethiopia', African Pastoralism: Conflict, Institution and Government,(U.S.A: Pluto Press,2001) p.161, See also Abebe Mulat et al, Supra Note 5, P.12

[61]Dessalegn Rahmato*(*2007*)*Custom in Conflict: Land Tenure Issues among Pastoralists in Ethiopia(Forum for Social Studies*)* Addis Ababa P.6, available at http://www.dessalegn.info.et/Dess%20ETHIOPIA%20CUSTOMS%20AND%20PASTORAL%20LAND%20ISSUES.pdf.

[62]See supra note 10, p. 72-73

[63]Alison Napier and Dr. Solomon Desta(2011)Review of Pastoral Rangeland Enclosures in Ethiopia, p.33-34, available at http://fic.tufts.edu/assets/Tufts-Range-Enclosure-Review-PLI.pdf

[64] Boku Tache & Ben Irwin (April 2003), Traditional Institutions, Multiple Stakeholders and Modern Perspectives in Common Property: Accompanying Change within Borana Pastoral Systems, p. 16

[65]See supra note 52, p.150

[66]See supra note 9, p.123

[67]See supra note 1, Art. 40 (8)

[68]See supra note 48, P.4

[69] See supra note 56, P,14

Tunisia indicates the importance of integrating and cooperatively doing with customary institutions in general and making use of the traditional resource management knowledge and experience in particular.

3.5. Experience of other Courtiers in Managing the Communal Grazing land

In 1960s, the Kenyan Government introduced tenure reform program aimed at individualization of the communal customary right over grazing areas but faced many challenges from opponents of individualizations and consequently Group Ranch was introduced in 1968.[70] This project also failed to perform well due to lack of interest from the community and institutional gaps disregarding the existing capacity and legitimacy of customary institutions.[71]

China also introduced Household Ranches in 1960s based on sedentary pastoralism in which the herders were able to have secured and long-term land use rights at household level but ownership.[72] Even if such interventions lead to contractual relations among the pastoralists it also resulted in degradation of the grasslands due to restriction of mobility[73]and ultimately caused fragmentation of livelihood asset and consequently the pastoralists are unable to develop effective livelihood strategy.[74] In Inner Mongolia, for example, the household responsibility program resulted in the fragmentation of the formerly communal pasture and breakdown of tradition of cooperation.[75]

Nigeria also introduced settlement program aided by grazing reserves to solve the long lasted problem of the pastoral community. The program was designed in such a way that the pastoralists will settle in certain area on a reserve so that they could get crop residue from farmers in exchange of dung. The Nigerian initiative failed to achieve the desired results due to the absence of clear cut scope of rights the pastoralists will have on the reserves and because of the fact that the program was implemented outside of the base area of the concerned pastoral communities.[76] The program resulted in land degradation due to overstocking and due to unmanaged combination of crop and livestock production.[77]

Tunisia seems to have followed somewhat effective strategies compared with others. In 1960, the Tunisian government came up with the initiative to divide the arable land on individual basis in addition to preserving the communal customary land use right of the pastoral community. The landowners who got a plot of the arable land have the right to choose whether they use the land for crop production or forage development for their livestock.[78] Empowerment of the pastoral community on the existing knowledge and following mixed approach which encourage but not limited to livestock production and crop cultivation, as the experience of Tunisia shows, seems somewhat better approach.

4. Results and Discussions

The land policies and laws in Afar and Somali Regional States are poorly implemented. Lack of budget and experts are factors hindering the implementation of land policies and laws in the two regional states as discussed here in under.

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[70]Robert M. Kibugi, 2009. A failed Land Use Legal and Policy Framework for the African Commons: Reviewing Range Land Governance in Kenya, P.11, available at http://archive.law.fsu.edu/journals/landuse/vol24_2/kibugi.pdf

[71]USAID (2015) Protection of the Pastoral Land Use Right: Lessons from the International Experience, p.41, Available at https://www.usaid.gov/sites/default/files/documents/1860/LAND%20Pastoralist%20Land%20Rights%2012-18-13.pdf

[72]Shuhao Tan and Zhongchun Tan. 2015. Rangeland Tenure, Livelihood Assets and Pastoralists' Resilience: Evidences and Empirical Analyses from China, Paper prepared for presentation at the "2015 world bank conference on Land and poverty, Washington DC, March 23-27, 2015, p.11, Available at https://www.conftool.com/landandpoverty2015/index.php/Tan-349 349_paper.pdf?page=downloadPaper&filename=Tan-349-349_paper.pdf&form_id=349

[73]See supra note 63, p. 24

[74]See supra note 64, p.11

[75]Emily Yeh. 2011. Joining Forces on the Grasslands, in Zhou Wei (edd.) China's Grasslands: Past and Future (31-35) p. 32, available at https://s3.amazonaws.com/cd.live/uploads/content/file_en/4683/china_grassland_en.pdf

[76]See supra note 63, p.40.

[77]O. Gefu, Jerome. 1999. Pastoralists perspective in Nigeria: The Fulbe of Udubo Grazing Reserve, Malta Grafiska: Sweden, P. 85.

[78] See supra note 63, p.46

4.1. Factors Hindering the Implimentation of the Land Laws and Policies in the two Regional States

Lack of budget is one of the factor hindering the implimentation of the land laws and policies in both regional states. In the Ethiopia Somali National Regional State (here after ESNRS), for example, there is shortage of finance and logistics which is required to increase the awareness of the public about the laws and the policies let alone implementation of the laws. This seems to have emanated from the little focus given to the land resource in the two regional states in general and in ESNRS in particular.[79] Similar problem also exist in the Afar National Regional States (here after ANRS). In Amibara district, for example, lack of budget constrained the experts to engage in the community as needed.[80] The agency that follows up the implementation of land laws and policies is responsible to the woreda administration office. This ultimately affects the budget process in that it complicates budget management process.[81] The structural adjustment is even worse in ESNRS in that implementation of the policies and laws related to natural resources is shouldered on a small natural resource department which is responsible to the Regional Livestock and Rural land Administration Bureau.[82] Shortage of land experts is also one of the factors hindering the implementation of the land laws and policies in the two regions. Experts of land administration, registration, planning, survey and land use are, for example, missing in Amibara Rural Land and Environmental Protection Agency.[83] Surprisingly, there is one expert for forest and one for land both at regional and woreda level in the ESNRS.[84]

4.2. The Security of the Land Use Right of the Pastoralists in the Study Area

There are different factors increasing tenure insecurity of the pastoralists in the study area. In Amibara Woreda of the ANRS, for example, expansion of investment in the grazing area is the major concern of the pastoralists. Recently an investor has got 2000 hectare of land for investment in Halidage Rangeland and, of course, deep well (about 100) are being dug by the federal government. Surprisingly, the local community does not have sufficient information for what purpose the deep wells are being dug.[85] Qurqura, Awash Arba. Halidabe, Bedulale, Angelele are part of Halidage rangeland found in Amibara woreda covering about 100,000 hectare of land.[86] The major concern of the pastoralists in this area is, therefore, expansion of park and investment of sugar plantations and, consequently, fear of dispossession of the communal grazing land. They really want their rights be respected in that they passed good and bad times in the area for 100s of years. The pastoralists claim, for example, forage development by irrigation and other development programs, which could sustainably change their life.[87] The pastoralists in ESNRS have also such fear and this ultimately hindered the implementation of the land law in the region.[88] Sub clan leader at Mile kebele of the Shinnle District expressed his concern as follows;

The government can take our holding one day in the future. If there are such plans, the government must once and again think over as to where we could graze our livestock. Where should we take our livestock? [89]

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[79]Group Discussion with experts NRM in NR Department of the Ethiopian Somali Regional State, Livestock and Rural Land Bureau, on August 6, 2015 , Jigjiga

[80]Interview with Process owner of the land Administration and Use Department In Amibara Woreda Environmental and Rural land Use and Administration Agency on July 26, 2015,Werer

[81]Interview with Process owner of the land Administration and Use Department In Amibara Woreda Environmental and Rural land Use and Administration Agency on July 26, 2015,Weror

[82]Group Discussion with experts NRM in NR Department of the Ethiopian Somali Regional State, livestock and rural land Bureau, on August 6, 2015 , Jigjiga

[83]Interview with Process owner of the land Administration and Use Department In Amibara Woreda Environmental and Rural land Use and Administration Agency on July 26, 2015,Werer

[84] Group Discussion with experts NRM in NR Department of the Ethiopian Somali Regional State, Livestock and Rural Land Bureau, on August 6 2015 , Jigjiga

[85]Interview with Process owner of the Land Administration and Use Department in Amibara woreda Environmental and Rural Land Use and Administration Agency on July 26, 2015, Werer

[86]Interview with NRM protection and rehabilitation process owner in the Amibara Woreda Pastoral development office on 24/07/15, Werer

[87]Interview with religious father on 26/07/15, Andido

[88]Group Discussion with experts NRM in NR Department of the Ethiopian Somali Regional State, Livestock and Rural Land Bureau, on August 6, 2015 , Jigjiga

[89]Interview with Shinille Woreda, Mile Kebele sub clan leader, on August 7, 2015, Mile

Fear of dispossession is, therefore, one of the major concerns of the pastoralists in the two regional states. The land policies and laws in the two regions have, however, very important provisions regarding the right of pastoralists. Its implementation, of course, requires the commitment of all stakeholders including the customary institutions. Respondents in the study area were also asked different questions regarding the security they feel over their land use rights. The findings are discussed here in under.

Table 1. Is there separate land for grazing, crop cultivation, settlement in your area?

Item	Afar				Somali					
	Amibara		Dulesa				Shinille			
	Ba/mo	An/do	Tir.		Maragajo	Kotrobele	Harewe	Mile		
Yes	20	16	15	11	19	20	5	4	110	68.75
No	0	4	5	9	1	0	15	16	50	31.25

The majority of the respondents (about 69%) indicated as to the existence of separate land for grazing, cultivation and settlement. This is, however, traditionally practiced use of land which is not based on land use suitability and economic importance. That is why about 31% the respondents were in negative as to the existence of such separate land use system. There is no, therefore, properly studied and practiced land use plan in the area under study and that is why most intervention including investment happens on the dry season grazing area. There were, of course, beginnings both at regional and federal level in preparing land use studies. It was, however, criticized for lack of clarity and non-inclusiveness. The absence of such well studied and practiced land use plan resulted in unwise use of the land resource and, ultimately degradation and violation of land use rights of the pastoralists.[90] Halidage Rangeland, in which about 100 deep wells were being dug, is the best example.[91] There is also overlap of claim among land users resulting into conflict. All the problems were the results of absence of proper land use plan and absence of clear cut tenure system which shows which land belongs to whom and what right the holder has on such holding. There are, of course, laws and policies governing these issues in Afar and Ethiopian Somali National Regional States, but poorly implemented.

Table 2. Are such separate land use types, if there exist any, always respected by other users?

Item	Afar				Somali				Total	%
	Amibara		Dulesa		K/beyah		Shinile			
	Ba/mo	An/do	Tir	Dul	Maq.	Kot.	Harawe	Mile		
Yes	13	2	6	4	8	13	1	0	47	29.4
No	7	18	14	16	12	7	19	20	113	70.6

From the total respondents, about 71% think that their land use rights were violated by others while for 29% of the respondents said their rights were respected. Here the majority of the respondents indicated that other users of land use type were not respecting their land use right. As the following discussion elaborates, the state is one of the violator of land use rights. The pastoralists themselves were, of course, the major violators of the major land use type, grazing.

[90]Interview with Process owner of the land Administration and use department in Dulessa woreda Environmental and Rural land Use and Administration Agency on July 29, 2015, Dulessa

[91]Interview with Process owner of the land Administration and use department in Amibara woreda Environmental and Rural land Use and Administration Agency on July 26, 2015 , Werer

Table 3. Who are the violators of such land use type, if there exist any?

Item	Afar				Somali				Total	%
	Amibara		Dulessa		K/beyah		Shinille			
	Ba/mo	And	Tir.	Dul.	Maq	Kot.	Harewe	Mile		
C/leader	0	1	5	3	0	0	0	0	9	6
Crop/P	0	0	0	0	2	2	4	5	13	8
Govt.	0	1	2	0	0	0	0	0	3	2
Grazers	4	15	3	11	7	10	6	9	65	41
All	0	1	4	0	0	0	1	1	7	4
	AC=4			AC=2	BD=4	BD=2	BD=8	BD=5	BD18 AC6	BD12 AC4

For 57% of the respondents grazers are the major violators. Grazers themselves did not, therefore, respect other grazers' right. That is why in pastoral community conflict is very much higher over grazing areas and this may sometimes goes to the extent of changing potential grazing areas into cultivation due to overlap of claims.[92] For 22% respondents, crop producers were also violators of their land use rights. This happens when crop producers start farming in the area previously used for grazing. Such crop production may also be supported by the government and could be large scale farming. Similarly for 14% of the respondents clan leaders were also violators of land use rights. As the response to the open ended questions indicated, clan leaders were restricted only to the interest of their clan members and close families. For 10% of the respondents, government is the other violator of land use rights. This usually happens when the government employs land previously used for communal grazing for investment purpose. There are times when development programs such as settlements are purpose driven in that they are taken as facilitation for other interventions such as large scale commercial farming in disregard of the best interest of the pastoralists.[93] Crop producers, clan leaders and the state have their own share in violating land use right of the pastoral communities under the study even if the degree of involvement varies.

Table 4. What do you think are the major problems facing communal grazing land in your area?

Item	Afar				Somali					
	Amibara		Dulesa		K/beyah		Shinille		Total	%
	Bad.	And.	Tir.	Dul.	Maq.	Kot.	Har.	Mi.		
Enclre	1	0	0	0	1	7	1	4	14	9
C/Pro	0	0	2	2	8	5	4	0	21	13
Invt.	0	0	3	0	0	0	6	5	14	9
Conflict	10	7	9	14	0	0	0	6	46	29
All	2	0	0	3	2	0	0	1	8	5
Others	Dro6	Dro13	Dro6	AD1	AB5 NO 4	AB5 No7	AB6B C1 AD2	AB2 AD2	Dro25&AB 18 AD4& No11	16 &11 3 &7

For 37% of the respondents, the major problem facing communal grazing land was conflict among users. The conflict most of the time happens among grazers due to overlap of claims over

[92]Interview Tirtira Religious father on July 29, 2015, Dulessa
[93]Interview with Sedentarisation representative of the Federal Affairs for Amibara on 20/11/2007, Awash Arba

grazing areas. It also happens when communal grazing areas are enclosed for private grazing or for crop production.[94] The frequent drought and scarcity of resources contributed to the occurrence of conflict not only between crop producers and grazers, but also among grazers (livestock producers).[95] There was, for example, such conflict in Asbehari area(Dulessa District) between Hablic Adali clan and Sidihabura clan and many people died because of overlap of claim over grazing area and charcoal production. There is also such conflict between Argoba & Afar over the land use in Dulessa District.[96] Similarly, there is conflict over grazing area of Gureyz in Kebribeyah District of ESNRS. The conflict in this area happens when clans from other area come to graze in the Gureyz area and the clan residing around claim ownership and requires others to leave. Currently the conflict in the area is minimized due to the presence of Regional Special Police Force (*Liyu Police*). Had it not been for the presence of Regional Special Police Force (*Liyu Police*), the conflict would have been frequent in Gureyz grazing area.[97]

For 29% of the respondents, crop producers also have their own share in violating land use right of the pastoralists on communal grazing area. There is a believe that one who has crop producing land is more secured than the one using the open communal grazing land. Such a believe make individuals to enclose portion of the communal grazing land. That is why 28% of the respondents perceive enclosure as one of the problem the communal grazing land is facing. Those who enclose part of the communal grazing area use the land either for crop production or private grazing. This is, of course a response to the absence of secured in land use right. Individuals who have enclosed land are more secured than those using the communal grazing in that they could easily get compensation when such land is employed for other purpose. The frequent drought makes the pastoralists to search for alternative livelihood such as crop production and trade.[98] Drought has become frequent than ever in the area under study. This consequently resulted in death of the livestock due to shortage of fodder and water.[99] Similarly 16% and 14% of the respondents are of the opinion that drought and investment are respectively posing treat on communal grazing areas. The frequency of drought also resulted in diversion of the grazing areas into crop production. Crop production is the last resort when their livestock die due to shortage of fodder.[100] The respondents were also asked about their feeling of security over land use rights. The response is somewhat mixed as discussed here in under.

Table 5. Do you feel discriminated in the land use rights in your area?

Item	Afar				Somali				Total	%
	Amibara		Dulessa		K/beyah		Shnile			
	Bad.	And.	Tir.	Dul.	Maq.	Kot.	Har.	Mil.		
Yes	5	6	6	5	4	3	6	5	38	24
No	15	14	14	15	16	17	12	15	122	76

About 76% of the respondents do not felt discriminated in their land use rights while 24% of the respondents had such a feeling. The non-inclusiveness of the settlement program; denial of the land resource for non-clan members; absence of private holding, exclusion of women; and absence of legally divided land make the 24% of the respondents felt discriminated in their land use right. In areas such as Amibara and Dulessa Districts, for example, there were clans who had good land and those who did not have such. The latter, therefore, felt discriminated due to such unfair distribution of land. If one clan member of Afar happens to be in other clan territory, he feels discriminated because of the fact that he is not member to the clan residing there, let alone other ethnic groups.[101] As per the land proclamations of the two regional states, acces to land is

[94]Interview with Harewe Kebele elder on August 7, 2015, Harewe

[95]Interview with Kebele Administrator of Dulessa Kebele on July 29, 2015, Dulessa

[96]Interview with Process owner of the land Administration and Use Department in Dulessa Woreda Environmental and Rural Land Use and Administration Agency on July 29, 2015

[97]Interview with Kebribeya, Woreda Mereqajo kebel sub- clan leader on August 5, 2015, Meqernajo

[98] Interview Tirtira Religious father on July 29, 2015, Dulessa

[99]Interview with sub clan leader on 26/07/15, Andido

[100]Interview with Tirtira clan leader, on July 28, 2015, Dulessa

[101] Interview Tirtira Religious father on July 29, 2015, Dulessa

not clan based and every resident of the region could, therefore, get regardless of ethnic and clan origin; and place of resdence.[102] The respondents were also asked about their feeling of security over their land use rights. Surprisingly, the majority of the respondents do not feel secured over their land use right as discussed here in under.

Table 6. do you feel secured over your land use in your area?

Item	Afar				Somali				Total	%
	Amibara		Dulesa		K/beyah		Shinille			
	Ba/mo	An/do	Tir.	Dul.	Maq.	Kot.	Har.	Mil		
Yes	10	5	7	8	14	16	9	7	66	41
No	10	15	13	12	6	4	11	13	94	59

About 59% of the respondents did not feel secured over their land use right while about 41% of the respondents believed that their land use right was secured. The majorities of the pastoralists in the study area, therefore, did not feel secured over their land use rights and demand intervention that could minimize such insecurity. Absence of private possession in addition to communal holding; absence of land certification; failure to implement the land law and policy; unfair distribution of land; absence of legally divided land resource; fear of dispossession from the communal land; and absence of formal land use system were factors contributing for the insecure nature of land use right of the pastoralists. As discussed in the following sections such state of insecurity increased the demand for certification.

Table 7. Do you think certification of such land use rights is necessary?

Item	Afar				Somali				Total	%
	Amibara		Dulesa		K/beyah		Shnile			
	Ba/mo	An/do	Tir.	Dul.	Maq.	Kot.	Har.	Mil		
Yes	20	20	17	19	16	20	7	6	126	79
No	0	0	3	1	4	0	12	14	34	21

For 79% of respondents, certification of their land use right was very important while the balance (21%) think certification was not necessary. For those who responded negatively, their major concern was that their holding may be dispossessed and in that it may restrict mobility. Such view was hold by the respondents from the Shinille District. The majority of the respondents in the study area, however, had great demand for certification. Even if pastoral specific legislation is absent in Oromia National Regional State, the steps taken to strengthen land tenure security of the pastoralists could be taken as best experience by Afar and Somali Regions. Advisory Committee composed of all interested groups has been established both at regional and zonal levels of Borana and Guji Zones. The advisory committee which is composed of stakeholders from both customary and formal institution are doing their best to strengthen the land use right of the pastoralists in the two zones.

[102] See the cumulative reading of Art.5(5) & 9(3) Land Use and Administration Proclamations and see also the cumulative reading of Art 5(6) and 9(3) the preamble of the Ethiopian Somali National Regional State Land Use and Administration Proclamation.

4.3. The Role of Customary Institution in Land Related Issues

4.3.1. Land management and division

The majority of the land resource in Afar Region is controlled by clan leaders and predominantly used for communal grazing.[103] Nothing will, therefore, be implemented if the clan leaders are not consulted.[104] Due to such influence the clan leaders in the region were invited to the conference organized by the regional government when the regional land law was enacted.[105] The clan leaders raised their major concern and finally agreed provided that the government fulfill social infrastructure and separate the grazing areas from other land use types.[106] When investors need land for investment in the regional state they are required to negotiate with the clan leaders. Clan leaders also played important role in division of land. Such division was, for example, done in the area called Blen(Amibara District) in which 4000h of land divided among clan members. Clan leaders participated in sellecting those who are benificiaries of the settlement programs and identify who should be given land.[107] The grazing system is also fasilitated by leaders of customary institutions even to the extent of negotiating resources with neibours.[108] In Shinille District, for example, every Issa can graze the communal land that belongs to Issa which is facilitated by clan leaders. Issa pastoralists, for example, could come even from Zeyla when drought happens there. This rule applies, of course, for Issa clan only and it is prohibited for other clan to come on Issa territory.[109]The customary institutions, therefore, play important role in distribution and supervision of the land resource in pastoral area under study. The respondents were also asked as to the law governing land, pasture, and water resource in the areas under study.

Table. What governs land, pasture, and water resources in your area?

Item	Afar				Somali				Total	%
	Amibara		Dulesa		K/beyah		Shnile			
	Ba/mo	An/do	Tir.	Dul	Maragajo	Kotaroble	Harawe	Mile		
Customary Law	1	1	11	9	7	9	2	3	43	28
Government Law	2	5	3	1	1	1	2	0	15	9
Both	17	12	6	10	12	10	16	17	100	62
None	0	2	0	0	0	0	0	0	2	1

For 62% of the respondants both customary rules and government laws govern the land resource while for 28% of the respondants said that the customary laws govern the land resources in their localities. For the remaining 9% of the respondants the government laws govern the land resource in their area. For the majority of the respondants both customary and the government institutions govern the land resource in the area under study.There is no, however, such area of collabration between the two institutions in administrating the natural resources; both institutions do separatelly their traditional activity.[110] This was not, however, a healthy situation. The formal institutions took the major share in the weakening of the customary institutions.[111] The formal instutions were not on the other hand effectivelly managing and administrating the natural resource in that the resource is under the control of customary institutions. A sense of stalemate

[103] Kelemework Tafere. 2013. Formal and Informal Land Tenure Systems in Afar Region of Ethiopia: Perceptions, Attitudes and Implications for Land Use Disputes, p. 46

[104]Interview with Process owner of the land Administration and use department in Dulessa Woreda Environmental and Rural Land Use and Administration Agency on July 29, 2015

[105]The meeting took 6 days even if planed for 3 days in that the clan leaders refused to handle the land resource to the government.

[106]Interview with clan leader on July 26, 2015, Werer

[107]Interview with Process owner of the land Administration and use department In Amibara Woreda Environmental and Rural land Use and Administration Agency on July 26, 2015,Werer

[108]Interview with sub clan leader on 26/07/15, Andido

[109]Interview with clan leader on August 7, 2015, Mile

[110]Interview with Process owner of the Land Administration and Use Department in Dulessa Woreda Environmental and Rural Land Use and Administration Agency on July 29, 2015, Dulessa

[111]Interview with sub clan leader on 26/07/15, Andido

is, therefore, created especially in pure pastoral area and in the wet farming areas where both the formal and customary institutions failed to properly regulate the resource112 and, of course, exposing the same to degradation due to sense of carelessness. Recent studies indicated that the pastoral community in ANRS was of great interest if clan leaders are empoweded to deal with land use and administration.113 Surprisingly, the land laws and policies in the two regional states empower the customary institutions in land administration and use, but poorly implemented. There was also little effort, if not none, in the area of natural resource conservation in pastoral community of the two regional states. The communal grazing area was used in open access without planed rotational grazing and resulted in over grazing and degradation.114 Consequently, formerly best grass lands turned into dust with little possibility of recovering.115 Dulessa, Andido, Harewe and Mile kebeles are the real examples as to the existence of such problem. In addition, the already existing small forest coverage is also being deforested without proper replacement and somewhat better and wet areas are being swallowed by prosopis.

4.3.2. Managing conflict arising out of land holding

Customary institutions were heavily involved in conflict resolution in pastoral community under study. When conflict happens, elders who know history were called and they decide on the existing facts. If two clans are in conflict, neutral clan will be invited to solve the problem.116 The formal institutions were not, however, effective due to the fact that they warn the disputants rather than identifying the root cause of the problem and providing viable solutions.117 If you take the conflict in the area of Humedu in Dulessa District, for example, the formal institutions failed to solve the conflict but customary institutions did.118 Customary institutions were effective in conflict resolution than that of the government structure, because they restore community relations back to normal.119 Finance is, however, their major challenge.

4.4. Institution Meriting More and the Gaps Each Have

The customary and formal institutios have their own strong and weak sides. the following section is, therefore, dedicated to discuss such features.

Table 9. Customary institutions are more effective in administrating land than the government institutions?

Item	Afar				Somali				Total	%
	Amibara		Dulesa		K/beyah		Shnile			
	Bad.	And.	Tir.	Dul.	Maq.	Kot.	Har.	Mil		
Strongly Agree	8	5	1	0	5	3	12	17	51	32
Agree	1	2	4	4	10	11	4	1	37	23
Disagree	6	9	8	10	0	3	0	0	36	23
Strongly disagree	1	2	1	0	0	0	0	0	4	3
I don't Know	0	0	1	2	2	0	0	0	5	3

For 55% of the respondents customary institutions were more effective if empowered in land administration and use areas. The control they have on land resource; timely & win-win solutions; easy availability; closeness to the public; making peace according to local custom, make customary institutions more effective than government institutions. On the other hand, for 26% of the respondents the formal institutions will be more effective than the customary institutions in administering the natural resources. Strong institution; capacity to solve problems; following

112Interview with Harewe Kebele elder on August 7, 2015 , Harewe

113See supra note 95, p.51

114Interview with Process owner of the Land Administration and Use Department in Amibara Woreda Environmental and Rural land Use and Administration Agency on July 26, 2015,Werer

115Interview with Process owner of the Land Administration and Use Department in Dulessa Woreda Environmental and Rural Land Use and Administration Agency on July 29, 2015, Dulessa

116Interview with religious father on 26/07/15, Andido

117Interview with Badhamo religious father on August 8, 2015, Awash Sebatkillo

118Interview Tirtira Religious father on July 29, 2015, Dulessa

119See supra note 95, p.60

procedures which are predictable; presence of land law & policy; fairness; capacity to fulfill the demand of its citizens; distribution of land; and protection given to the right of women made the formal institutions more effective than that of the customary institutions. About 16% respondents, surprisingly, indicated that both institutions should work in cooperation. Effective administration and management of the natural resources in pastoral areas, therefore, demands cooperation between both the informal and formal institutions.

According to Afar and Somali customs, women are denied access to the land resource in that it is customarily believed that when a woman maries outside the clan the land, resource will be accessed by other clans.[120] In short, women are denied access to the land in customary institutions. There is also problem of fairness in distributing the 30% benefit collected from investors from communal farming in Afar Regional State. Those who have close relationship with investor and clan leader are better-off while others take what is given for them.[121] It is only on rare cases that members take measures on those who are expected to collect and distribute the benefit.[122]

The open access to communal grazing land coupled with the absence of rotational grazing, the weakening of customary institutions; and poorly handled natural resource conservation turned the communal grazing land into bare lands. The customary institutions currently failed to handle such issues. Unless the land resource is properly managed and utilized, pastoralists in the study area are at risk let alone the future generation. In addition, reluctance, carelessness and absence of futurity; restriction around the interest of clan members and sometimes close members; lack of creativity & motivation; failure to cooperate with government institutions; and failure to communicate the problem of the community to the government were identified as the weak sides of the customary institutions. On the other hand absence of follow up; failure to implement the land policy &law; failure to give much emphasis to the land resource of the area; absence of natural resource protection; absence of land use plan: expansion of investment and crop production; failure to fully cooperate with the customary institutions; failure to properly administrate the land resource and the people (Harewe & Mile in particularly); and failure to give land certificate were categorized as weakness of the formal institutions.

4.5. The **Impact of the Gaps on Interventions**

Conflict of interest happens between investors and the local community due to disagreement over the type of plantation. There is such problem, for example, in Amibara District of the ANRS. The clan residing there wants cotton to be produced while the investors want to produce sugarcane.[123] The clan uses the cotton for their livestock as a fodder at the end of production year.[124] Offended members of the community, therefore, graze their livestock on the sugarcane planted by investors.[125] Investors are also forced to pay money for different claimants at different time including double payment by the time of compensation. What is even surprising is that there are claims for compensation on yearly basis.[126] Eventhough licenses were granted from ESNRS, there were reported cases of disturbance of investors by the local community. . The clan members demanded the investors to leave the area claiming clan ownership over the resource. Such problem happened throughout the pastoral community of Ethiopia.[127]

Rengeland develepment is also challenged due to such gaps. APARI experts, forexample, faced many challenges when they tried to enclose portion of the range land for rehabilitation in Assayta area in that lots of issues such as; "*who will use the developed area*? *what are the criteria to exclude others? and enclosure restricts mobility,*" were raised. Such issues were being raised in many pastoral areas and will contiue to be raised in the ansence of clear cut land use righs. Similarly, PRIME members did

[120]Interview with Kebribeya Woreda Mereqajo kebel sub- clan leader August 5, 2015 Meqernajo

[121]Interview with Badhamo religious father on August 8, 2015, Awash Sebatkillo

[122]Interview with Process owner of the land Administration and use department In Amibara woreda Environmental and Rural land Use and Administration Agency on July 26, 2015,Weror

[123]Interview with NR Protection and Rehabilitation Process owner in the Amibara Woreda Pastoral Development Office on July 24, 2015, Werer

[124]Interview with Process Owner of Land Administration and Use Department in Amibara Woreda Environmental and Rural land Use and Administration Agency on July 26, 2015,Weror

[125] Interview with NRS protection and rehabilitation process owner in the Amibara woreda Pastoral development office on July 24, 2015, Werer

[126]Key informant interview with experts at MoFA indicated that the government officials themselves are hindrances for the non implementation of the policies and the laws related to land. There is also a complaint that some officials have a large tract of land by their name and by the name of others of others July21, 2015, Addis Ababa

[127]Key informant interview with experts at MoFA, July21, 2015, Addis Ababa

rangeland improvements in Andido kebele of Amibara District by enclosing portion of the communal grazing land. Prosopis was cleared and good grasses grew. Such improvement was, however, damaged in that member of the community grazed the developed area before the maturity level.[128] Unless the scope of land use rights is not properly determined, intervensions will, therefore, be difficult in pastoral areas.

The existing gaps were also challenging public service expansion. When concerned government institutions try to expand such services or engage in other developmental activities, clan members come and claim ownership over that land and request money to be paid even if the area is not cultivated.129 There were lots of challenges when settlement was started in Amibara District. The community residing there and clan leaders thought that their holding would be dispossessed.130 The absence of clearly identified land use right indicating which land belongs to whom and the scope of such right is, therefore, challenging for the expansion of social services in the area under study.

4.5. Assesing the Coopratіve Environment

There are potential areas for collaboration in areas such as demarcating claims, mobilization of the community for development; natural resource protection. Such potential areas are not, however, exploited properly due to the problems attributed to both formal and customary institutions.131 Cooperation over water harvest, awareness creation, natural resource protection, catchment development, settlement area identification; and proper land use and administration were required if the livelihood of the pastoralists is to be enhanced.132 As the experiences of other countries show, disregarding the customary institutions result in failures.133 The formal tenure system will not be effective in the absence of recognition and integration with the customary institutions. Collaboration is very much helpful in that the customary institution in general and the clan leaders in particular could easily mobilize the community while the formal institutions could give support in finance and logistics.

5. Conclusions and Recommendations

5.1. Conclusions

Violation of land use rights and insecurity of tenure are highly felt by the pastoral communities under study. Grazers were the major violators of the major land use, grazing (livestock production). That was why conflict in the study area was was higher and went to the extent of changing potential grazing areas into crop cultivation. Crop producers, clan leaders and the state also violated land use rights. On the other hand, enclosure (either for farming or private grazing), conflict, investment, and drought were the major problems facing the communal grazing land in the study area. Conflict in the area happens due to the absence of proper land use plan indicating which land is better for what land use type and absence clear land use rights.

Even if the majority of the respondents did not feel discriminated in their land use rights, few respondents were feeling discriminated. This group raise convincing reasons such as non-inclusiveness of the settlement program; the control of the land resource by clan leaders; absence of legally divided land; difficulty of access for non-clan members; and absence of private holding. The majority of the respondents, of course, feel unsecured in their land use right due to absence of private holdings; absence of land certification; failure to implement the land law and policy; unfair distribution of land; absence of legally divided land; fear of dispossession; and absence of formal land use system.

Customary institutions play important role in the division and supervision of the land resource and they are consulted in any decisions to be made on land. Member of the community most of the time

[128]Interview with Process owner of the land Administration and use department In Amibara woreda Environmental and Rural land Use and Administration Agency on July 26, 2015, Werer

[129]Group discussion with NRM experts in Kebribeyah Woreda, Livestock and Rural Land Office, on August 5, 2015, Kebribeyah

[130]Interview with Sedentarisation representative of the Federal Affairs on 20/11/2007, Awash Arba

[131]Interview with Process owner of the land Administration and use department In Amibara woreda Environmental and Rural land Use and Administration Agency on July 26, 2015, Werer

[132]Interview with Kebribeya Woreda Mereqajo kebel sub- clan on August 5, 2015, Meqernajo & Interview with Process owner of the land Administration and use department In Dulessa Woreda Environmental and Rural land Use and Administration Agency on July 29, 2015,Dulessa

[133] Land Administration to Nurture Development, LAND (2014) Oromia Pastoralist Advisory Committee (OPAC) Field Visits, Meetings, and Presentations Report, October 27-November 5, 2014, p.24

resort to such customary institutions in that they used them for a loner time and they have solutions for every problem. The majority of the respondents indicated that the customary institutions were functioning well in the case of conflict management. They were, however, so weakened in the area of resource management and administration. The control they have over natural resource; timely solutions, win-win result; availability; and respected decisions made the customary institutions more effective than the government institutions. Disregarding the rights of women; failure; reluctance, carelessness; restriction around the interest of their clan members; lack of motivation; and failure to cooperate with that of the formal institutions are the major weakness of the customary institutions.

Predictability, guaranteed documents; existence of law & policy; fairness; capacity to fulfill the demand of citizens; enforcing the right of women were the strong sides of the government institutions while absence of follow up; failure in implementing policy &law; failure to give much emphasis to the land resource; absence of natural resource protection; absence of land use plan; failure to fully cooperate with the customary institutions are the weak sides of the formal institutions. The gaps in both formal and customary institutions were challenging rangeland development, investment and social service expansion. Potential cooperative areas between the formal and customary institutions were not properly exploited.

5.2. Recommendations

- Proper implementation of land laws and policies in the two regional States requires more budget, independent institutions, trained experts and committed officials at all level.
- Increasing the awareness of the pastoral community regarding the objective and the content of the land laws and policies is required. This could be achieved by building positive relationship between customary and formal institutions.
- It would be better to have well studied, inclusive and fair land use plan in order to control unwise use of land resource, degradation of natural resources and conflicts due to overlap of claims.
- Identifying which land belongs to whom; indicating the scope of the right; practicing legal, inclusive, and well studied division of land in addition to communal holdings must be done in cooperation with the local community.
- The formal and customary institutions are required to work in cooperation beyond conflict resolution. Customary institutions could play very important role in mobilizing the community while the formal institutions could facilitate finance and logistics.
- The sustainability of livestock production which is the major as well as potential livelihood for the pastoral communities require intervention in the area of special breeds, irrigated forage development, rangeland rehabilitation and natural resource protection. It is also required to support alternative livelihood such as crop production in well studied and selected areas in addition to livestock production.

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13. Smallholder Farmers' Choice of Climate Change Adaptation Options: The Case of East Hararghe Zone, Ethiopia

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Abstract
Climate change remains a severe problem in Africa that has the potential of undermining sustainable development efforts if steps are not taken to respond to its adverse consequences. This study analyzed farmers' perceptions and major adaptation strategies to climate change, the factors that affect choice of adaptation strategy and barriers to adaptation in east Hararghe zone of Ethiopia based on a cross sectional survey of 296 sample households selected from Kersa, Fedis and Babile districts. It is evident that the majority of farmers in eastern Ethiopia are aware of climate change patterns such as increase in temperature and changes in precipitation patterns. Such changes are perceived by the farmers to have significant adverse effect on income level, food security, diversity, livelihood, forest resources, food prices, and crop and livestock diseases. To respond to these adverse negative effects, farmers adopted different strategies including cultivating different crops, planting different crop varieties, changing planting dates, use of soil and water conservation techniques, changing tillage and rotation practices, mulching, and engaging in non-farm income activities. The multivariate probit model result indicated that gender of household head, family size, farm size, distance from market, number of farm plots, and agroecological setting are among the significant determinants of the choice of climate change adaptation strategies. The major barriers to adaptation were lack of access to irrigation, lack of knowledge and information about weather and modern adaptation technologies, and lack of access to capital for acquiring technologies. To enable farmers in the study area develop more effective climate change adaptation strategies, there is a need for the government to support farmers through provision of the necessary resources such as credit, information and extension services on climate change adaptation strategies and technologies, and investing in climate resilient projects.

Keywords: climate change; farmers' perceptions; adaptations; multivariate probit.

1. Introduction

Evidence has showed that the global climate is changing and that greenhouse gases emissions are growing alarmingly (Maarten *et al.,* 2007) which in turn is leading to a rise in the earth's temperature. This, intermingled with growth in the world's population, threatens food and livelihood security for large numbers of people especially those in the developing countries. Increasing temperatures, declining and more unpredictable rainfall, more frequent extreme weather and higher severity of pest and disease are among the more drastic changes that would impact food production (Parry *et al.,* 2007; Kotschi, 2007, Morton, 2007; Brown and Funk, 2008; Lobell *et al.,* 2008). Some of the most important effects of climate change will be felt among smallholder farmers, predominantly in developing countries (Morton, 2007). Developing nations especially those in sub Saharan Africa will be more vulnerable to the effects of climate change due to their geographical and climatic conditions, high dependence on agriculture and natural resources driven activities and limited capacity to adapt to the changing climate (Eriksen *et al.,* 2008). Quantitative assessments also show that the most profound and direct impacts of climate change over the next few decades will be on agriculture and food systems and the poorest will be at risk both by global climate variations and global commodity price fluctuations (Brown and Funk, 2008; Schmidhuber and Tubiello, 2007; Diaz *et al.,* 2006). Climate change is thus a serious threat to poverty eradication and the attainment of the various development goals.

Ethiopia can be cited as a good example of a developing country whose economy is highly influenced by climate change (Negash, 2013). The country's economy is dominated by subsistence agriculture. The agriculture sector plays a dominant role in the economic development of the country accounting for about 42% of the gross domestic product (MoFED, 2010). Its dependence on the agriculture sector made its economy sensitive to climate change and variability, especially variations in rainfall (USAID, 2007). The nature-dependent agricultural sector of the economy, mingled with the country's geographical location, topography and low adaptive capacity, made the country highly vulnerability to adverse impacts of climate change (Negash, 2013). The country has been historically suffering from natural catastrophes and is prone to extreme weather events. Rainfall in Ethiopia is highly erratic, and most rain falls intensively, often as convective storms, with very high rainfall intensity and extreme spatial and temporal variability. Hence, food production has failed to keep up to high population growth rates, resulting in high levels of food insecurity. Decreasing farm size, decline in soil fertility, severe land degradation, fragile ecosystems, and recurrent weather-induced shocks such as drought are the main causes of food production deficits and of high livelihood vulnerability, especially in the densely populated areas of the eastern highlands.

The specific objectives were to:

- identify the main climate change adaptation strategies employed by smallholder farmers in the study areas;
- examine factors that influence households' choice of climate change adaptation strategy;

2. Research Methodology

2.1.. Description of the Study Areas

The study was conducted in eastern Hararghe zone, Oromiya regional state of Ethiopia. The zone has a total population of 2,723,850, of whom about 51% are men. While 216,943 (8.27%) are urban inhabitants, a further 30,215 (1.11%) are pastoralists. A total of 580,735 households were counted in this Zone, which results in an average of 4.69 persons to a household. With an area of 17,935.40 square kilometers, east Hararghe zone has a population density of 151.87 (CSA,2007).
The zone has a complex agro-ecological area in which heavy population density, high ratio of cash to food crops, unpredictable rainfall and significant differences between the agricultural practices within the three main altitude zones create a complicated agricultural profile, and at the same time support a population that is in general highly vulnerable to food insecurity. Food shortages are often difficult to detect, as green fields tend to mask vulnerability, and pockets of extreme hunger may exist literally a few kilometers from areas of relative food stability.

Fedis district, having an area of about 2193.8 km^2, is located in the central part of East Hararghe Administrative zone. It is bordered by Girawa, Harmoaya, Babile and Kurfachele districts, and Harari and Somali Regional States and stretches between 500 and 2100 meters above sea level. The district is classified into *woinadega* (15%) and *kola* (85%) agro climatic zones. The population's livelihood mainly consists of agriculture, husbandry, and small-scale trade. The population is about 170, 560, of which about 98% are rural (48.5% females). The district's crude population density is estimated at 72 persons per km^2 (CSA, 2007). Maize, haricot bean, sorghum and groundnut are widely cultivated crops in the district. The farm units are small family holdings with an average agricultural land area of less than one hectare. The use of irrigation is still very limited. Variations in the amount and occurrence of rainfall, low utilization of modern agricultural inputs due to low purchasing power of the farmers, inadequate infrastructural facilities, shortage of schools, health institutions, veterinary services, and potable water supply as well as deterioration of natural resources are some of the major problems in the district. On the other hand, irrigable land, large livestock resources as well as varied soil types with different fertility status are the major potentials of the district (FWAO, 2013).
Having an area of 3022.2 km^2, Babile district is found in the eastern part of East Hararghe Zone. It is bordered by Gursum, Fedis, Harari, and Somali Regional States. Babile town is the district capital and stretches between 950 (Daketa valley) and 2000 meters above sea level. The district falls under *woinadega* (15%) and *kolla* (85%) agro climatic zones. Babile had about 52,800

population, of which about 81% were rural (49% females). An average family sizes for rural and urban areas were 5.7 and 4.7 persons, respectively. Young, economically independent and old age populations accounted for 51.1%, 47.1%, and 1.8%, respectively. The district's crude population density is estimated at 17 persons per km² (CSA, 2007). Sorghum, maize and haricot bean are the most widely cultivated crops. Variability in the amount and occurrence of rainfall, traditional farming method, low adoption of modern agricultural inputs, shortage of school, sub surface water, health institutions and veterinary services, and backward infrastructural facilities are the major problems in the district. On the other hand, the district has large tracts of arable land, and favorable weather condition for the production of groundnut and livestock rearing.

Having an area of 544.9 km², Kersa district is found in the northern part of East Hararghe zone. It is bordered by Haromaya, Kurfachele, Bedeno, and Meta districts as well as Dire Dawa Administrative Council. Altitudinally, it extends between 1400 and 3200 meters above sea level. Kersa is classified into *dega* (7%), *woinadega* (91%) and *kola* (2%) agro climatic zones. Of the 126,930 total population, about 94% are rural (48.5% females). Average family sizes for rural and urban area were 4.3 and 4.0 persons, respectively. The crude population density of the district is estimated at 233 persons per km² (CSA, 2007). Unreliability of rainfall, low adoption of modern agricultural inputs due to low purchasing power of the farmers and lack of credit facilities, shortage of schools, health institutions, potable water supply and veterinary services, backward infrastructural facilities and resource deterioration (deforestation and low soil fertility) are the major problems in the district. On the other hand, the district has large tracts of irrigable land.

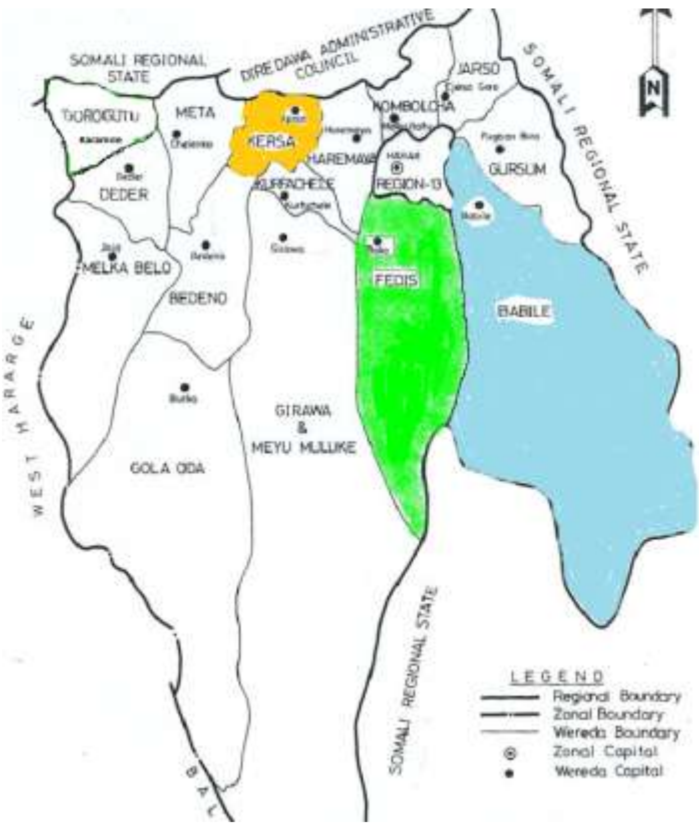

Figure 2. Map of the study districts .
Source: Adapted from (Canali and Slaviero, 2010) with modification .

2.2. Data Type and Sources

Data used in this analysis were collected from a household survey conducted in Kersa, Babile and Fedis districts of east Hararghe zone. The districts were chosen in order to take a representative sample for the study. Data were gathered at household level on socio-economic and demographic characteristics, institutional and market characteristics, sources of income and livelihoods, crop production, geographic features, climate change perceptions and adaptation strategies. Secondary data were collected from district agricultural offices through desk review.

2.3. Sampling Design

A multi-Stage sampling technique was used to randomly select 296 households from the three districts. The selection of the districts was through purposive sampling, which took into consideration the agroecological setting, location in the district, food security condition, and farming system. Proportional sample was taken from each district with sample frame collected from the district Agricultural Offices. First, rural villages (peasant associations) were randomly selected from each of the districts. The sample was drawn randomly from 14 villages (5 from Kersa, 5 from Fedis and 4 from Babile). From the selected rural villages, households were selected using a probability proportional to size sampling method. Hence, the data was generated through a survey of 296 households.

2.4. Methods of Data Collection

The primary data were collected through household survey questionnaire (interview schedule). Before the actual survey, the questionnaires were pre-tested. For the data collection, enumerators were employed and trained on the ways they approach the respondents and execute the interview. Secondary data were collected through desk review and interview of key officers at district level.

2.5.Methods of Data Analysis

Data analysis was carried out using descriptive statistics and econometric models using SPSS and Stata statistical packages. Descriptive statistical tools such as mean, standard deviation, and percentages were used to analyze and present socio-economic characteristics, perception of climate change and its effects, climate change adaptation strategies, households' food security status, climate induced risks, and coping mechanisms. Analysis of variance (ANOVA), t-test, χ^2 (chi-square), and mean comparison statistical tests were run to compare groups with respect to variables of interest.

Model for Choice of Climate Change Adaptation Strategies

Farmers are more likely to adopt a mix of adaptation strategies to deal with a multitude of climate induced risks and constraints than adopting a single strategy. Different studies in Africa have used various empirical methods to analyze the determinants of adaptations to climate change and choice of adaptation strategies. Most commonly used analytical approaches include discrete choice regression models like the binary probit or logit (Acquah de Graft and Onumah, 2011; Fosu-Mensah *et al.,* 2010), multinomial probit or logit and multivariate probit (Hassan and Nhemachena, 2008; Deressa *et al.,* 2008; ACCCA, 2010; Sofoluwe *et al.,* 2011; Nzeadibe *et al.,* 2011; Aemro *et al.,* 2012). Other empirical studies used Principal Component Analysis (Mandleni and Anim, 2011) and the Ricardian Model (Kurukulasuriya and Mendelson, 2006). A shortcoming of most of the previous studies on adoption of climate change adaptation strategies is that they do not consider the possible inter-relationships between the various strategies (Yu *et al.,* 2008). These studies mask the reality faced by decision makers who are often faced with alternatives that may be adopted simultaneously and/or sequentially as complements, substitutes or supplements.

Some recent empirical studies of technology adoption and climate adaptation decisions assume that farmers consider a set (or bundle) of possible technologies (strategies) and choose a particular technology (strategy) bundle that maximizes expected utility (Moyo and Veeman 2004; Marenya and Barrett, 2007; Nhemachena and Hassan, 2007; Yu *et al.,* 2008; Kassie *et al.,* 2009). Thus, the adoption decision is inherently multivariate and attempting univariate modeling excludes useful economic information contained in interdependent and simultaneous adoption decisions. Based on this argument, the study adopted multivariate probit (MVP) econometric technique to simultaneously model the influence of the set of explanatory variables on each of the different strategies, while allowing the unobserved and/or unmeasured factors (error terms) to be freely correlated (Belderbos *et al.,* 2004; Lin *et al.,* 2005). Source of correlation can be complementarity (positive correlation) or substitutability (negative correlation) between different strategies (Belderbos *et al.,* 2004).

The dependent variable in the empirical estimation for this study was the choice of a certain adaptation option from the set of adaptation measures (cultivating different crops, planting different varieties, changing planting dates, and soil and water conservation measures). Following Lin *et al.* (2005), the multivariate probit econometric approach for this study was characterized by a set of *n* binary dependent variables y_{hpj} such that:

$$y^*_{hpj} = x'_{hpj}\beta_j + u_{hpj} \quad j = 1, 2, \ldots \text{ m. and} \tag{1}$$

$$y_{hpj} = \begin{cases} 1 & if \quad y^*_{hpj} > 0 \\ 0 & otherwise \end{cases} \tag{2}$$

where j = 1,2, … m denotes the climate change adaptation strategies available; x'_{hpj} is a vector of explanatory variables, β_j denotes the vector of parameter to be estimated, and u_{hpj} are random error terms distributed as multivariate normal distribution with zero means and unitary variance. It is assumed that a rational h^{th} farmer has a latent variable, y^*_{hpj} which captures the unobserved preferences or demand associated with the j^{th} choice of adaptation strategy. This latent variable is assumed to be a linear combination of observed household and other characteristics that affect the adoption of adaptation strategy, as well as unobserved characteristics captured by the stochastic error term.

Given the latent nature of the variable y^*_{hpj}, the estimation is based on the observable variable y_{hpj} which indicates whether or not a household adopt a particular climate adaptation strategy. Since adoption of several adaptation strategies is possible, the error terms in equation (1) were assumed to jointly follow a multivariate normal distribution, with zero conditional mean and variance normalized to unity. The off-diagonal elements in the covariance matrix represent the unobserved correlation between the stochastic component of the j^{th} and m^{th} type of adaptation strategies. This assumption means that equation (2) gave a MVP model that jointly represents decisions to adopt a particular adaptation strategy. This specification with non-zero off-diagonal elements allows for correlation across the error terms of several latent equations, which represent unobserved characteristics that affect choice of alternative adaptation strategies.

3. Results and Discussion

3.1. Household Level Adaptation Strategies

in response to adverse effects of perceived climate changes, farmers adopt different practices which will reduce variability on economic livelihoods and food security. the most common practices reported in empirical studies included cultivating different crops, changing crop variety, changing planting and harvesting dates, planting trees, irrigation, off farm income diversification, conservation agriculture, and soil and water conservation (accca, 2010; bryan *et al.,* 2012; juana *et al.,* 2013).

Figure 2 summarizes the climate change adaptation strategies used by the farmers in three districts of the study areas. The major climate change adaptation strategies used by the farmers in the study areas are discussed below.

The result indicated that planting different crop varieties and cultivating different crops were selected as most important strategies in all the districts. Soil and water conservation measures were selected most by farmers in Fedis and Babile than those in Kersa. Changing planting dates is also selected most by farmers in Kersa. Small proportion of farmers in Kersa also reported expanding land under crop production and use of chemical fertilizer in response to climate change. Conservation agriculture practices such as mulching, changing rotations and tillage practices are reported by few farmers as adaption strategy. Irrigation is reported by some farmers in Babile district as good adaptation strategy. Over and above, planting different crop varieties, cultivating different crops, use of soil and water conservation measures and changing planting dates are found to be the major climate change adaptation strategies in the study area. Aemro *et al.* (2012) and Belaineh *et al.* (2013) reported similar results.

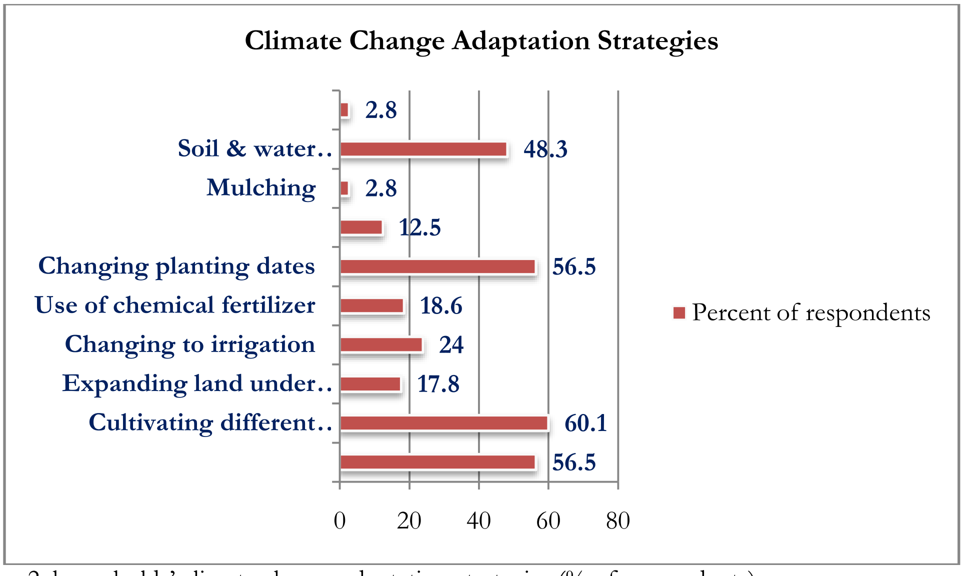

Figure 2. households' climate change adaptation strategies (% of respondents).

Cultivating different crops

One of the possible farmer adaptations to climate change is to switch crops to something better suited to the new climates they face. Crop diversification was identified as a potential farm-level adaptation to climatic change and variability (Smit and Wendal, 2006; Bradshaw *et al.,* 2004; Speranza, 2006). When climate changes, farmers could also switch what crops they grow since farmers' choices about what crops to grow depend on climate and expected prices at harvest. Over the long run, climate exerts clear influence on crop choice. The highly variable climates of much of Africa induce poor risk-averse farmers to grow lower-value but drought-tolerant crops such as cassava. If climate matters to crop choice, then farmers could plausibly gain by switching crops if new climates favor a different crop over the one currently grown. This is the basic thrust of the so-called "Ricardian" estimates of climate change impacts on agriculture. In the study, about 29% of the sample farmers in Kersa, 18% in Fedis districts, and about 14% in Babile district selected planting different crops as the first important climate change adaptation strategy. The highest percentage in Kersa district indicates that crop diversification is common in mid-highland areas since they can choose crops which suit new climates and the lower percentages in relatively hotter areas (Fedis and Babile districts) shows that hot areas will not have alternatives to switch crops.

Farmers in east Hararghe highlands usually employ crop diversification (cultivating different crops) as a dominant strategy to reduce risk of crop failure (Degye *et al.,* 2012; Wondimagegn *et al.,* 2011; Belaineh, 2003). It is also argued that growing one crop might switch to a faster-maturing crop if drought becomes more common, or might choose to grow a potentially more drought-tolerant crop like sorghum although such decisions will not be made on the basis of climate alone. The result is supported by Ogalleh *et al.* (2012) who reported crop diversification as one of the most practiced adaptation strategy.

Planting different crop varieties

The other possible farmer adaptation to climate change is to switch varieties to something better suited to the new climates they face. Beyond shifting among crops, farmers could also switch what varieties of crops they grow as the climate changes. Growing drought tolerant crop varieties is an important adaptive strategy practiced by farmers in developing countries. Planting different crop varieties was ranked first by about 23% of the sample farmers in Kersa and Fedis districts and

34% in Babile. This result signifies that changing crop variety is a feasible climate change adaptation option in hotter areas such as Fedis and Babile. As with choice of crop, farmers' choices about what variety of crops to use depend on climate. The result is supported by Ogalleh *et al.* (2012) who reported use of various crop varieties as the most practiced adaptation on most farms.

To the extent that climate change affects the relative profitability of different varieties in ways apparent to farmers and in ways they can respond easily to variety switching could constitute a fruitful adaptation strategy. In the case of switching varieties, climate change suggests two primary adaptation alternatives, the choice of which depends on whether moisture or heat is expected to be limiting. In low-rainfall areas such as Fedis where moisture stress is expected to remain a primary constraint on plant growth, a promising adaptation might be to plant faster-maturing varieties that avoid drought or heat stress during sensitive stages of plant growth, such as flowering or grain filling. Developing faster-maturing varieties for areas with short and variably rainy seasons (i.e. much of Africa) is a common goal of many breeding programs, and such a strategy would seem promising anywhere climate change is expected to shorten growing seasons.

In areas where moisture regimes exhibit little change, however, a move in the opposite direction toward longer maturing varieties might be preferred, because warmer temperatures tend to speed development and lower yields. Longer maturing varieties would thus be required to maintain the length of time for total crop development as temperatures warm. In areas with recurrent droughts but where temperatures will warm significantly under climate change (i.e. most of Africa), the optimal variety choice might be far from apparent: choose a shorter maturing variety that avoids big losses in very dry years, or a longer-maturing variety that might maintain average yields as the climate warms. Tubiello *et al.* (2002) find that switching to longer-maturing winter wheat varieties at a site with plentiful moisture fully offsets the 15% projected yield losses under climate change, but find somewhat smaller gains for more arid areas. However, adopting such strategy in Africa is constrained by the poor development of seed systems and where they are developed, poor and risk averse farmers are often slow to adopt such new technologies.

Changing planting dates

One of the more straightforward on farm climate adaptation strategies is the option to shift when in the year crops are planted. Year-to-year shifts in planting dates are already a demonstrated farmer adaptation in the face of climate variability, particularly for farmers in rain fed environments who often must wait for the onset of the rainy season in order to plant. Decisions about when to plant were made based on factors such as available soil moisture, the expected timing of temperature extremes and the demands of multi-cropped systems. Farmers in most parts of Africa routinely shift planting dates by a month or more from year to year in response to variability in rainfall (Falcon *et al.,* 2004; Tadross *et al.,* 2005).

It is found that systematically shifting planting 2 weeks earlier transforms what would have been 20 to 25% yield losses by 2030 into modest gains (Tubiello *et al.,* 2002). This is because cold temperatures limit early planting in current climate, subjecting the crop to heat and drought stress during critical stages of plant growth, and warmer climates appear to allow earlier planting and less stress during sensitive growth stages. Similarly, cropping systems where irrigation is possible for much of the year might also benefit from shifting planting dates, particularly for crops likely to experience frequent temperature extremes in their current growing season as the climate warms.

Soil and Water Conservation

Soil and water conservation techniques reduce soil loss from farmers' plots, preserving critical nutrients and increasing crop yields. It is evident that land degradation and soil fertility decline are critical problems in Ethiopia by aggravating poverty and food insecurity. Climate change is one of the causes for land degradation and soil loss. Soil and water conservation technologies serve not only the social good but also increase on-farm yields; hence, they are considered "*win-win.*"

Hence, soil and water conservation techniques have been linked with addressing climate change since they conserve the soil and improve water availability for crops by conserving water and the soil structure which in turn reduce erosion (Dumanski *et al.,* 2006). Significant proportion of sample farmers in Fedis district (52%) and Babile districts (39.4%) ranked it as the first important climate change adaptation option.

3.2. Factors Influencing Households' Choice of Adaptation Strategies

To respond to climate changes and reduce its negative effects, cultivating different crops, planting different crop varieties, changing planting dates, and soil and water conservation techniques are used by farmers in the study areas as major climate change adaptation strategies. These adaptation measures help farmers guard against losses due to increasing temperatures and decreasing precipitation. However, there are a number of factors which influence households' decision to choose a particular adaptation option(s). The analyses presented in this study identify the important determinants of adoption of various adaptation measures using a multivariate probit model to provide policy information on which factors to target and how, so as to encourage farmers to increase their use of different adaptation measures. Socioeconomic characteristics, institutional characteristics, and climatic variables are modeled to assess whether they have influence on households' choices of the aforementioned adaptation strategies. Description of the explanatory variables used in the model is given in Appendix (Table 1-A).

Model characteristics

The likelihood ratio test (P(χ^2 (6)>46.16 = 0.000) of the independence of the disturbance terms (independence of choice of multiple adaptation strategy) was strongly rejected, implying that choice of multiple adaptation strategy in the study area was not mutually independent and supporting the use of a multivariate probit model. The binary correlations between the error terms of the four adaptation equations are presented in Table 1. Results of the correlation between the error terms indicated that some strategies were complementary (positive sign), while others werwe substitutes or compete (negative sign) for the same scarce resources. The correlation coefficients were statistically different from zero in 5 of the 6 cases, confirming the appropriateness of the multivariate probit specification and choice of climate change adaptation strategies is not mutually independent.

Results from the multivariate probit model of determinants of choice of adaptation measures using data from a cross-sectional survey of 296 sample households are presented in Table 6. The results of the correlation coefficients of the error terms are significant (based on the t-test statistic) for any pairs of equations indicating that they are correlated. The results on correlation coefficients of the error terms indicate that there is complementarity (*positive correlation*) and substitutability (negative correlation) between different adaptation options being used by farmers. The results support the assumption of interdependence between the different adaptation options which may be due to complementarity in the different adaptation options and also from omitted household-specific and other factors that affect uptake of all the adaptation options. However, the simple correlation between two adaptation strategies, ignoring other strategies, is misleading. With increase in the number of bundled strategies, they are increasingly likely to be complementary with another, even if subsets are substitutes when viewed in isolation (Yu *et al.,* 2008). Another important point to note from the results is that there are substantial differences in the estimated coefficients across equations that support the appropriateness of differentiating between adaptation options.

Regarding the determinants of climate change adaptation strategies, the results suggest that different household, socioeconomic, farm and location characteristics were significant in conditioning the households' decisions to choose adaptation strategy (Table 1.)

Table 4. Coefficient estimates for the multivariate probit model .

Variables	Different crop type		Different crop variety		Changing planting dates		Soil & water conservation	
	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Gender of head	-0.6094**	0.2874	0.6093**	0.2533	-0.1116	0.2532	-0.2029	0.3206
Education status	0.2807	0.1908	0.1203	0.1798	0.2419	0.1758	0.0768	0.2277
Farming experience	-0.0115	0.0129	-0.0131	0.0112	0.0175	0.0123	-0.0176	0.0145
family size	0.0573	0.0740	-0.0464	0.0708	-0.1336*	0.0716	0.1611*	0.0828
Farmer organization	0.0840	0.1926	-0.0320	0.1800	-0.1385	0.1848	-0.0452	0.2278
Climate information	-0.0196	0.2132	-0.1932	0.2142	0.1383	0.2100	0.1185	0.2495
Fertilizer use	0.4505	0.2979	0.1068	0.2715	1.0392***	0.2907	0.1429	0.3487
Chemical use	-0.2818	0.2377	-0.0648	0.2170	-0.2667	0.2116	0.9694***	0.2874
Credit access	0.3336*	0.2000	0.1785	0.1953	0.1406	0.1906	-0.0961	0.2375
Off farm income	-0.1442	0.2553	0.2694	0.2405	-0.0638	0.2428	0.0446	0.2944
Market distance	0.0431*	0.0220	0.1058***	0.0244	0.0624***	0.0207	-0.4145***	0.1015
Extension contact	-0.0044*	0.0023	-0.0004	0.0025	0.0014	0.0023	0.0003	0.0034
Social safety nets	-0.5669***	0.1848	0.0129	0.1793	0.0652	0.1758	0.4028*	0.2132
Percapita income	-7.95e-6	0.0000	-0.0001	0.0001	-1.2-e5	0.0001	-0.0001*	0.0001
Farm plots	0.4188***	0.1040	-0.0356	0.0855	0.1703*	0.0872	-0.2243**	0.1019
Farm size	-0.5287***	0.1859	0.1585	0.1949	-0.2425	0.1677	0.4734*	0.2784
Land fertility status	0.2734	0.1997	0.3054*	0.1841	-0.1307	0.1855	0.1155	0.2353
Crops grown	0.5429***	0.1258	-0.0889	0.1187	0.0501	0.1162	-0.0848	0.1331
Marketed surplus	-0.0113*	0.0064	0.0024	0.0061	-0.0021	0.0058	-0.0238***	0.0084
Livestock holding	-0.0167	0.0182	-0.0128	0.0185	0.0063	0.0154	0.0217	0.0445
Fedis	-0.9267**	0.4666	0.5958	0.4606	1.4469***	0.4642	0.6238	0.6457
Kersa	-2.2189***	0.6773	-0.2363	0.6187	2.0621***	0.6240	-0.1675	0.7929
Mid highland	1.1707***	0.4265	1.1165***	0.4003	-1.4643***	0.4127	-1.8695***	0.4435
Constant	-1.0121	0.7682	-1.1519	0.7527	-2.2334***	-0.7543	2.7925**	1.1040
Correlation	Coeff.	Std. Error						
$\hat{\rho}_{21}$	-0.48***	0.135						

$\hat{\rho}_{31}$	0.24**	0.114						
$\hat{\rho}_{41}$	-0.53***	0.165						
$\hat{\rho}_{32}$	-0.33***	0.115						
$\hat{\rho}_{42}$	-0.25*	0.140						
$\hat{\rho}_{43}$	-0.09	0.142						
ρ_{21}	-0.45***	0.108						
ρ_{31}	0.23**	0.108						
ρ_{41}	-0.48***	0.126						
ρ_{32}	-0.32***	0.103						
ρ_{42}	-0.24*	0.132						
ρ_{43}	-0.09	0.142						
Predicted probability	0.60	0.016	0.56	0.016	0.45	0.014	0.47	0.022
Joint probability (success)	0.018	0.002						
Joint probability (failure)	0.014	0.002						
Number of observations						296		
Number of simulations						5		
Log likelihood						-536.35		
Wald χ^2 (95)						288.48		
Prob > χ^2						0.0000		
Likelihood ratio test of $\rho_{ij} = 0$, P > χ^2 (6) = 46.16						0.000		0.000

4. Model Results

The multivariate probit model showed that households' decision to choose cultivating different crops wasw influenced by gender of the household head, access to credit, distance from market, extension contact, access to social safety nets, farm size, number of farm plots, number of crops grown and marketed surplus. Gender of the household head is an important variable affecting adoption decision at the farm level. The negative coefficient for gender variable showed that female-headed households were more likely to take up crop diversification as an adaptation options. Possible explanation is that women have more farming experience and information on various management practices acquired while doing much of the agricultural work. Hence, they can easily adjust themselves to respond to shocks based on available information on climatic conditions and other factors such as markets and food needs of the households. The important policy message from this finding is that targeting women groups and associations in smallholder rural communities can have significant positive impacts for increasing the uptake of adaptation measures by smallholder farmers. This result is consistent with the findings of Nhemachena and Hassan (2007).

The negative effect of extension contact on cultivating different crops is more probably due to the fact that the extension system was much more concerned with profitability, giving less emphasis to risk management by farmers. Aemro *et al.* (2012) and Wondimagegn *et al.* (2011) reported similar findings. Access to credit was another important determinant enhancing the adoption of various technologies (Kandlinkar and Risbey, 2000; Tizale, 2007). With more financial and other resources at their disposal, farmers were able to make use of all their available information to change their management practices in response to changing climatic conditions. Better access to credit services found found to have a strong positive influence on the probability of adopting cultivating different crops as adaptation measure and abandoning the relatively risky monocropping systems. Same result was found by Nhemachena and Hassan (2007). The positive effect of market distance on adoption of crop diversification indicates that remoteness from markets tends to favor multiple cropping over specialized crop cultivation. This is an indication that more market integration promotes specialization in production and hence is an important area for public investment in adaptation infrastructure. Nhemachena and Hassan (2007) also reported a similar result. The negative coefficient for the marketed surplus variable indicated that subsistent households were more likely to cultivate different crops in response to climate change. The finding is supported by Nhemachena and Hassan (2007).

Only a few factors influence whether farmers change crop variety as an adaptation option. This is probability due to the fact that planting crop variety decisions are autonomous decisions taken by farmers. Household's choice of crop varieties as climate change adaptation strategy is found to be dictated by gender of household head, market distance, land fertility status and agroecology. Male headed households are more likely to plant different crop varieties as a climate change adaptation strategy. Aemro *et al.* (2012) found same result. Farmers with access to fertile soils and located far from market centers were more likely to change crop variety (Bryan *et al.,* 2011). Distance from market is found to influence adoption of crop variety as adaptation strategy. This indicated that households located far from market centers were likely to plant crop of different varieties. The result is consistent with that of Bryan *et al.* (2011) and Nhemachena and Hassan (2007).

Choice of changing planting dates as climate change adaptation strategy was determined by few variables (family size, fertilizer use, market distance, number of farm plots, and agroecology). The possible reason was that planting decisions were autonomous decisions taken by farmers. The negative effect of family size was+ likely to be due to the fact that changing planting dates does not require more labor. Farmers who use fertilizer are more likely to change planting since fertilizer can help in growing crops earlier than they need. Farmers located at distant from market centers are also more likely to change planting dates in response to adverse effects of climate change. Farmers having more number of plots also change planting dates than their counterparts.

The model results show that households who were more likely to employ soil and water conservation measures in response to perceived climate change were those who had larger family size, use chemicals, were located closer to market centers, receive food aid, had lower percapita income, had less number of plots, larger farm size, subsistence and located in the lowlands. In general, an increase in farm size increases the likelihood of adapting to climate change using soil and water conservation. Empirical adoption studies found that farmers with larger farms had more land to allocate for constructing soil bunds and improved cut-off drains (Anley *et al.,* 2007; Nhemachena and Hassan, 2007; Negash, 2013). The positive effect of family size on adoption of soil and conservation measures may be due to the fact that larger family size enables farmers to take up labor intensive adaptation measures (Dolisca *et al.,* 2006; Nyangena, 2007; Anley *et al.,* 2007; Birungi, 2007; Nhemachena and Hassan, 2007) such as soil and water conservation. Farmers who market large proportion of their produce were less likely to adopt soil and water conservation measures. Possible explanation is that subsistence farmers are more likely to notice climate and adapt to it than other kinds of farmers (commercialized).

Adoption also varies by districts and agroecology. It is also hypothesized that different households living in different agroecological settings use different adaptation methods. This is due to the fact that climatic conditions, soil, and other factors vary across different agroecologies, influencing farmers' perceptions of climate change and their decisions to adapt. The negative coefficients for Fedis and Kersa district dummies for adoption of crop diversification suggested a lower probability of adoption if a farm household is located in these districts, rather than in Babile district (reference district). It is also found that farmers in these districts were more likely to adopt changing planting dates in response to climate change. Farmers in the highlands and mid-highlands were more likely to choose cultivation of different crops, and planting different crop varieties but less likely to change planting dates and use soil and water conservation measures compared to those in the lowlands. These results likely reflect unobservable spatial differences.

5. Conclusions and Recommendations

5.1. Conclusions

The most pronounced effects of climate change are income and yield decline, food insecurity, diversity changes, crop and livestock diseases and pests, high food prices, decline in forest resources, and change in livelihood patterns of the households. Important adaptation options being used by farmers include crop diversification, using different crop varieties, changing planting and harvesting dates, increased use of irrigation, use of water and soil conservation techniques, conservation agriculture and diversifying from farm to non-farm activities.

Robust evidence was found that the probability of adopting a specific climate change adaptation strategy is conditioned by whether another strategy has been adopted indicating the interdependence between adoption decision of different adaptation strategies which is attributed to complementarities or substitutability between the strategies. The multivariate probit model revealed that gender of the household head, access to credit, distance from market, extension contact, farm size, number of farm plots and crops grown are major factors influencing households' decision to choose cultivating different crops as climate change adaptation strategy. Use of different crop varieties as an adaptation strategy is governed by gender of household head, market distance, land fertility status and agroecology. Family size, fertilizer use, market distance, number of farm plots, and agroecology were the variables affecting decision to change planting dates in response to climate change. Households' use of soil and water conservation measures as climate change adaptation strategy was dictated by family size, use of chemicals, distance from market, food aid, percapita income, farm pots, farm size, and agroecology. In sum, gender of household head, family size, market distance, farm plots, farm size, and agroecology are the significant determinants of households' choice of climate change adaptation strategies.

5.2. Recommendation

Based on the findings of the study, the following recommendations were made to help policy and decision makers in making decision towards adaptation to changes in climate.

Strengthening efforts on enhancing farmers' adaptive capacity to climate change should be at the top of the agenda. Designing policies that aim to improve the barriers to adaptation for smallholder farming systems have great potential to improve farmer adaptation to changes in climate.

Research and development also plays important role in changing crop varieties. Programs aimed to reduce impacts of climate change need to encourage investment on soil and water conservation measures and development of disease and drought tolerant crop varieties. Supporting farmers through training on climate change adaptation options such as soil and water conservation measures, changing planting dates, and crop diversification (types and varieties) can improve adaptation practices to climate change. It is also believed that better access to inputs like credit, fertilizer and chemicals has to be improved.

Government policies need to support research and development that develops and diffuses the appropriate technologies to help farmers adapt to changes in climatic conditions. Such policy measures include drought resistant crop technologies, promoting farm-level adaptation measures, such as the use of crop diversification, soil and water conservation measures, and irrigation technologies. Accessibility to key agricultural production information like these water and soil conservation techniques as well as the other adaptation options identified above is essential in promoting farmer adaptation to changes in climate.

Increased diversification of crops, through the cultivation of crops that are drought or flood tolerant and resistant to temperature stresses, as well as activities that make efficient use of the prevailing water and temperature conditions, serves as an important form of climate insurance against rainfall or temperature variability. Growing a number of different crops on the same plot or on different plots reduces the risk of complete crop failure as different crops are affected differently by climatic events. It is important to note that these adaptation measures should not be taken as independent strategies but should be used in a complementary way.

Government need to include climate change adaptation policies in the development agenda. This includes supporting farmers in increasing these adaptation measures through the provision of necessary resources such as credit, information and the provision of extension service on climate change adaptation strategies and technologies. There is also a need for governments and non-governmental organizations to invest in climate resilient projects.

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14. Does Drought Risk Perception Lead to Coping and Adaptation Decision among Smallholders? An Empirical Analysis

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Abstract
Policies and interventions to enhance resilience to climate variability and change should promote active participation of the intended end-users. The cooperation of the communities in turn depends on their level of perception about the risks and the benefits associated with the adaptation interventions. In an attempt to address the objectives of examining factors influencing smallholders' drought risk perception and coping decisions, this study utilized cross sectional data collected from 384 households and employed Heckman selection probit model for its analysis. The study revealed that perceiving climate variability and change does not always guarantee coping and adaptation responses, particularly among the rural people who face more binding constraints that deter adaptation decisions. While educated farmers and those with strong social network are more likely to perceive climate variability and change, farmers with better access to weather forecast and extension services are more likely to respond to the perceived change. Strategies targeted at enhancing smallholder adaptive capacity to the impacts of current and predicted climate change need to focus not only on creating awareness but also on improving enabling conditions through provision of tailored weather forecast and extension services as well as strengthening social network and rural infrastructure.

Keywords: Adaptive capacity; Climate; Heckman; Resilience; Variability

1. Introduction

Climate variability and change causes negative impacts upon agriculture (Below *et al.,* 2010). Because of the size and sensitivity of the agricultural sector, the impact is relatively high in developing countries (IPCC, 2014). Climate change is a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties that persists for an extended period, typically decades or longer (IPCC, 2007). Climate variability means deviations in the mean state of climate and inconsistencies (e.g. in occurrence of drought and flood), on temporal and spatial scales, including short term fluctuations that happen from year to year (Ziervogel *et al.,* 2006). Variability in this case is an integral part of climate change, in which, a change in mean climatic condition is experienced through changes in the nature and frequency of particular yearly conditions including extremes (Smit *et al.,* 2000). In the present report, we use both terms regularly.

Like in many sub-Saharan African (SSA) countries, smallholder agriculture underpins most rural livelihoods and the national economy in Ethiopia. About 93% of the resource-poor rural communities are predominantly engaged in subsistence agriculture (ERSS, 2013). The nature of Ethiopia's agriculture is primarily rain-fed, and hence, the production is sensitive to fluctuations in rainfall (Conway and Schipper, 2011), and other climatic stresses (Yesuf *et al.,* 2008). Recent studies on long-term climate trends indicate that large areas of Ethiopia experience high seasonal rainfall variability (Conway and Schipper, 2011) and a number of regions in the country are found to be prone to drought recurrently (Funk *et al.,* 2012; NMSA, 2001). Besides the past trends, various climate projections (IPCC, 2007; Conway and Schipper, 2011; Funk *et al.,* 2012) reveal a drying trend in all agricultural production seasons across the country. Drought is a recurrent phenomenon and is perhaps the most important climatic challenge in Ethiopia resulting in a sharp reduction of agricultural output (Benson and Clay, 1998; Buckland *et al.,* 2000; FDRE, 2011) and thereby low economic performance. However, drought is not a new phenomenon in Ethiopia as it was recorded as long ago as 250BC (Degefu, 1987; Webb and von Braun, 1994). What is new is its increase in scale and frequency of recurrence during recent decades (Lautze *et al.,* 2003; NMS, 2007). The fact that climate has changed in the past and will continue to change in the future underlines the need for developing a well thought early warning and adaptation interventions. Developing effective adaptation policy on the other hand requires better understanding of the process of adaptation (Below *et al.,* 2012).

Historically, farming community in Ethiopia remained isolated and poorly supported. However, they have a history of responding to the impacts of change in exogenous factors including climate variability and extremes. For instance, farmers claim to have shifted to more drought-resistant crops due to declining rainfall during the last couple of generations (Meze-Hausken, 2004). However, such local level coping and adaptation responses as well as the role of perception in shaping smallholders decision are not well documented. Smallholder farmers often engage in autonomous type of adaptation practices, i.e. based on experience and prevailing conditions (Smithers and Smit, 2009). Their adaptive capacity is, therefore, influenced by the knowledge and perception they have about climate change (Adger, 2003) and decisions are hardly made based on extensive numerical datasets or cost-benefit analysis (Maule *et al.,* 2002). Moreover, as agricultural systems evolve not to average conditions but in response to unpredictable and extreme conditions (Smit *et al.,*1996), the role of perception is rather critical in shaping farmers' adaptation decision in cases where the stress goes beyond their previous experiences (Tucker *et al.,* 2010). Earlier studies on smallholder farmers' perception in the Sahel (Mertz *et al.* 2009), Nile basin of Ethiopia (Deressa *et al.,* 2011), Zambia (Nyanga *et al.,* 2011), and semi-arid central Tanzania (Slegers, 2008) indicated that the majority of the farmers are aware of climate variability and extremes. However, numerous recent studies caution that having perception or knowledge about climate change may not necessarily lead to adaptive responses (Kahan *et al.,* 2012; Lemos *et al.,* 2012; Weber, 2010).

Some consider coping with climate risk as a two-step process (Gbetibouo, 2009; Maddison, 2006) which initially requires the perception that climate is changing, and then responding to the changes through coping and adaptation. In such situations, the adoption process often starts with the perception of the adopter about the problem as well as the type of technology proposed (Adesina and Zinnah, 1993). On the other hand, the level of awareness and perception of climate change is found to be influenced by different socioeconomic and environmental factors including culture, education, gender, age, resource endowments, and institutional factors (Hamilton, 2011; Milfont, 2012; Posthumus *et al.,* 2010). Therefore, understanding the perception of farmers is important precondition to guide policymakers regarding adaptation investments.

Despite the fact that there is consensus that local level responses are part of the solution to effective adaptation (Mertz *et al.,* 2009; Tschakert, 2007), there are limited studies that have elaborated on factors affecting smallholder perception and coping to climate variability. Various recommendations have been proposed to enhance the resilience of smallholders. Although it is hardly put in practice, mainstreaming adaptation into national development process is one such recommendation (Boko *et al.,* 2007). Moreover, ensuring enhanced resilience among smallholder farmers requires policies and programs to build on the already existing measures being implemented by the local people (Mertz *et al.,* 2009) and also to reflect the divers environmental and socioeconomic conditions in which people live (Ziervogel *et al.,* 2006). In most cases, lack of mainstreaming leaves the smallholders' adaptive role in agriculture overlooked (Tschakert, 2007; Adger *et al.,* 2006). Coping mechanisms consists of household practices used as a reactive responses when confronted with immediate and unexpected threats such as drought (Thomas *et al.,* 2007), whereas adaptive strategies refer to proactive and anticipatory measures in response to actual and/or expected climatic stimuli and their impacts (IPCC, 2012).

By providing local level evidence on determinants of perception of smallholders about drought risk and their coping decisions, this study will build on authors who have analyzed the role of perception in long-term climate change adaptation. We ask whether smallholders' perceive climate variability, who and how are they coping with the perceived climate risk. We then provide empirical evidence on the factors that facilitate or hamper smallholder's perception and coping decisions. In order to answer these questions, we analyzed primary data collected from the Central

Rift Valley of Ethiopia, where serious ecological and socio-economic changes have already been reported (Biazin and Sterk, 2013; Garedew *et al.,* 2009).

2. Methodology

2.1. Study Setting and Data Collection

The study was conducted in the Ethiopian Central Rift Valley (CRV) region which is part of the East African Rift System. The area is located between $7^{0}10'$ - 40' N and $38^{0}25'$- 50'E. The mean annual rainfall in the CRV area is 929.45mm and the mean annual minimum and maximum temperatures are 13.5^{0}C and 27.7^{0}C, respectively. More than 85% of farmers in the study area mostly practice crop-livestock mixed farming, which is predominantly rain-fed while part of the lowland areas practice agro-pastoral activities.

The study followed a multistage-stage stratified random sampling procedure to select the final sample units. Initially CRV area was selected purposively based on severity of climate variability and extremes. The area is then stratified into three agroecological zones based on elevation, rainfall and temperature criteria. In the second stage, 3 from lowland, 2 each from midland and highland, a total of 7 kebeles (the smallest administrative unit) were randomly selected. In the third stage, the survey randomly drew a total of 384 farm households (146 from lowland, 123 from midland, and 115 from highland) based on proportional to size sampling technique.

Empirical approach and model specification

The main objective here is to explain why some farmers take measures to cope and adapt to climate change while others do not. In theory, decision on adaptation to climate change involves perception of climate change and its seriousness. Conditional on perception, a given farmer is expected to decide on whether or not to respond to the perceived change. As such, coping and adaptation to climate change entails a two-stage process (Maddison, 2006). The assumption is that only those who perceive drought risk will respond to the perceived risk provided that the perceived benefit of coping outweighs its costs. In this regard, a Heckman's sample selection model is applied to explain farmers' decision to adapt to climate change.

Heckman's sample selection model assumes that there exists an underlying relationship which consists of the latent equation given by:

$$Y_j^* = X_j \beta + U_{1j} \tag{1}$$

where Y_j* is the latent variable (the propensity to cope to perceived climate change), X is a k-vector of explanatory variables expected to have influenced farmers' decision to adapt to climate change, β is a vector of parameter estimates and U_{1j} is an error term. The latent variable (Y_j^*) is related to the observed binary dependent variable (Y_j) as follows:

$$Y_j^{probit} = \left(Y_j^* > 0\right) \tag{2}$$

The dependent variable is observed only if the observation *j* is observed in the selection equation:

$$Y_j select = \left(Z_j \gamma + U_{2j} > 0\right) \tag{3}$$

$$U_1 \sim N(0,1)$$
$$U_2 \sim N(0,1)$$
$$Corr(U_1, U_2) = \rho$$

Where $Y_j select$ is whether a farmer has perceived climate change,Z is an m vector of explanatory variables, which include different factors hypothesized to affect perception; γ is the parameter estimate, U_{2j} is an error term and U_1 and U_2 are error terms, which are normally distributed with mean zero and variance one. When the error terms from the selection model and the outcome equations are correlated or when $\rho \neq 0$, applying standard probit techniques to the Equation (1) yield biased results. In such conditions, Heckman probit provides consistent, asymptotically efficient estimates for all the parameters (Van de Ven and Van Pragg, 1981).

It is hypothesized that age, gender, and education of the head of the household, access to information on climate, access to extension services, participation in local institutions, social network, quality of farm land, household income, prior experience of climate induced shocks, dependence on aid, year round access to food, distance to nearest town, and agro-ecological settings influence farmers' perception of climate variability and extremes (Deressa *et al.,* 2011; Gbetibouo, 2009; Maddison, 2006; Diggs, 1991; Ishaya and Abaje, 2008; Semenza *et al.,* 2008). Correspondingly, the explanatory variables selected for the outcome equation include age, gender, and education of the head of the household, number of wives, farm size, quality of the farm land, number of economically active member of the household, non-farm income, number of oxen, access to information on climate, access to extension services, participation in local institutions, social network, land tenure arrangement, distance to nearest town, year round access to food, and agro-ecological settings (Deressa *et al.,* 2011; Maddison, 2006; Bryan *et al.,* 2009; Gebremedhin and Swinton, 2003; Kassie *et al.,* 2009; Nhemachena and Hassan, 2007; Seo and Mendelsohn, 2008; Teklewold *et al.,* 2013).

The suitability of Heckman probit model over the standard probit model (i.e. without accounting for selection) was tested and the result indicated the occurrence of sample selection problem (i.e. dependence of the error terms from the outcome and selection models) justifying the use of Heckman probit model with *rho* significantly different from zero (Wald $\chi 2=3.71$, with $P=0{\cdot}054$). Moreover, the likelihood function of the Heckman probit model was significant (Wald $\chi 2=49{\cdot}74$, with $p<0{\cdot}001$), showing its strong explanatory power. Furthermore, results show that most of the explanatory variables and their marginal values are statistically significant at $p<0{\cdot}05$ and generally in the directions that were expected.

3. Results and Discussion

3.1. Descriptive Statistics and Model Variables

Sampled households are heterogeneous in various attributes. Of the total sample households, 84% are male headed. In the study area, the land size per household ranges from 0.13 - 13 hectares with the average land holding of about 1.89 hectares. Table 1 presents the descriptions and summary statistics of the variables used in the econometric model.

3.2. Climate related shocks and Coping measures

With the assumption that climate change may alter the frequency of extreme events such as drought and flood, the survey sought information on the types of climate shocks households experienced over the last 5 years and the types of coping strategies employed by households in response to these climate shocks. Accordingly, the surveyed households reported to have encountered many environmental shocks mainly droughts, floods, dry spells, pests and disease epidemics. Over the previous five years period, the households reported that about 63% of the shocks resulted from droughts, 39 % from flood and 35 % from animal diseases. The relatively high frequency of drought-affected households is consistent in Ethiopia as it is a drought prone country and particularly so in drought prone areas like CRV. According to respondents, the effect of drought shock is highly pronounced in lowland/kola agro-ecosystem while occurrence of flood is prevalent in the midland and highland agro-ecosystems (Figure 1).

Table 1. Description of variables and summary statistics of the variables used in the perception and coping equations for the Heckman probit selection model.

Variable	Description	Mean	SD
AGE	Age of the head of the household (years)	41.53	14.36
SEX	1= Male-headed; 0 otherwise	0.84	0.37
WIFE	Number of wives per household	1.09	0.79
EDUCHEAD	Years of education of the household head	0.69	0.46
LAND	Size of the farm land (hectare)	1.89	1.68
LABOR	Economically active members in the house	2.52	1.86
OXEN	Number of oxen owned	1.41	1.33
	Farmers perception of fertility level of their farm land:		
HIGHLYFERTILE	1= Highly fertile; 0 otherwise	0.27	0.45
MODERATEFERT	1= fertile; 0 otherwise	0.57	0.50
LESSFERTILE	1= less fertile; 0 otherwise	0.15	0.36
DISTOWN	Distance of the household from nearest town (Walking hours)	3.70	2.70
TENURE	1= registered and certified land; 0 otherwise	0.58	0.49
FARMINCOME	Gross annual income (log)	13386.04	11369.27
NONFARINC	Annual income from nonfarm activities (Br)	1834.57	3882.14
	Local agroecological setting:		
HIGHLAND (Dega)	1= Dega; 0 otherwise	0.30	0.46
MIDLAND (Weynadega)	1= Weynadega; 0 otherwise	0.32	0.48
LOWLAND (Kola)	1= Kola; 0 otherwise	0.38	0.49
FDACCESS	1=Year round access to food; 0 otherwise	0.78	0.41
EXTENSION	1= received extension advise; 0 otherwise	0.81	0.39
FORECAST	1= access to weather forecast; 0 otherwise	0.85	0.36
SOCIALNETWORK	1= have family ties in different agroecology; 0 otherwise	0.75	0.43
LOCALINST	1= participated local institutions ; 0 otherwise	0.38	0.49
AIDSAFNET	1= received food aid/ safety net ; 0 otherwise	0.63	0.48
SHOCK	1= experienced climate induced shock; 0 otherwise	0.84	0.36

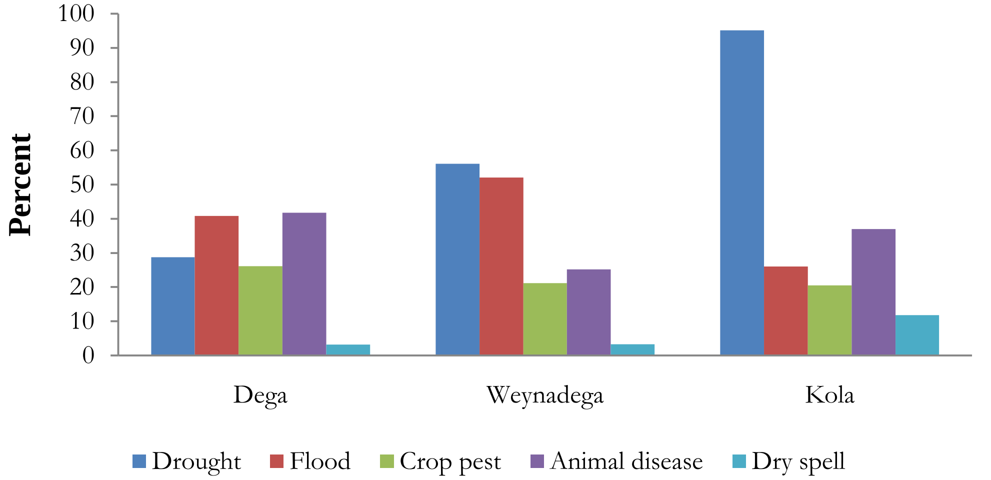

Figure 1. Major shocks encountered by surveyed farmers by agroecological zone.

These shocks resulted in a variety of reported losses, primarily consisting of crop yield declines, loss of asset/income and food insecurity (Table 2).

Table 2. Effects of climate shocks on surveyed farmers.

	Respondents (%)			
	Highland	Midland	lowland	Total
Decline of crop yield	80.87	74.80	73.97	76.30
Loss of income	55.65	65.85	77.40	67.19
Food shortage	60.87	55.28	40.41	51.30
Death of livestock	44.35	30.89	65.75	48.18
Loss of assets	41.74	33.33	45.21	40.36
Decline in consumption	39.13	28.46	41.10	36.46

Those farmers who perceived variability and change were subsequently asked if they had taken measures to cope with the impact of these changes notably drought. Table 3 and Table 4 illustrate the main coping responses to climate shocks by agroecological zone and income tercile, respectively. Due to the fact that the main effect of climate shocks was a decline in crop yield and food shortage, the major coping response involved reliance on food aid and safety net and consuming less amount of food in stress periods. With respect to agroecological setting, the majority of the farmers in the lowland relied on food-aid and safety-net and also collects fuelwood, charcoal and other woodland based forest products to prevail over drought shock. Selling livestock was also important strategy for households coping with climate shocks. However, livestock selling is a less viable strategy among agro-pastorals in the lowland areas as they are reluctant to sell their livestock even in periods of drought preferring to take the risk that many will survive. A large percentage of households in the lowland have low adaptive capacity and were reliant on external support particularly through food-aid and safety-net programs. The low probability of adaptation in the lowland areas may be partly due to the fact that they have already adjusted to more difficult production conditions such as drought-tolerant crop varieties and also to low consumption level and hence have limited additional options at their disposal.

Table 3. Major drought coping measures across agroecological zones.

Agroecology/ coping strategies	Percentage respondents							Total
	1	2	3	4	5	6	7	
Highland	18.89	1.22	5.55	22.32	28.87	14.62	8.52	24.38
Midland	19.77	16.76	12.04	19.01	12.03	7.48	12.89	32.31
Lowland	20.53	36.73	10.03	10.03	3.51	17.29	1.89	43.31
CRV	19.88	21.62	9.59	15.93	12.45	13.47	7.06	100.00

Table 4. Major drought coping measures across income groups.

Income tercile/ coping strategies	Percentage respondents							
	1	2	3	4	5	6	7	Total
Poor	26.96	35.82	8.39	3.51	3.47	19.43	2.42	34.01
Medium	24.56	21.87	8.25	16.27	6.96	16.78	5.32	32.01
Better-off	7.32	6.01	5.90	27.84	25.83	14.38	12.72	33.98
CRV	19.52	21.23	7.50	15.86	12.18	16.86	6.85	100.00

Note:1 = Did nothing; 2 = Seeking aid and safety net; 3 = Engaging in off farm opportunities; 4= Selling livestock; 5 = Reducing consumption; 6 = Increasing dependence on woodland and forest resources; 7 = Borrowing

In terms of income level of the household, majority of the income poor households relied on food-aid and safety-net programs. Livestock selling and reducing consumption level were preferred by relatively better-off families. This is probably due to the fact that poor households were already at low consumption level and will face difficulty in acquiring back livestock resources. Use of woodland and forest based products such as collection of fuelwood and charcoal to generate income was an important coping strategy during stress period regardless of household's income level and geographical location. This is maybe related to the fact that most income generating activities in the CRV is related to the fuelwood and other woodland forest based products. Additional coping strategies employed by the households include seeking off-farm opportunities mainly seasonal migration and labor supply, borrowing from relatives and rural microfinance institutions.

Farmers who perceived variability and change in climate but failed to cope and adapt gave various reasons as hurdles to coping including shortage of land (47%), poor potential for irrigation (45%), lack of money/credit (40%), large family size (16%), lack of market access (17%), and lack of information (3%).

3.3. Empirical Results on Factors Influencing Drought Risk Perception and Coping Decisions among Smallholders

Results of the selection model showed that factors that positively affect farmers' perception of climate variability and extremes were the age of the head of the household, his/her education status, farm income, social network, participation in local institutions, farming in the lowland, and prior experience of climate induced shocks. However, farming in the highland, year round access to food, land quality, and access to aid and safety-net programs negatively affected perception (Table 5). The outcome model helped identify variables that positively influenced coping with drought. These wewre the number of economically active labour in the household, nonfarm income, access to extension advice, access to weather forecast, distance to nearest town, and whether the head of the household was male. Farming in the highland, and having more than one wife negatively affected households coping decisions.

The absence of significant variation in climate perception due to gender of the household head implies that women in the study area have comparable perception with that of men. However, the gender of the household head had a positive effect on coping with drought which implies that, even though female-headed households perceive a change in climate, they cope less easily than male-headed households. This reflects the limited access women in the study area have to assets and productive capital which will potentially limit their capacity to respond to weather shocks. For instance, due to societal construction of gender roles and differential household responsibilities of women in rural Ethiopia, they attend school less often than men which in turn may limit their capacity to diversify their livelihood and cope with drought as also indicated in Knight *et al.* (2003). Other studies, e.g. Demeke and Zeller (2011) and Viatte *et al.* (2009) indicated female-headed households are vulnerable, less food secure and have low technology adoption rates. However, such variation might also happen due to the fact that women have different coping strategies than men (Fothergill, 1996), which were not exhaustively investigated within this study. Other social factors including lack of mobility, lack of power and legal protection and social position (UNIFEM, 2010; Mutton and Haque, 2004) might also undermine women capacity to cope.

The age of the household head, used as a proxy for farming experience, positively affected the propensity of detecting changes in climate variability and extremes. Previous works, e.g. Maddison (2006) and Ishaya and Abaje (2008) also arrived at a similar conclusion. Conversely, results also showed that elderly people do not have better ability to convert their perception into taking coping action suggesting that risk awareness alone is not sufficient for making coping decisions. Given the risk adverse behaviour of aged farmers, older age may mean less coping. In a study conducted in the highlands of Ethiopia, Yesuf *et al.* (2009) found that the older the age of the household heads, the less likely they were to adopt soil conservation technologies.

Table 5. Determinants of drought risk perception and coping decision in the CRV of Ethiopia.

	Outcome model				Selection model			
	Regression		Marginal effect		Regression		Marginal effect	
	Coef.	P-level	Coef.	P-level	Coef.	P-level	Coef.	P-level
AGE	-0.003	0.695	-0.001	0.692	0.025***	0.000	0.008***	0.000
SEX	0.647**	0.041	0.162**	0.023	0.100	0.644	0.033	0.650
WIFE	-0.241**	0.028	-0.73**	0.036				
EDUCHEAD	-0.159	0.528	-0.047	0.510	0.525***	0.007	0.176***	0.009
LAND	0.068	0.270	0.0205	0.270				
LABOR	0.171***	0.009	0.0515**	0.017				
OXEN	0.065	0.408	0.020	0.410				
HIGHLYFERTILE	-0.076	0.759	0.231	0.764	-0.417**	0.037	0.139**	0.047
LESS FERTILE	-0.402*	0.083	0.132	0.104	0.760**	0.017	0.177***	0.007
DISTOWN	0.004	0.001	0.001***	0.002	-0.001	0.280	-0.0005	0.285
TENURE	0.051	0.869	0.154	0.869				
FARMINCOME	0.009	0.818	0.0027	0.819	0.057**	0.031	0.018**	0.032
NONFARMINCOME	0.00006*	0.088	0.00002*	0.095	-0.00003	0.209	0.0000005	0.207
HIGHLAND (*Dega)*	-0.661*	0.076	0.216	0.121	-0.827***	0.004	-0.283***	0.005
LOWLAND *(Kola)*	-0.722	0.109	-0.228	0.101	2.333***	0.000	0.566***	0.000
FDACCESS	0.319	0.241	0.089	0.200	-0.485**	0.022	-0.166**	0.031
EXTENSION	0.741***	0.001	0.224***	0.002	-0.300	0.127	-0.093	0.111
FORECAST	1.361***	0.000	0.488***	0.000	0.063	0.816	0.020	0.818
SOCIALNETWORK	-0.511	0.225	-0.176	0.268	1.125***	0.003	0.228***	0.000
LOCALINST	-0.046	0.850	-0.014	0.850	0.644***	0.008	0.178***	0.001
AIDSAFTYNET					-0.575***	0.002	-0.194***	0.001
SHOCK					0.661***	0.001	0.189***	0.000
Constant	-1.6229	0.048			-1.090**	0.044		
Total observation	383							
Censored	142							
Uncensored	241							
ρ	-0.662**	0.013						
Wald $\chi2$ (zero slopes)	49.7	0.001						
Wald $\chi2$ (indepen. Equations)	3.71	0.054						

*Note: ***, **, * implies significance at 1%, 5%, and 10% probability level, respectively*

Consistent with previous studies (Deressa *et al.,* 2011; Semenza *et al.,* 2008; Bryan *et al.,* 2009; Demeke and Zeller, 2012), higher income level increased the probability of drought perception. However, this is in contrast with Legesse and Drake (2007) who reported that in the eastern highland of Ethiopia, farmers with increased wealth and asset were less perceptive of drought risk. The fact that economically active members in the household increases the likelihood of coping is probably because higher labour endowment would enable a household to engage in various agricultural and non-agricultural tasks especially during stress periods. The probable reason for the effect of proximity to town on farmers coping decision could be due to the fact that households close to towns may look for alternative income earning opportunities in towns than making input-demanding coping decisions.

Compared to illiterates, households headed by an educated farmer have 18% higher probability of perceiving a change in climate. However, education did not significantly influence farmers' coping decisions. A similar result was reported by Clay *et al.* (1998). On the other hand, adaptation studies in Ethiopia (Deressa *et al.,* 2009) and in many other countries (Maddison, 2006) concluded that the probability of adapting to climate risk increases with education level of the household head. The fact that education contributes to improved perception of risk but not on coping decision indicate that farmers may construct different meaning out of the perceived risk as also indicated in IPCC (2012).

In terms of agro-ecological settings, farming in the highland agro-ecosystem was negatively related with drought perception thus suggesting that the issue of drought was not a primary concern to the highland farmers whereas farming in the lowland was strongly associated with drought risk perception. Our findings concurs with Diggs (1991) who, in his drought perception study, revealed that farmers living in drier areas with frequent droughts were more likely to perceive the change than those living in a relatively wetter areas with less frequent droughts. Lowland areas of Ethiopia are drier with higher drought frequency than other areas (Belay *et al.,* 2005). Hence, compared to the midlands, farming in the highlands negatively and significantly affects perception towards drought risk while farming in the lowlands had a positive and significant effect on drought risk perception. Despite high level of perception, however, lowland farmers were found to be less likely to employ coping measures in response to the perceived drought risk, which concurs with Admassie and Adnew (2008). The likely reason for this could be lack of means and other binding limitations that deter coping decisions among lowland farmers which is also confirmed by our qualitative investigation within this study that lowland farmers mentioned the various resource and livelihood constraints that they face in order to respond to the perceived change in climate. Farmers drought perception is also influenced by land quality, i.e. households with more fertile land were less worried about drought than those with poor land quality as good quality land produces more even under bad weather. Thus, receiving adequate and timely rainfall is more critical for farmers with less fertile farm plots. Poor quality of the farm plot was also found to discourage coping decisions as it may require a relatively large investment to improve the quality of the plot.

Access to climate-related information positively and significantly affected drought coping. This is consistent with Bryan *et al.* (2009) and Ziervogel and Calder (2003). This may suggest that farmers in the study area rely more on traditional knowledge, social networks, and locally existing institutions for weather-related information. Contrary to our expectation, access to extension advice did not reveal strong association with probability of perception but positively and significantly influenced coping decision of farmers. The fact that access to extension services enhance the probability of adaptation but failed to influence farmers' perception of climate change raises questions about the message and approach of the rural extension. This finding suggests that it is not the extension contact that matters but the relevance of the message discussed for farmers' actual production decisions (Gebremedhin and Swinton, 2003; Zinnah *et al.,* 1993). Furthermore, the extension message in Ethiopia may lack adequate focus on climate change indicating the need to revisit the content and communication approach.

Results also uncover the importance of aid and safety net in influencing farmers' perception of climate risk. Households that rely on aid and safety net were less likely to perceive drought risk. This could be linked both from the problem of dependency syndrome from the recipients' side and targeting problem on part of the government strategy. Previous studies, e.g. Grosh *et al.* (2008), Harvey and Lind (2005), Lind and Jaleta (2005) claim that recipients developed dependency syndrome and did not make the maximum effort required to improve their livelihoods. Others, e.g. Bakewell (2000) and Harrell-Bond (1986) argue that part of the problem lies at the heart of the government's strategy itself as it focuses more on provision of aid rather than solving the problem of production failure from its root.

Households with strong social network were positively and significantly related with high level of risk perception. Social network can serve as a means to access and exchange various information, protect against unforeseen events, and reduce information asymmetries (Barrett, 2005; Fafchamps and Minten, 2002) and hence are increasingly promoted as a long-term adaptation strategy among adaptation scholars and policymakers (Adger, 2003; IPCC, 2012; Pelling and High, 2005). During our qualitative assessment, farming communities in the CRV also largely cited social networks as an imperative medium of climate information exchange, which concurs with Melka *et al.* (2013). Overall, the present result indicated that households with strong social network and participation in local institutions were in a better condition to access required information for enhanced climate risk awareness.

Polygamy negatively affected farmers' coping decisions. A household with more than one wife was found to be less likely to cope with climate variability and extremes as compared to a monogamous household. This could be linked with large number of children and high dependency ratio, which may limit available resources to be used for coping in drought periods. The likelihood of perceiving drought risk has increased with prior experience of climate induced migration. In particular, households with prior experience of seasonal or long-term migration were 19% more likely to be alert and notice variability and change in drought compared to those with no such experience. This result is in agreement with Bryan *et al.* (2009) who reported that adaptation response of South African and Ethiopian farmers is enhanced by their risk awareness triggered by extreme climate events. Contrary to the argument on lack of clear relationship between migration and climate change (IPCC, 2014; Black, 2001), migration remains to be an important strategy for reducing vulnerability and to diversify livelihoods (Banerjee *et al.,* 2013) especially when all other coping measures are exceeded (Meze-Hausken, 2000).

4. Conclusion and Recommendations

The study analysed local people's perception of climate variability and change as well as the role of such perception on influencing coping and adaptation decisions. Evidence from this study highlighted that perceiving drought risk would not always lead to coping and adaptation decision especially among the rural farming community who face more binding constraints such as poverty, lack of appropriate incentives as well as other social, economic, institutional, and cultural limitations that deter coping and adaptation decisions. Therefore, one should consider perception as a necessary but not sufficient condition for influencing adaptation decisions. Nevertheless, more than half of those who felt that the climate has changed had employed at least one coping measure in light of the changes they perceive. The fact that they are making adjustments to their agricultural practices, however, does not necessarily mean that those autonomous adaptations measures are appropriate and effective.

In terms of policy implications, it appears that improved education and reinforced social network would enhance the perception of local communities whereas improved access to weather forecast and extension services encourage farmers' adaptation decision making processes. The fact that education has contributed towards enhancing climate risk perception but failed to enable farmers engage in adaptation intervention raises intriguing question. Early warning and access to reliable weather forecast, particularly rainfall distribution is vital for making informed decisions in agricultural activities. In this regard, the spatial variability of rainfall and lack of meteorological stations with reliable long-term records are limitations that need to be addressed. Likewise, more engagement towards capacity building in downscaling and communicating the information to farmers as well as increasing the network of automatic weather recording stations is one of the areas to be intervened. The study also highlights the need for improving the rural agricultural extension program particularly through improving the approach, enriching the message as well as the orientation of the extension workers towards climate resilience. The other important policy issue is food-aid and safety net program which is acknowledged for its contribution towards reducing the negative consequences of drought. However, as it is one of the central approach and policy instruments for the Ethiopian government in drought affected and food insecure areas like CRV, the study findings highlight the need for revisiting the program in terms of approach and targeting so as to avoid creation of dependency syndrome. In general, while some coping and adaptation takes place autonomously, the role of the government intervention in promoting the adaptation process particularly through provision of tailored weather forecast, infrastructure development, creating enabling policy environment is required.

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15. Impacts of Climate Variability and Change on Maize Production in Adama District, Ethiopia

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Abstract
In this study, all the 20 GCMs data from the Coupled Model Inter-comparison Project 5 (CMIP5) were downscaled using delta statics method in which two Representative Concentration Pathways (RCPs) of 4.5 and 8.5 for mid (2040-2069) and end (2070-2099) century were downscaled. All CMIP5 GCMs projects show a general increase in maximum and minimum temperature at all locations. Most GCMs projected an increase in rainfall at all locations. Particularly, IPSL-CM5A-LR, IPSLCM5A-MR, BNU-ESM and CanESM2 show an increment greater than 50%. Once we have found the projected climate change scenarios at each location, the assessment of climate change impacts on maize production and model sensitivity test to various environmental parameters were undertaken. Both crop simulation and sensitivity analysis were carried out in all agro-ecology zones (AEZs) on 240 households' farmland with diverse and farmer-specific climate, soil, crop and management parameters using calibrated and validated crop simulation models of Agricultural Production Simulator (APSIM) and Decision Support System for Ago-technology Transfer (DSSAT) under baseline and changed climate scenarios for all the 20 GCMs (RCPs 4.5 and 8.5) from mid to end century. The crop simulation models result shows that maize yield will increase in all AEZs except in sub-moist AEZs zones. The models also simulated fairly similar responses in grain yield to changes in temperature and rainfall. We also found out that short maturing variety would not perform well under projected climate change as the long varieties will do. Adverse impacts of climate change were also observed in case of farmers planting late and using low plant population. The economic impact per capita income due to climate change was calculated using the Trade-off Analysis Multi-Dimensional (TOA-MD) impact assessment tool. The climate change will lead to an increase in per capita income of 26-53 and 20-43USD/annum/ha as per APSIM and DSSAT model respectively at all AEZs.

Keywords: APSIM; Climate change; DSSAT; Ethiopia; Maize; TOA-MD

1. Introduction

One of the key messages emerging out of the recent IPCC reports is that the climate change is real, happening and will continue to happen for the foreseeable future. The report also estimates with high confidence that the negative impacts on agriculture outweigh the positives which makes adaptation an urgent and pressing challenge. However, adaptation planning requires accurate information about where, when and how the impacts are going to be felt and who will be more vulnerable. Eastern Africa is considered as one of the most vulnerable regions in the world due to its high dependence on agriculture for subsistence, employment and income. Generally, the region experiences prolonged and highly destructive droughts covering large areas at least once every decade and more localized events more frequently. The negative impacts of climate are not limited to the years with extreme climatic conditions. Even with normal rainfall, the countries in the region do not produce enough food to meet their needs. Overlaid on this challenging scenario is the dominance of semi-arid to arid climatic conditions which are marginal for crop production, degraded soils, extreme poverty and lack of infrastructure which make the countries in the region highly vulnerable to current and future changes in climate.

There is a rapidly growing literature on vulnerability and adaptation to increased climatic variability and change but most of these assessments are based on statistical and empirical models that fail to account the full range of complex interactions and their effects on agricultural systems. For developing and implementing adaptation programs, more detailed information about how the components of the prevailing farming system such as which crops and varieties are more vulnerable and which management practices are unviable under the predicted climates is needed. However, several problems such as non-availability of downscaled local level climate change projections, lack of information on how the projected changes impact agricultural systems and scarcity of information on how these changes on production and productivity of agriculture translate into economic impacts including food security at household and national levels are constraining such an assessment.

In Ethiopia, the agricultural sector accounts for more than 40% of national GDP, 90% of exports, and provides basic needs and income to more than 90% of the poor (Xinshen Diao, 2010). According to recorded rainfall data analysis, there were 18 droughts or famines in 38 years since 1950, which indicate that there was one drought every two years. Moreover, there has been an increasing trend of drought in the country from the 16th century onwards (Vijendra et al., 2005). Generally East African Region experiences prolonged and highly-destructive droughts covering large areas at least once every decade and more localized events occur more frequently. Based on the analysis of data from the International Disaster Database (EM-DAT), it has been demonstrated that there had been an increase in the number of reported disasters in the region, from an average of less than three events per year in the 1980s to over seven events per year in the 1990s and 10 events per year from 2000 to 2006 (Shongwe et al., 2009). Ethiopian agriculture is dependent on rain fed and under heavy pressure. Food insecurity and often famine is caused by natural disaster such as drought and is likely to be affected by climate change (Mendelsohn and Tiwani, 2000).

This assessment is aimed at generating more accurate information on how projected changes in climate might affect smallholder farmers through impacts on productivity and profitability of agricultural systems that are widely adopted in Ethiopia, as the case of Adama District, using protocols and methods developed by the Agricultural Model Inter-comparison and Improvement Project (AgMIP) (Rosenzweig et al., 2013). The assessment is designed to capture the complexity and diversity that exists in the smallholder-farming systems, including the different ways in which the system is managed. AgMIP has developed methods and protocols that integrate state-of-the-art downscaled climate scenarios, using crop and economic models (Porter et al., 2014). This paper examines the results from the integrated assessment carried out on smallholder farming systems in different agro-ecological zones of Adama Districts in Ethiopia and explores their possible impacts on income, poverty and food security. It also discusses some of the available options that can be used to effectively mitigate the negative impacts while capitalizing on the opportunities created.

2. Description of Investigated Farming Systems

2.1. Settings and Locations

The project districts, Adama district in central part of Ethiopia (latitude 8°53'S and longitude 37°45'E), are characterized by hot and semi-arid climate, where rain-fed farming is predominant; thus making production of maize crop is a risky business; with major effects on farm household productivity and profitability. This project also anticipated that the global climate change will have an adverse multiplier effect on local area crop productivity.

At the beginning, three dominant agro-ecologies were identified in the Adama districts (Figure-1). These maize growing agro-ecologies in the district include Dibi Qalo (semi-arid (SA2)), Geldiya Mukiya Egu (submios3(SM3)) and Adulala Hate (sub-moist(SM2)).

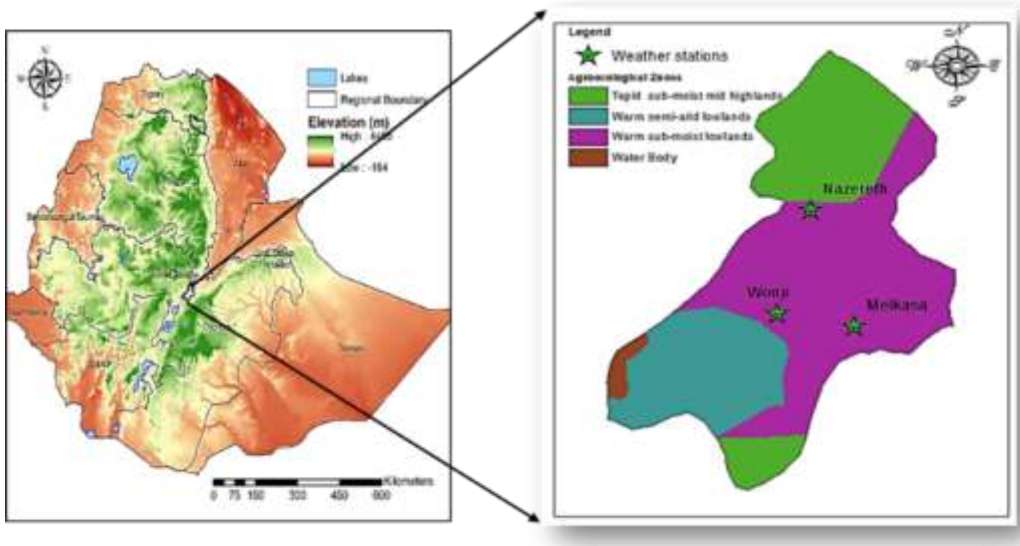


Figure 3: Target agro-ecology zones in Adama districts, Ethiopia

2.2. Farming Systems

The most common farming systems in Adama District are small-scale cash crop and subsistence farming. The cropping patterns as well as the productivity of maize are different for all the agro-ecology zones. The intensity of land use decreases from Warm semi-arid lowlands (Wonji) to Warm sub-moist lowlands (Melkassa). The fertilizer application rate and maize productivity were also high in Warm sub-moist lowlands. Some important characteristics of the farming systems in the target AEZ areas are as shown in Table-1.

Agriculture in the selected AEZs is characterized by extreme dependence on rainfall. The amount and fluctuations in the temporal distribution of rainfall and surface temperature are the most important determinants of inter-annual variability in crop production. Farmers practice low-input agriculture that is low in productivity mainly due to the risk associated with erratic and unreliable rainfall during and between the seasons. A mixed crop-livestock system is the most wide-spread practice.

Table 5. Characteristics of smallholder farms in different AEZs of the Adama District.

AEZ	Mean Household size	Mean Farm size (ha)	Fertilizer use (kg N/ha)	Dominant maize variety	Average maize yields (kg/ha)
SA2	6.63	1.2	5	Melkasa1	500
SM2	5.23	1.8	10	Melkassa-2	774
SM3	6.15	1.4	2	Katumani	530

3. Data and Methodology

3.1. Weather Data

Rainfall, minimum and maximum air temperatures, and solar radiation for the selected climate stations of the study sites were obtained from the National Meteorological Agency of Ethiopia to characterize variability in the observed climate, develop future scenarios and to use with crop simulation models of DSSAT and APSIM. As per the AgMIP protocol, the time period from 1980 – 2009 were used as a baseline or historical period. The NASA MERRA data set is used to fill missing records as well as a proxy for the climate data where observations are not available. A simple bias correction was applied to the MERRA data set and the bias corrected MERRA data set is used to fill missed records in the observation.

The three selected sites of Adama District were part of Central Ethiopia which has 37 administrative villages that are divided into three agro-ecologies of warm semi-arid lowlands SA2, Warm sub-moist lowlands SM2, and Tepid sub-moist mid highlands SM3.

3.2. Soil and Climate Data

Single soil profile was opened for each of the agro-ecologies that helped in construction of datasets for soil physical and chemical analyses from surface soil to the depth of 1.80 meter covering the rooting zones from the three agro-ecology zones of Adama District.

The profile description taken from the soil survey reports was considered to represent average soil conditions in the study area. Considering the high variability in soil conditions across the farms and the need to account for the same, for each of the soil profiles selected three variants (good, average and poor) were created by increasing or decreasing the soil organic matter and plant available water contents by 20%. With these variants, a total of nine soil profiles were created, and a summary of the key characteristics of the profiles under the category 'good' was presented in

Table 6 (which was actually the data taken from each AEZs). These profiles were assigned to individual farms, based on the location of the farm and the perception of the farmer about the fertility status of his farm as captured in the survey. During the survey, farmers were asked to rate the fertility status of their farm as 'good', 'average', or 'poor' when compared to general conditions in the farms of that area.

Table 6. Representative Soil profiles classified as "good".

Properties	Melkassa	Wonji	Nazareth
Target Agro-ecology	SM2	SA2	SM3
Soil type	Leptosols	Fluvisols	Fluvisols
Soil layers/depth (cm)	3/230	7/215	4/215
Sand, silt, clay (% in 0-15cm)	78,17,5	54,35,11	68,22,9
Plant available water	20	35	75
Organic matter (top three layers)	2.09, 1.49, 0.91	3.61,2.29,1.58	2.29, 1.58,0.92

3.3. Methodology

Model setup

Agricultural Model Inter-comparison and Improvement Project (AgMIP) is a global initiative aimed at making comprehensive assessment of impacts of climate change on agricultural systems by integrating state-of-the-art climate products with crop and economic models (see Table-3). The assessments were structured around a set of questions aimed at better understanding climate sensitivity of locally adopted agricultural systems, assessing impacts of projected changes on the performance of smallholder agricultural systems and options available for adaptation as well as benefits from adaptation (see Figure 2).

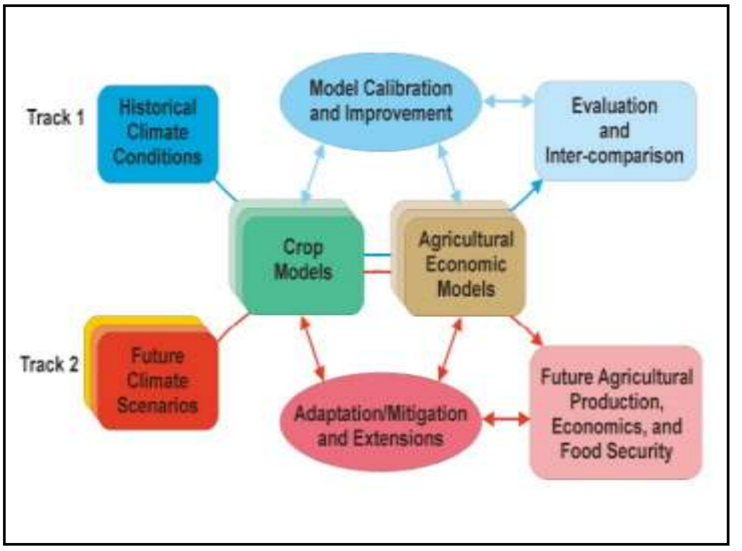


Figure 4. AgMIP approach to assess impacts of climate change.

Table 7. Core questions that this assessment answers.

Core Questions	Simulation Sets	
What is the sensitivity of current agricultural systems to climate change? Economic Simulations #1	Current Current climate (Current production system) 1980-2009 climate Crop Simulations no adaptation (#1) TOA without RAP	Climate change sensitivity Future climate (Current production system) 2040-2069 climate Crop Simulations no adaptation (#2) TOA without RAP
What is the impact of climate change on future Agriculture production systems? Economic Simulations #2	Future without climate change Current climate (Current production system with Trend) 1980-2009 climate Crop Simulations no adaptation (same as #1) TOA with RAP1	Future with climate change Future climate (Current production system with Trend) 2040 – 2069 climate Crop Simulations no adaptation (same as #2) TOA with RAP1
What are the benefits of climate change adaptations? Economic Simulations #2	Future climate change without adaptation Future climate (Current production system with Trend) 2040 – 2069 climate Crop Simulations no adaptation (same as #2) TOA with RAP1	Future climate change with adaptation Future climate (Current production system with Trend) 2040 – 2069 climate Crop Simulations with adaptation (same as #3) TOA with RAP1 and Adaptation

4. Results and Discussion

4.1. Future Projected Climate Change

Weather data for the selected climate stations located in the study sites were obtained from the National Meteorological Agency and Ethiopian Institute of Agricultural Research. As per the AgMIP protocol, the time period from 1980 – 2009 were used as a baseline from the historical period. The NASA MERRA data set was used to fill missing records as well as a proxy for the climate data where observations were not available. A simple bias correction was applied to the MERRA data set and the bias corrected MERRA data set was used to fill missed records in the observation. In general, both annual and seasonal (JJAS) rainfall totals do not show a significant trend over the historical period. However, the coefficient of variation of rainfall shows an increase from time to time. Particularly Nazereth and Wonji stations show a significant positive trend with p-value of 0.000055, 0.000006, 0.043 and 0.00038 for annual and seasonal rainfall totals respectively (see Figure-3). This indicates that the in-season variability of rainfall shows an increase from time to time. On the other hand, the seasonal rainfall shows more variation than the annual rainfall. As shown in **Error! Reference source not found.**, annual average maximum temperature shows a decreasing trend (0.40c per decade with p-value of 0.011 and 0.0018) at Nazereth and Wonji. Annual minimum temperature shows an increasing trend (0.5 and 0.3 ^{0}c per decade with p-value of 0.0002 and 0.0067) at both locations.

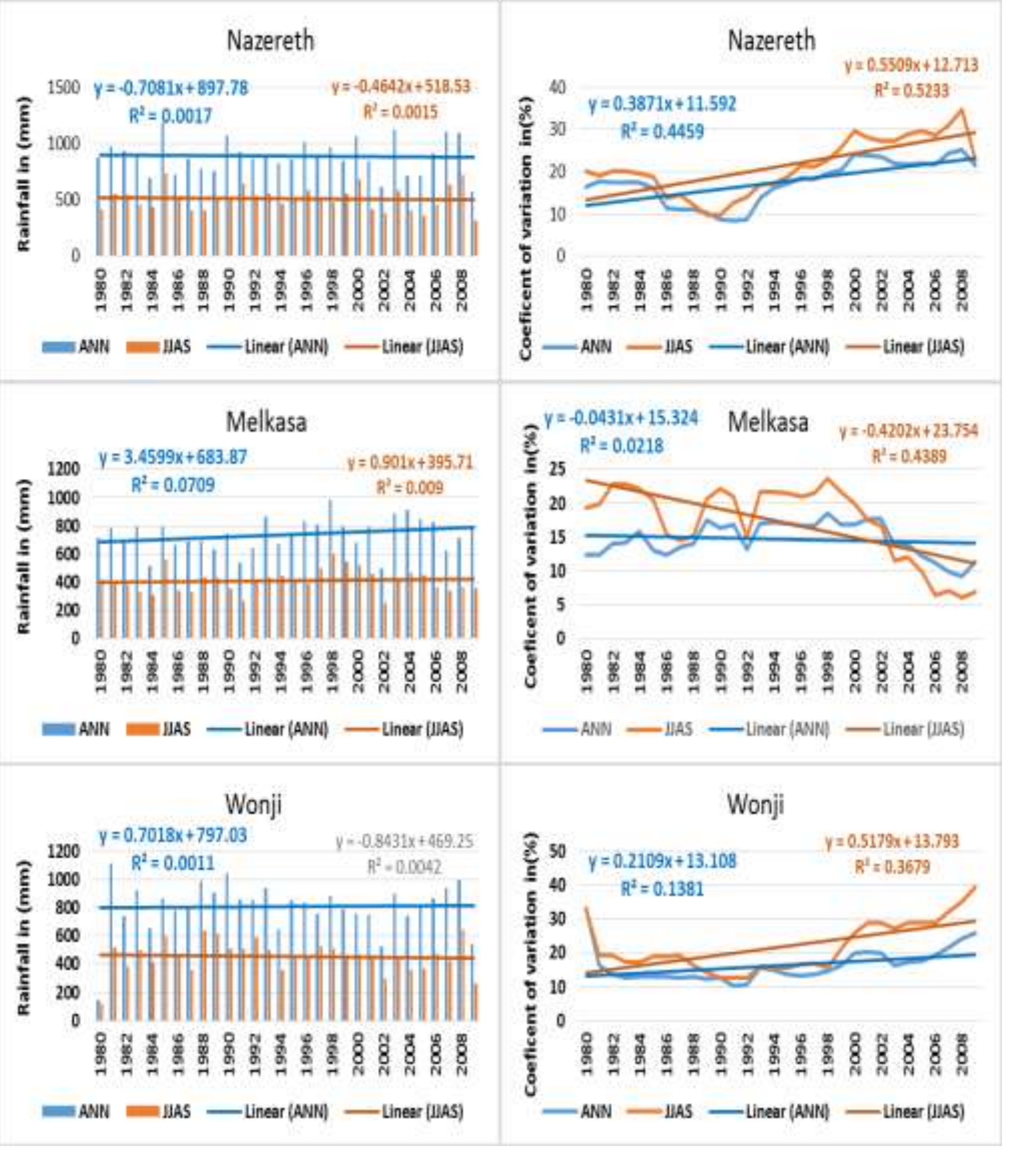
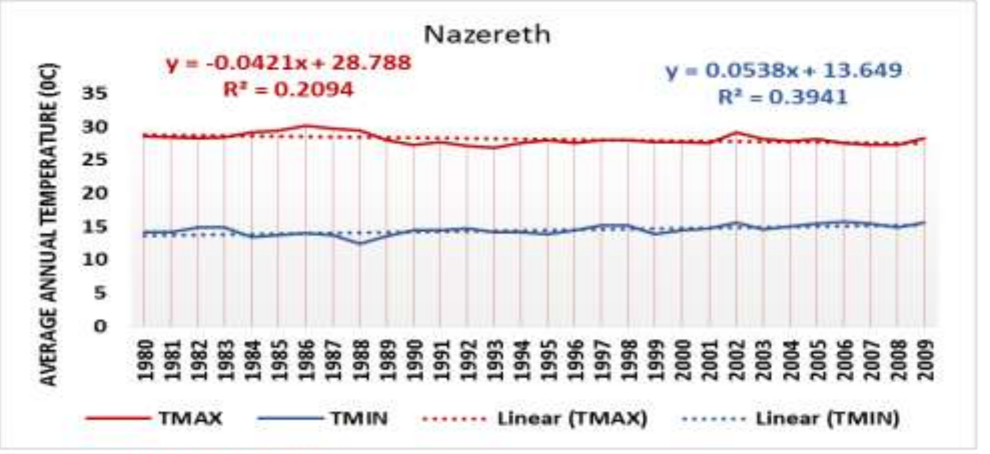


Figure 5: Left panel shows trend in annual and seasonal rainfall totals while right panel shows trend in variability in coefficient of variation of annual and seasonal rainfall totals.

Despite the availability of overwhelming evidence in support of climate change, uncertainty prevails over the precise nature of these changes, especially at local level. Global predictions become less clear as to the magnitude and timing of the changes at national and local levels.



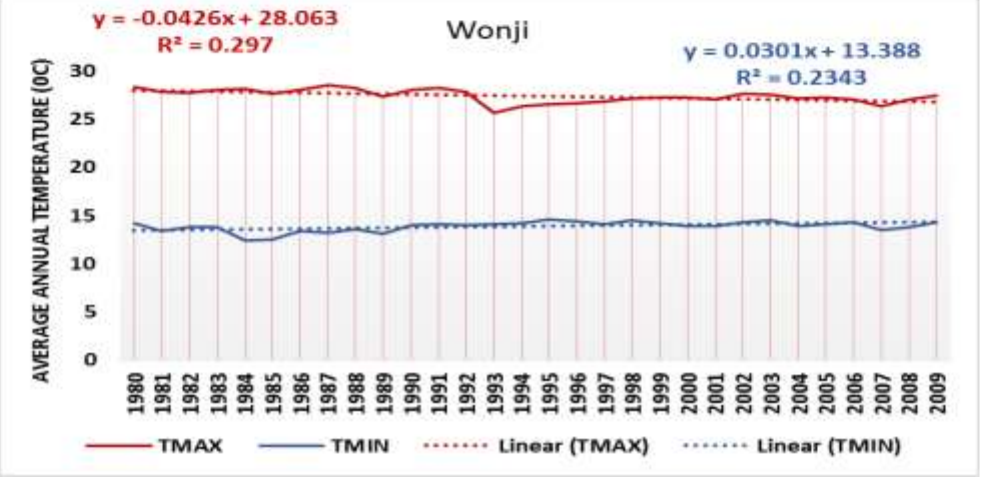


Figure 6. Observed trend of maximum and minimum annual average temperature of Nazaret (Top) and Wonji (Below)

Even at the global scale, there will always be uncertainty in predicting future climates, partly due to uncertain levels of future greenhouse gas (GHG) emissions and partly due to differences among GCMs in their sensitivity to GHG emissions. In order to fully account for the uncertainty due to both GHG emissions and GCMs, downscaled location-specific climate change scenarios were developed to mid (2041-2070) and end-century (2071-2100) periods for 20 GCMS from the Coupled Model Inter-comparison Project 5 (CMIP5) under Representative Concentration Pathways (RCPs) 4.5 and 8.5 for the six locations in Adama districts.

IPCC climate models projected an overall warming trend towards the end of the 21st century all over the world (IPCC 2007). Similarly, all CMIP5 GCMs project a general increase in maximum and minimum temperature at all locations. However, the magnitude of increase differs with in GCMs and RCPs (Figure-5). Most CMIP5 GCMs project an increase in rainfall at all locations. Particularly, IPSL-CM5A-LR, IPSL-CM5A-MR, BNU-ESM and CanESM2 show a deviation of >50%. On the other hand few GCMs project a slight decrease in rainfall during some decades (Figure-6).

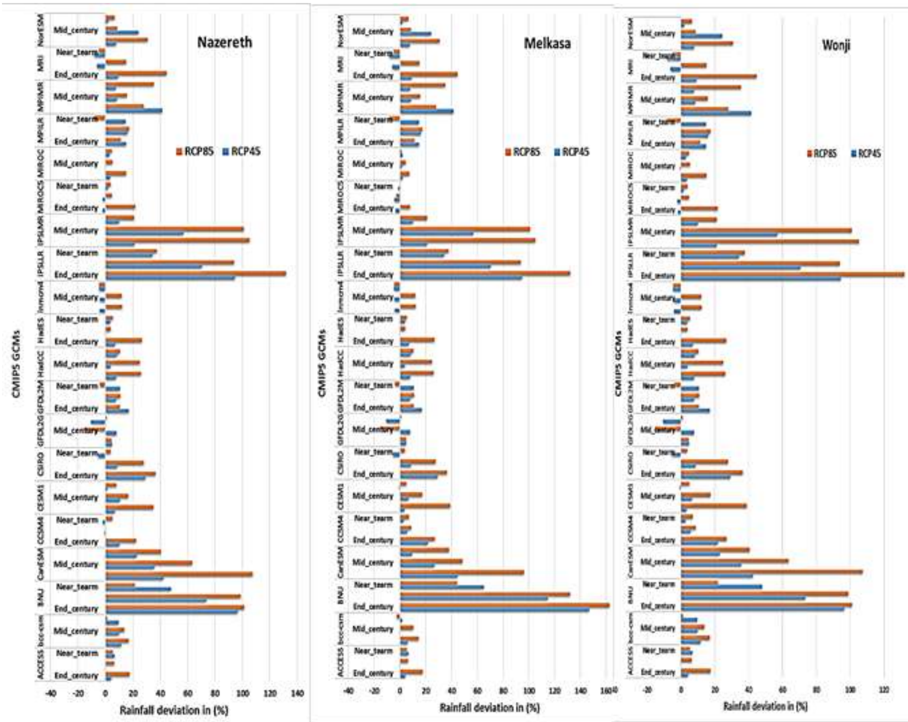


FIGURE 7: *PROJECTED CHANGE IN TEMPERATURE AT TARGET AGRO-ECOLOGY ZONES*

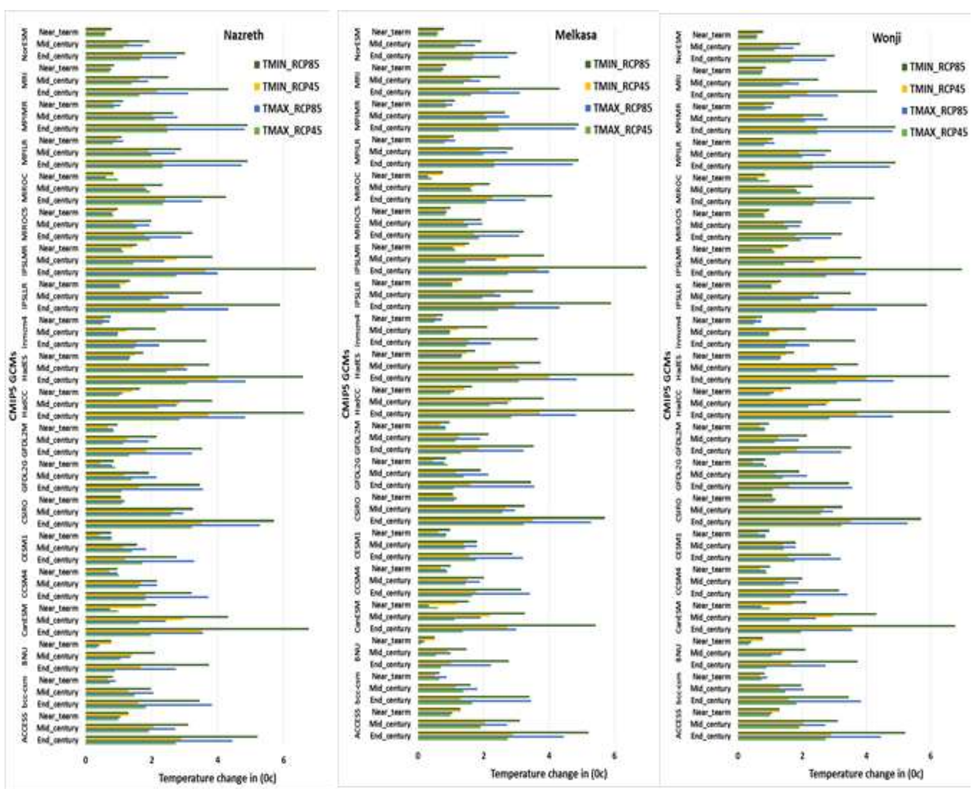


Figure 8. Projected change in rainfall at target agro-ecology zones.

4.2. Impacts of Climate Change on Agricultural System

In order to assess the impacts of climate change on maize production in the three AEZs, simulation analysis was carried out on 240 farms with diverse and farmer-specific climate, soil, crop and management parameters using calibrated and validated crop models (APSIM and DSSAT) under baseline and climate change scenarios of all combinations of 20 GCMs and RCPs 4.5 and 8.5 to mid and end-century periods.

Simulation results show that maize yields increase in all agro ecology zones except in SM3 under 4.5 End and 4.5 MID in DSSAT and APSIM model respectively (Figure-7). The predicted increase in maize yields under climate change scenarios was attributed to temperatures remaining within the optimal range for maize production. The higher grain yield increase was observed in SM2 and SA2 AEZs under DSSAT and APSIM crop simulation models. Impact of climate change on performance of maize was also influenced by the management adopted such as variety used, planting time, plant population and amount of fertilizer applied; and these effects varied from one AEZ to the other. Local and short maturing variety like Katumani and Melkassa-1 that were grown in the study area were the most vulnerable to projected changes in climate under all the three agro-ecology zones. Nonetheless, Katumani performed well in SM2 Agro-ecology zone (Figure 10). This result indicated that short maturing variety may not perform well under projected climate change as the long varieties will do. Moreover, farmers using low input production systems were found to be less affected compared to farmers with high input systems. Climate change seems to have adverse impact on farmers planting late and using low plant population.

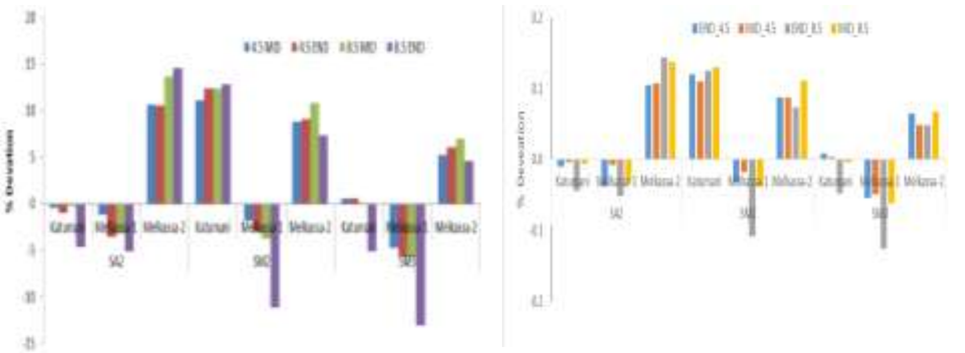


Figure 9. Effect of climate change on maize yields Without CO2 effect in DSSAT (left) and APSIM (right).

4.3. Implication of the Impacts of projected Climate Change on Food Security of Farmers

Potential impacts of climate change on the well-being of farmers were assessed using the Trade-off Analysis Multi-Dimensional (TOA-MD) impact assessment tool. The two scenarios tested were a) sensitivity of current agricultural production systems to climate change and b) impact of climate change on future agricultural production systems. Maize production under the climatic conditions predicted by five GCMs (CCSM4, GFDL, HadGEM, MIROC and MPI-ESM) to mid-century under RCP 8.5 as well as estimated impact of climate change on other farm activities through Representative Agricultural Pathways (RAPs) were used in this assessment.

The sensitivity of per capita income to climate change is calculated by considering the difference in per capita income with and without climate change. Climate change will lead to increase in per capita income at varying degrees with the biggest gains made in ME and WO (APSIM) and in MK and ME (DSSAT). The change in per capita income ranges from ETBirr 511 (25.5 USD) to over ETBirr 1060 ($53) per annum with APSIM simulations and from ETBirr 393.29 ($19.7) to over ETBirr 857.11 ($42.9) per annum as per DSSAT estimations (Figure-9 and Figure-10).

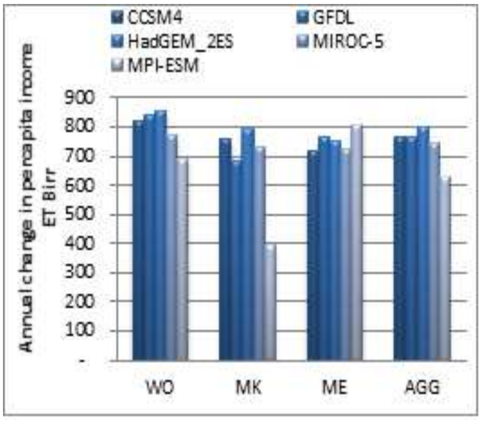


Figure 10. Change in per capita income with climate change (APSIM).

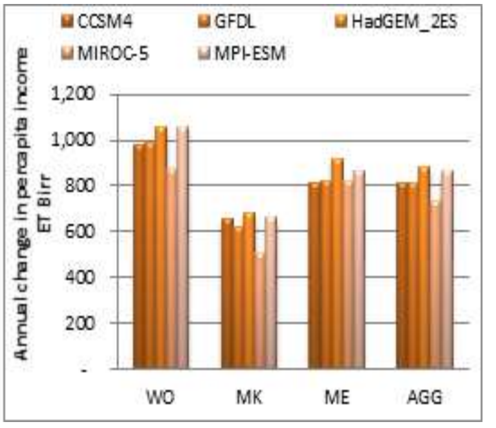


Figure 11. Change in per capita income with climate change (DSSAT).

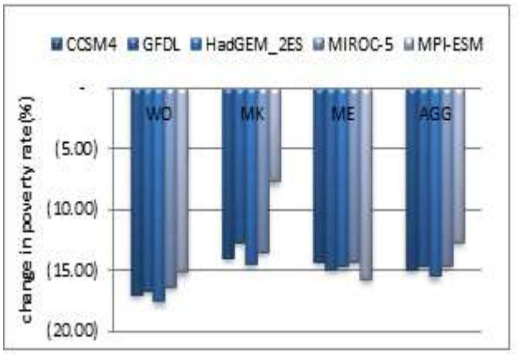


Figure 12.Percent of decline in poverty levels (DSSAT).

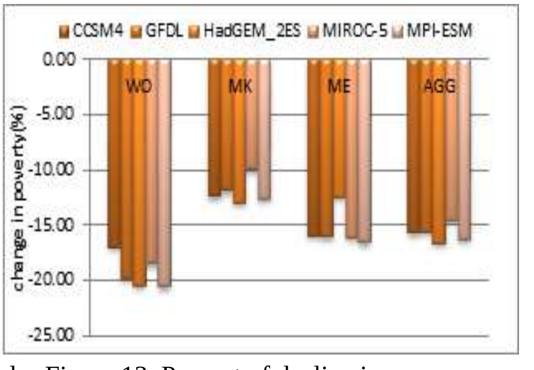


Figure 13. Percent of decline in poverty levels (APSIM).

Another important indicator of farmers' welfare is the poverty level. In this study, estimated poverty levels with and without climate change indicate that in all cases, climate change will reduce the poverty levels in all AEZs for all GCMs. However, the levels do vary as seen from AEZs. The highest reduction in poverty rate is in WO, where APSIM records declines of up to 20.6%, while DSSAT records declines of over 17.5%. The least reduction in poverty rate will be in MK, with minimal declines of 9.9% (APSIM) and 7.7% according to DSSAT. Overall, the mean reduction in poverty rate in all the AEZs with climate change is almost 16% (APSIM) and 14.5% (DSSAT) (Figure-10 and Figure-11).

4.4. The Benefits of Climate Change Adaptation to the Smallholder Farmers

Critical analysis of performance of different varieties and management practices that are currently used by farmers has indicated that it is possible to adapt and make better use of future climatic conditions by adopting some of the available technologies. Season and AEZ specific package of practices were developed (

Table 8) by combining the best performing variety, planting date, plant population and fertilizer rate under current and future climatic conditions. If the package of practices is adopted by all farmers in the target AEZs, it is possible to increase the maize yields significantly even under climate change.

In this scenario, the question we are answering is how the various indicators of income poverty and per capita income change if the future system under climate change is subjected to adaptations. In other words, what would be the levels of these indicators if farmers in the future adapt to the changing climate. Using TOA-MD, impact of these adaptations to climate change on the indicators of per capita income, net farm returns and poverty were assessed. The assessment also determined the percentage of farmers in each AEZ who will gain from climate change adaptations. This scenario compares a future climate with future technology against a future climate-future technology with adaptations i.e. the adaptation package involves higher utilization of fertilizer and higher seeding rates both of which imply increases cost of production to the farmer. For this reason, the total variable cost of production is expected to increase. All the other variables in the other sub-systems were held constant. From Table-4.

Table 8, we find that adaptation to climate change is expected to increase maize yields in all AEZs, with Nazareth gaining the most from adaptations. This is an indication of the existing yield gap in this AEZ. It shows that farmers are producing way below their potential production under optima yields and it would be feasible for farmers in this AEZ to more than double or triple their yields.

Adaptation to climate change is expected to increase maize yields in all AEZs, with MK gaining the most from adaptations. All GCMs in this AEZ show that maize yields will more than double. This is feasible given the low maize yields in this AEZ. The least gains are recorded in WO GFDL under APSIM where the yields are increased by 1.2 times while the highest gains are in ME CCEM4 under APSIM where yields increase by more than 3.4 times, as a result of increased in the yields we expect high percentage of adopters in this scenario.

Table 8. APSIM and DSSAT mean maize yield simulations (kg/ha) for different AEZs in future, with adaptation.

AEZ	Projected future mean maize yield (Kg/ha)	Question 3: The benefits of climate change adaptations									
		APSIM Time-averaged relative yield (r=s2/s1)					DSSAT Time-averaged relative yield (r=s2/s1)				
		CCSM 4	GFDL	HadGEM_2ES	MIROC-5	MPI_ESM	CCSM4	GFDL	HadGEM_2ES	MIROC-5	MPI_ESM
WONJI	600.8	2.24	2.19	2.30	2.26	2.32	2.28	2.28	2.28	2.27	2.36
MELKASA	783.6	2.70	2.69	2.70	2.66	2.69	2.75	2.73	2.76	2.62	2.73
NAZRETH	764.0	3.48	23.45	3.39	3.47	3.40	3.69	3.66	3.66	3.69	3.61
AGG	716.2	2.80	2.78	2.80	2.8	2.8	2.90	2.89	2.89	2.86	2.70

<1 indicates that climate change has a negative impact on production
>1 indicates that climate change has a positive impact of production
r=s2/s1 is the relative yield; where s2 is the future simulated yield and s1 is the base simulate yield

5. Conclusion and Recommendation

This paper presents evidence of climate change and projections of future changes along with accompanying risks and opportunities. The results clearly indicated that the predicted changes in climate offer both opportunities and risks.

For designing adaptation strategies that are appropriate to the local conditions, it is essential to conduct this type of comprehensive assessments in all the agro-ecologies of the country taking into consideration the diversity that exists in smallholder farming systems in managing various crop and livestock enterprises. This assessment demonstrated that much of it can be done using the available data, but it requires concerted efforts by all relevant national government departments and agencies, donor communities and research organizations. A positive step in this direction will be establishing core teams of scientists from climate, crop and economic fields with skills and capacities to make robust and credible assessments using the new science tools. The members of the AgMIP team and protocols and methods developed by AgMIP can serve as a starting point.

Climate science is fast developing and new and more accurate projections will be available from time to time. Moreover, significant advances are being made in improving the crop and economic models to capture the impacts of temperature and CO2 on crops and other components of the agricultural systems and in translating these into socio-economic impacts. Hence, the teams established must liaise with the global and advanced institutions to take advantage of the latest developments and apply them to refine and re-run the assessments from time to time so that policy and national adaptation programs have latest information.

The analytical framework developed by AgMIP, when integrated with the short term forecasts, can serve as a powerful tool to predict food security situation and strengthen early warning systems at the national and local levels.

6. Acknowledgements:

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16. Analysis of Factors Affecting Rainwater Harvesting Technology in Dryland Agriculture of Northern Ethiopia

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Abstract

The data for this study was taken from Tigray of northern Ethiopia. In the course of this study multistage sampling technique was employed. Primary data were collected from 210 respondents of which 106 users and 104 non users of water harvesting. Descriptive statistics such as mean, standard deviation and percentage were used to describe sampled respondents in terms of some desirable variables. Eighteen items were developed and administered. In order to maintain its reliability, two likert items with value greater than the covariance Alpha was dropped. Accordingly, 16 likert items were analyzed using attitude scale (1-5). As a result of this, water harvesting technology demand of labour, cost, land, skill and knowledge were found to be highly important items related to utilization of water harvesting to reducing vulnerability in moisture stress area. The item water harvesting took large area & increase cost showed significance difference at ($P<0.05$) and ($P<0.10$) probability level among user and non users. Moreover, the grand mean for both categories were found to be 3.46, which shows favorable attitude towards the innovative practice as adaptation strategy to climate change. The scale statistics mean score of the sampled household calculated of 69 per cent indicated that there were favorable attitude towards water harvesting as climate smart technology. The non user farmers explain that almost 95 per cent of them had positive attitude towards water harvesting in building resilience to drought. Taking their resource and implementation capacity visa-vis the perceived reality, about 75 per cent of the farmers planed to practice water harvesting structure technological and institutional options to foster adaptation and enhance resilience of crop and livestock producers to moisture stress.. This implied that as the result of the favorable attitude for both group of the users and nonusers there may be some thresholds influencing investment & utilization of water harvesting. The plausible explanation indicates that households involved in those activities could benefit more to improve their livelihood through the utilization of the water harvesting.

Keywords: Attitude; Perception; Dryland Agriculture; Rain Water Harvesting

1. Introduction

Ethiopia With An Area Of 1,127,127 Square Km Is Located Between 3024' And 14053'north And 32042'and 12012' East. The Ethiopian Economy Is Predominantly Agricultural Which Is For The Most Part Subsistence (Abadi.T. 2006). The Majority Of The Ethiopian Smallholders Appear To Believe That Effective Water Harvesting Management And Use Of Water Is An Important Issue In The Agricultural Sector. However, There Is Evidence That Considerable Number Of Segment Of The Smallholder Do Not Have Adequate Knowledge Of Water Harvesting Technique. During A Period Of Good Grain Harvest Farmers Are Not Able To Produce Beyond The Subsistence Level. During Good Rainy Season Also Field Crop And Productivity In The Agricultural Sector Perform With Poor Result. This Led The Government Of Ethiopia And The Concerned Parties To Take The Issue Seriously And Seek To Design Water-Harvesting Program As Solution To The Problem (Abadi, 2006). Poverty Reduction For Obvious And Well-Founded Reasons Ranks High On The International Development Agenda. Unfortunately Water Harvesting Management Rarely

Ranks Very High In The Strategies Suggested To Actually Battle Poverty, Despite The Fact That The Poorest Of The Poor Depend For Their Livelihoods On Rainfall-Based Land-Use.

In sub Saharan Africa Countries like Ethiopia, over 90 % of the farmers depend on rainfed agriculture. In modern time, the interest in water harvesting grew out of the meteorological droughts in the 70's and 80's and the opportunities documented in the successful experiences from the Negev desert in Israel.

In India, 75 % of the agriculture is rainfed and most parts of the country receive rainfall no more than 50 days in short but heavy showers. Water harvesting is an ancient technique dating 4,000 - 5,000 years back, and currently under revival. Rainwater harvesting is now rapidly expanding in response to an escalating water scarcity. In China water harvesting systems are adopted to make drinking water available and stabilize farm yields through supplementary irrigation. Rainwater is harvested from a variety of compacted surfaces and the irrigation practices follow the principle *"irrigating the crops and not the land"*. Water Harvests have proven to increase by 40 %. Cash crops and fruits that could not previously be grown in the region have given the farmers an improved economic situation.

Rainwater harvesting practices in Ethiopia

In Ethiopia, there is evidence that ancient Churches, Monasteries and Castles used to collect rainwater from roof tops and the history of rainwater harvestings by the Axumit Kingdom dates back as early as 560BC (Abadi, 2008; Mitiku, *et al.,* 2001). During this period rainwater was harvested and stored in ponds for agricultural and domestic water supply purposes. Moreover, remains of water harvesting setups still exist in the oldest places of Axum, Gonder, and Lalibela, which were used for different productive and religious rituals (Ibid).

Surface irrigation including river diversions spring development and pond system, is widely used in Tigray to irrigate plots. In the highlands of Tigray, farmers construct ponds for the storage of spring water to irrigate their farms (Abadi, 2007; Mitiku, *et al.,* 2001). Diversions structures are made simply of stones and wood. The floods frequently wash them away. The canals are not lined and water loss through seepage is significant

Even to this day, there are several traditional rainwater harvesting technologies in Ethiopia, which have been used by communities in areas of water shortage since long ago. For many traditional communities in rural areas where natural sources of water are lacking, collection of rainwater from pits on rock outcrops and excavated ponds are common practices.

Birkas for storage of rainwater are commonly practiced in Ogaden, runoff irrigation practices in Chercher plains, around Mahoni and Waja near Alamata, the Geto valley in North Omo, parts of Eastern and Western Hararghe and many other places. Moreover, small storage systems, especially for livestock water supply, are found all over Ethiopia, for example, at Tigray and Amhara regions and other place in Africa (Mitiku, *et al.,* 2001, Abadii, 2006).

The promotion of low cost household RWH technologies, especially for small-scale land users, has given encouraging results. Moreover, minimum governments' or external agencies' interference may have promoted development of the traditional RWH technologies, especially spate irrigation in Ethiopia. However, further development seems to be hampered by non-conducive land tenure systems, which may have contributed to low adoption of this promising technology in Ethiopia despite its obvious potential.

The view is that the adoption of RWH technologies, households would be food self-sufficient and the surplus would be generating income. In addition, incomes have been generated through sale of water. In Kobo, the outputs from flood diversion (spate irrigation) are giving confidence to the farming community. Traditional flood harvesting systems in Kobo are fully managed by the farmers who implemented flood harvesting systemh with their own resources and know-how (Abadi, 2006; Mitiku, *et al.,* 2001). Similarly, the people in Konso, Gidole and many other parts of Wolayta & Wollo, the southern part region, have been exercising the art of conserving soil and water (Frangtn et al 15.,Abadi, 2007).

However, implementation presents a number of challenges, of which careful use of water is one. In some areas, farmers in Ethiopia start to grow vegetables next to water harvesting structure. Mostly they use hand watering to apply water but this method is highly inefficient. Surprisingly, despite the fact that rainwater harvesting have been around for hundreds of years, it has never been given sufficient attention as viable solution to our food and environmental problems.

Rainwater harvesting is a relatively new technology to most people, and only few institutions and trained personnel, in particular at community level, have acquired adequate knowledge.

Rainwater harvesting practices in Tigray

From 1991 onwards, every household farmer in Tigray region is expected to give 90-120 day per every dry season for resource conservation. The treatment of the catchment areas and coordination of management of the irrigated areas including the region rested upon the BoARD. The conservation strategy focuses on the construction of physical structures. Accordingly, terracing and afforestation program started in 1970 under USAID sponsored food for work (FFW) program. Following this program, about 1500 has were treated and planted.Since 1991, about 883,229 ha of land has been treated and 433,177 ha of land has been under afforestation program. An average of nine million-persons' labour was utilized per year. So far, as part of the reafforestation program, more than 684 nurseries have been established for raising seedlings in every Tabia of Tigray Region.

Presently, the number of days allocated for unpaid voluntarily involvement in resource conservation activities is twenty days per year. FFW and cash for work program are used to mobilize additional labor force for such activities. Recently, in a place where farmers are involved in RWHT, they are freed from contributing 20 days for communal activity. In Tigray, farmers are concerned about conserving water. The majority of the farmers consider moisture stress as the most limiting problem to agricultural activites.

River diversions such as Midimar, Senafti, Genfel and Guguf were built by the government and the then Bureau of Natural Resources (BoNR),while Adiaha was built by REST and Feleg by SARET. Maynegus, Wedicheber and Maygundi dams were constructed by the then BoNR. The rest of the dams and diversions were built by SARET, an organization which was responsible for building dam in Tigray region. It was assumed from the engineering point of view that each dam with an average water holding capacity of 1.74 million M^3 can create a ground to cultivate 90.04 hectare of land. if the water do not percolate. (Abadi, 2006). In 1995, the regional government of Tigray initiated an ambitious plan to construct 500 dams within ten years with a capacity of irrigating 50,000 ha in the moisture stress areas. At the end of 2001, there were 57 dams and 10 diversions with annual capacity of irrigating 4248 ha of land. But most of the completed dams are operating much below their capacity of irrigating farm lands due to the fact that most of the dam do not hold water after the rainy season due to seepage and percolation. Farmers have started growing some cash crops such as maize, onions, potatoes, and tomatoes in irrigated areas. Participation in the extension programmes and use of inputs such as fertilizer and improved seeds is reportedly high in these areas, and farmers' yields and incomes are substantially higher by two fold from irrigated plots. The Raya valley development feasibility study has indicated that there is a potential to irrigate 12,000 ha of land. The Tekeze basin master development plan has also identified places with 150,000 ha of good potential for the supplementary small-scale irrigation.

According to Commissions for Sustainable Agricultural Rehabilitation of Tigray (Co-SARET), SARET has played a dominant role in managing water resource, but there has been inefficient use of water and poor cost recovery for operating and maintenance expenses. The maintenance cost of developing new water resources, and problems with the quality of service in agency managed systems has led to a search for alternatives that make water allocation and management more efficient.

The government of Tigray has recently adopted a strategy of "area based development", which focuses on whatever opportunities for exploiting water resources may exist whether it be through dams, ponds, river diversions, wells, or other water harvesting structures rather than focusing only on construction of dams as originally envisioned (Abadi, 2006).

2. Statement of the Problem

In a country where rainfall variability is high, good rainwater harvesting and management will play an important role in reducing crop failure and soil erosion. To that effect, the government has placed due emphasis to the promotion of water harvesting techniques especially in moisture deficit areas. This necessitated the efficient use of water available in these areas through water harvesting techniques. Thus, it demands technical assistance, technology assessment and importation, capacity building, piloting of water storage structures and other related activities such as water abstraction and utilization of the RWHT .

The persistence of poverty and environmental degradation demand a constant effort to improve the effectiveness of agricultural and natural resource management. The majority of the Ethiopian smallholders appear to believe that effective water harvesting management and use of water are important issues in the agricultural sector. However, there is evidence that considerable number of segment of the smallholder do not have adequate knowledge of water harvesting technique. As a result, crops grown are of low yielding. Therefore, productivity in the agricultural sector could not meet the food demand of the people. During a period of good grain harvest, farmers are not able to produce beyond the subsistence level. During good rainy season also, field crop and productivity in the agricultural sector perform with poor result.

This led the government of Ethiopia and the concerned parties to take the issue seriously and seek to design water-harvesting program as solution to the problem. The potential of water harvesting to improve productivity received great attention. The government of Tigray believes irrigation intervention to be drought proofing. However, few of the water harvesting technologies have succeeded in combining technical efficiency with low cost and acceptability to the local farmers or agro-pastoralists. This was partly due to the lack of technical 'know how' and also often due to the selection of an inappropriate approach to the prevailing socio economic conditions. There is limited tradition and technology in harvesting and storing rainwater from runoff and flood. The practices of using irrigation for crop production are also very limited.

Hence, analyzing the utilization of currently available water harvesting technologies remains a point of debate. This study, therefore tries to address the socio psychological and institutional aspects of rainwater harvesting technologies utilization in rural community.

Objective of the Study

The principal objective of this study was to analyze the social, psychological factors influencing adoption of rainwater harvesting technology in Northern Ethiopia.

This study, therefore, focuses on the following objectives:

1. To assess farmers perception towards adoption of rainwater harvesting technologies;
2. To identify the socio psychological factors affecting adoption of rainwater harvesting.

3. Research Methodology

This research was conducted in Tigray Region, where water-harvesting system is widely implemented by farmers in purposively selected Districts of Atsbi-Wenberta & Wukro

3.1. Description of the Study Area

Tigray, found in the northern most part of Ethiopia, is the cradle of the country glorious civilization.

Fig 1. Location of the study area Tigray, Ethiopia

Tigray National Regional State is located between the geographical coordinates of $36^{0}27'$ to $41^{0}30'$ east and $12^{0}15'$ to $14^{0}57'$north, and has a total area of 54572.6 sqkm (Abadi,2006). The Land cover types and their area coverage in Tigray Regional State in percentage looks as following: The cultivated land 28.2per cent, wood land 5.8per cent, grass land 22.8per cent, bush land and grass land 36.2per cent, natural forest 0.2 percent, exposed rock 2.7 per cent, exposed soil 3.9 percent, water 0.1per cent, urban area 0.1 percent. Most of the hydrographic (87 percent of Tigray) is associated with the Mediterranean hydrological regime. Only 13 percent of the Tigray drains to the Indian Ocean. There are western and eastern hydrographic regions and three main river basins; the Tekeze, Mereb, and Afar. About 77 percent of Tigray falls within a slope range of between 0-8per cent. Steeper areas than this are found around northeastern part of the escarpment in Atsbi-wenberta, Erob and at the foot of the escarpment of Ofla, Alaje and Welkait-Tsegede (Abadi, 2006).

3.2. Data Types and Data Sources

Data for this study were collected from households using a structured interview schedule. Likert type scales were developed to measure the attitude object of sampled household farmers. The technique included a checklist to guide. The secondary data were collected from relevant sources, such as reports, socioeconomic survey documents of the area, maps, books and Non Governmental Organizations (NGO).

3.3. Sampling Design and Sampling Techniques

A multi stage sampling technique was used to select households. In the first stage, two Districts were selected purposely from the eastern Tigray. In the second stage, based on simple random sampling technique, three Villages from each District were selected. Households in the selected Villages were stratified into user of RWHT and nonuser of RWHT, in the third stage, based on probability proportional to sample size (PPS), respondents from each household category were selected. Given the limited time at the disposal of the Author, only 210 households were selected and interviewed out of this 9 interview schedule was dropped and the analysis was done with only 201.

3.4. Data Collection and Analysis Method

Quantitative data were collected by employing scheduled interview. Structured and pre-tested interview schedule was used. Secondary data were collected from GO, NGO, and CBO as well as from different resource centers. Likert type item scale was used to measure the attitude object of the water harvesting. Eighteen Likert items were developed and administered to 210 farmers through face-to-face interviews. Each stem had five alternative responses. The available data was compiled using statistical package for social science (SPSS) software. The data were analyzed using descriptive statistics, which gave a clear picture of the characteristics of RWHT *adopters* and non-*adopters* sample units. In this study, descriptive statistics, such as mean, standard deviation, percentages, frequency of occurrence, were used, along with econometric models, to analyze the collected data.

3.5. Development of Likert type scales

Measuring attitude implies quantifying a qualitative variable. Attitude scale is one of the scientific measures of a psychological construct. A number of interrelated social, economic, institutional and psychological factors are affecting utilization of RWHT. These important variables were analyzed using attitude scale and descriptive statistics.

Eighteen items were developed and administered to 210 sampled households. The attitude object in this study was RWHT. The Likert type items developed have taken into account household objectives of RWHT and household production assets. A scale of 1-5, where 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree), 5 (strongly agree) were used in the scale measurement and scoring of the Likert item. Prior to computing the values, scoring is reversed for items unfavorable to RWHT, such that disagreement with an unfavorable item results in a high score.

Households production objective vary depending on the socioeconomic status of the household. This difference emanates from the variation in household characteristics such as land, labor availability, and capital assets (e.g. financial capital and livestock, knowledge base/ traditional knowledge and knowledge gained through formal education), off farm and nonfarm income.

Sampled households make their management decision depending on characteristics of the household such as number of men, women and children, their age, status of health, farming experience, and knowledge and skill. In spite of their diversity, farm households tend to have some common objectives such as "productivity, security, continuity and identity". In view of these attempts were made to understand their attitude towards RWHT in the study areas.

The dependent variable of the study utilization of RWHT was measured using items that were selected through systematic procedures mentioned above. It was important to note that reliability was not just a property of an individual scale items in structured scales typically it consists of item stimulus part and response part. The positive and negative Likert type items were developed based on advises and pre-testing of the original list of items. Alpha as an indication of the proportion of variance in the scales attributes to the true scale is influenced by inter correlation (Table1) and in order, to elicit response on frequency and extent of the face validity 18 items were tested using reliability scale the items were ensured from relevancy rating and the reliability analysis result was found (α=0.598) their reliability detail analysis was presented in Table 2.

Table 1.Inter-Item Correlation Matrix

Inter-Item Correlation Matrix(Correlation Matrix of farmers Perception towards RWHT)

(A)-(code)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1-Rainfall Agriculture is sufficient to feed family	1.00																	
2-RWHT increase yield	.162	1.00																
3-RWHT is important to secure food	.280	.548	1.00															
4-RWHT is appropriate technology	.139	.516	.495	1.00														
5-RWHT is profitable technology	.342	.501	.616	.577	1.00													
6-RWHT can help improve livelihood	.087	.040	.094	.119	.227	1.00												
7-RWHT increase cost	.222	.201	.231	.283	.214	.178	1.00											
8-.RWHT is labor demanding	.100	.037	.073	.155	.036	-.091	.172	1.00										
9-RWHT demand much knowledge and technical skill	.107	.175	.030	.197	.092	.315	.520	.124	1.00									
10-RWHT sustain production	-.022	.223	.240	.291	.244	.211	.257	-.027	.201	1.00								
11-Possible to sustain production without RWHT	.107	.220	.314	.184	.193	.154	.075	-.145	.082	.080	1.00							
12-RWHT structure& design are easy to implement	.203	.239	.252	.237	.306	.061	.278	-.007	.289	.136	.036	1.00						
13-RWHT are not costly	.021	.009	.076	-.005	.033	-.175	-.089	.370	-.108	-.174	-.151	-.186	1.00					
14-RWHT take a large area	.094	.041	.011	-.007	.038	.075	.274	.072	.440	.112	.149	.042	-.062	1.00				
15-RWHT cause human health problem such as malaria	-.073	.219	.211	.261	.106	-.057	.199	.149	.272	.248	.115	.086	-.055	.257	1.00			
16-.RWHT is environmental friendly	-.143	.026	.086	-.013	-.039	.027	-.067	.121	-.010	.087	.136	-.062	-.043	.064	.216	1.00		
17-RWHT cause animal health problem	.030	.174	.067	.083	.072	.105	.113	.046	.153	.026	.096	-.101	.075	.007	.251	.022	1.00	
18-Indigenous knowledge of RWH is superior than the new RWHT	.350	.101	.171	.192	.257	.154	.313	.279	.257	.039	.128	.172	.161	.233	.109	.046	.188	1.00

(A). Code in the table =1. Rainfall Agriculture is sufficient to feed family. 2. RWHT increase yield. 3. RWHT is important to secure food. 4. RWHT is appropriate technology. 5. RWHT is profitable technology. 6. RWHT can help improve livelihood. 7. RWHT increase cost. 8.RWHT is labor demanding. 9. RWHT demand much knowledge and technical skill 10. RWHT sustain production. 11. Possible to sustain production with out RWHT. 12. RWHT structure& design are easy to implement. 13. RWHT is not costly. 14. RWHT takes a large area. 15. RWHT cause human health problem such as malaria. 16. RWHT is environmental friendly. 17-RWHT cause animal health problem 18-Indigenous knowledge of RWH is superior to the new RWHT.

Table 2. Cronbach's Alpha Reliability Statistics.

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items		N of Items
.598	.733		18
Scale Statistics			
Mean	Variance	Std. Deviation	N of Items
61.0452	65.245	8.07746	18

Table 3. Item-Total Statistics (Reliability Analysis for Perception Statements towards RWHT).

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Rainfall Agriculture is sufficient to feed family	57.7538	60.096	.182	.264	.589
RWHT increase yield	56.7236	61.847	.375	.452	.580
RWHT is important to secure food	56.7889	60.693	.446	.545	.572
RWHT is appropriate technology	56.9146	59.866	.426	.488	.568
RWHT is profitable technology	56.8894	60.301	.434	.575	.570
RWHT can help improve livelihood	57.2261	60.832	.191	.267	.588
RWHT increase cost	58.6533	56.056	.415	.384	.554
RWHT is labor demanding	58.8442	60.708	.224	.312	.584
RWHT demand much knowledge and technical skill	58.8844	57.103	.430	.506	.556
RWHT sustain production	57.4874	58.898	.277	.217	.575
Possible to sustain production with out RWHT	57.3869	60.218	.230	.205	.582
RWHT structure& design are easy to implement	58.2764	60.090	.202	.270	.586
RWHT are not costly	58.1658	65.361	-.086	.273	.629
RWHT take a large area	58.2312	59.148	.273	.303	.576
RWHT cause human health problem such as malaria	58.0000	57.182	.373	.314	.561
RWHT is environmental friendly	57.3920	53.118	.043	.140	.698
RWHT cause animal health problem	57.1106	61.240	.177	.179	.589
Indigenous knowledge of RWH is superior than the new RWHT	57.0402	59.544	.398	.318	.568

4. Result and Discussion

4.1. Characteristics of Sampled Households

The average family size of the sampled households was about 6.5; the largest family size being 11 and the smallest being three. The average number of economically active family members 15-64 years of age was 2.74 for user and 2.23 for non-user of RWHT. The age structure of the sample households showed that the average age of the *adopters* farmers was about 45.95 years whereas that of non- *adopters* was 42.95 years. The average land size of sample households was 1.08 ha of which users of RWHT and nonusers own on average 1.19 and 0.97 ha respectively. With regard to land use patterns, from the total land holdings sampled households allocated on average 0.62 ha cultivable land, 0.05ha forest land, 0.06 ha grazing area, 0.24 ha homestead and 0.05 ha perennial crop land. The T-tests indicate the mean difference of the perennial cropland holding is significant at ($P<0.01$) probability level. The mean distance between home and farmland was 0.68 km and 0.70 km for *adopters* &non *adopters* respectively

Out of a total agricultural production in the study area livestock and beekeeping contributed to 25 percent of household income. The mean size of the TLU of the sampled farmers was 2.08 with standard deviation of 3.57. The user farmers on the average had 2.54 TLU, while the non-users had 1.56 TLU . The T-test result showed significant difference in the livestock ownership of the two groups at less than ($P<0.01$) probability level. The major livestock problem in the study area was lack of grazing. About 48 percent of the sampled households reported labor shortage to effectively undertaken their agricultural activities. Almost 53.2 percent of labor shortage was for RWHT. The major strategies used towards overcoming labor shortage as reported by the respondents were hired labor, assistance from relative and social assistance such as "*wefri*" and "*mahber*".

The average number of extension contact for users and nonusers of RWHT was 7.78 and 2.38 respectfully, these showed statistically significant difference at ($P<0.01$) probability level. About 72.3 percent of RWHT *adopters* and 37 percent of non *adopter's* farmers took part in extension package. The chi-square test indicated that there was significant difference at ($P<0.01$) probability level in the participation of the extension service between the users and non-users sampled households. The average distance of farmer training and extension center was found to be 3.19 km and 2.79 km. The total average distance from market center was 7.89 km of which 8.14 km and 7.63 km with standard deviation of 7.14 and 6.96 for users and nonusers respectively. Access to market shows statistically significant difference at ($P<0.05$) probability level.

4.2. Factors Affecting Adoption of RWHT

Institutional factors affecting RWHT

The regional Bureau of Water (BoW) and Relief Society of Tigray (REST) dominated the RWHT planning process in collaboration with Bureau of Agriculture and Rural Development. However, since BoW did not have adequate staff at District or field level, other stakeholders like the Bureau of Agriculture and Rural Development (BoARD) come into picture. BoARD has relatively good implementing capacity at District, Tabia and Kushet level. The technical management aspect was handled by, BoARD, REST, BoW and the Food Security Desk (FSD). Logistic and resources were facilitated through REST & BoARD. District steering committee consists of BoARD, BoW, REST, Health Office, FSD, Information Officer, youth and women respectively. Village level, Village Baito, Development Agent, Health Center, Education, supervisor of BoW are working as member. In the sampled Districts RWHT structure 11.15 per cent blanketed with plastic 4.4 per cent cemented, 18.7 percent percolated pond and 65.75 per cent clay blanketed pond were established by the RWHT users. The cost of the plastic material was 157 USD and farmers do pay 40 per cent. The cost of cement was 140 USD and they were obliged to pay 30 per cent.

Farmers attitude towards RWHT

The feasibility of a given technology partly depends on the perception of farmers about reality. The technology is meant for and their attitude towards the technology itself. Farmer's perception of the moisture status, location and topography of their farm land and their attitude towards RWHT technology were those partial indicators of the utilization of the technology. The covariance alpha (Table2) where the extent of covariance among the Likert items except the item (RWHT was environmental friendly and RWHT were not costly), all were less than $\alpha=0.598$ (Table3).

Attitude scale is one of the scientific measures of a psychological construct. Eighteen items were developed and administered to 210 sampled households. These items followed the Likert techniques of scale construction and were known as Likert type scale. Farmer's perception of the moisture status, location and topography of their farm land and their attitude towards RWHT technology are those partial indicators of the utilization of the technology. The relevancy rating and reliability analysis result of Alpha was found $\alpha=0.598$. Therefore, in order to maintain optimum trade-off between brevity and reliability dropping items with value greater than the covariance Alpha was recommended. Hence the items with Alpha $\alpha=0.698$, $\alpha=0.629$ respectively were omitted from the scale and the analysis was done with the remaining 16 Likert items. For the subsequent analysis, the items were grouped into two categories. The items in category one were used to asses attitude of users farmers. The item in category two were used to estimate both adopters and non adopter's attitude towards RWHT.

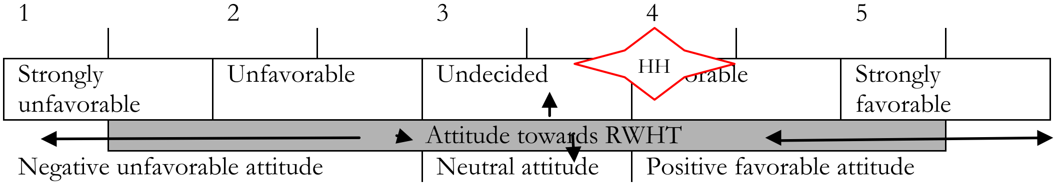
Table 4. Analysis of sampled households farmers attitude towards rwht (scale 1-5,).

	User		Non-user		Total			Sign of Items
1. Category one Likert item for RWHT users	Mean	SD	Mean	SD	Mean	SD	T-value	
RWHT is important to secure food	4.37	0.54			4.37	0.54		+Ve
RWHT is appropriate technology	4.21	0.73			4.21	0.73		+Ve
RWHT is profitable technology	4.33	0.57			4.33	0.57		+Ve
RWHT can help improve livelihood	3.83	1.15			3.83	1.15		+Ve
RWHT increase yield	4.46	0.50			4.46	0.50		+Ve
RWHT is labor demanding	2.07	0.95			2.07	0.95		_Ve
RWHT sustain production	3.76	1.12			3.76	1.12		+Ve
RWHT structure& design are easy to implement	3.06	1.20			3.06	1.20		_Ve
RWHT cause animal health problem	3.85	1.10			3.85	1.10		_Ve
Grand mean	3.77				3.77			
2. Category two Likert item for both group user & nonusers								
Rainfall Agriculture is sufficient to feed	3.27	1.29	3.32	1.23	3.30	1.259	0.780	_Ve
RWHT increase cost	2.56	1.35	2.22	1.08	2.39	1.231	0.051*	_Ve
RWHT demand much knowledge & skill	2.27	1.26	2.05	0.83	2.16	1.072	0.147	_Ve
Possible to sustain production with out RWHT	3.71	1.19	3.62	0.96	3.67	1.081	0.557	_Ve
RWHT take a large area	3.00	1.23	2.62	1.01	2.81	1.14	0.018**	_Ve
RWHT cause human health problem, malaria	3.15	1.33	2.93	1.01	3.04	1.18	0.189	_Ve
Indigenous knowledge superior to new RWHT	3.98	0.78	4.03	0.86	4.01	0.82	0.667	_Ve
Grand mean	3.13		2.97		3.05			
3. Summary of Likert item of category one and two								
Category one, Likert item for RWHT users					3.77			
Category two for both group user & nonusers					3.05			
Total Grand mean					3.46			

**** Significant at 1%, ** 5%, and * 10% probability level*

Analysis of the farmers' response on the utilization of RWHT using scale measurement the response of the users and nonusers for item stating "RWHT increase cost" and "RWHT take a large area" showed a significant difference at (P<0.10) and (P<0.05) probability level respectively. The grand mean 3.46 were supposed to represent favorable attitude towards RWHT and it lies between favorable attitude towards RWHT this lies between neutral and agree (Table 5)

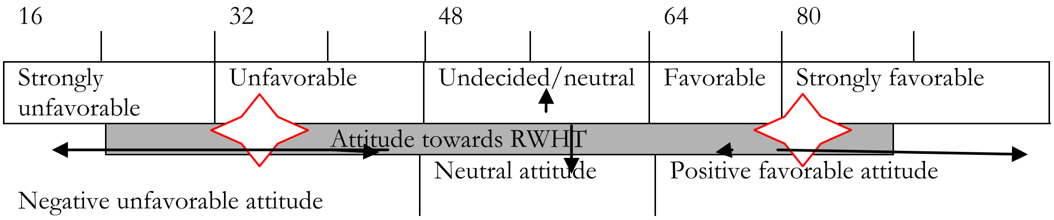
Table 5. Analysis of sampled household farmers attitude towards RWHT (scale 1-5,)



Sampled households position of attitude scale

The overall score of 16 means that every sampled household strongly disagreed, whereas the score of 80 means every sampled household strongly agreed with all the items. Likewise the score of 32, 48, 64, 80 corresponds with the scale values of 2, 3, 4, 5 respectively (Table 6).

Table 6. Analysis of sampled households attitude towards RWHT (score 16-80,).



Sampled households attitude item possibility of highest, medium and lowest score

Attitude score of the sampled households obtaining summing across all his/her item scores showed that 69.2 per cent of the sampled households had favorable attitude towards RWHT since their score is greater than 48 which represented a neutral attitude. The score of most sampled households is greater than 55.36 tilting towards the favorable of the attitude scale (Table 3).

Generally, the analysis revealed that using 16-likert item showed favorable attitude towards the RWHT. Both groups, the adopters and non adopters, believed that RWHT increase cost, require managerial skill and knowledge as well as wasteland for RWHT structure construction, which was unfavorable attitude for both adopters and non adopters of the RWHT. This showed that farmers had low perceived control over the technology. However, they mostly believed that they can acquire the knowledge and skill the technology demands. The non adopters farmers explain that almost 95 per cent of them had a positive attitude to practice RWHT. Taking their resources and implementing capacity vis-à-vis the perceived reality, about 57 per cent of them planed to practice the RWHT.

State of RWH activities

Table 7. Distribution of households belief, participation in utilization of RWHT.

Utilization	User	
	N	Percent
RWHT utilization		
Yes	101	100
No	0	0
RWHT participation		
Voluntarily	87	86
Compulsory	14	14
Total	101	100
Irrigation practiced		
Practiced	59	58
Not practiced	42	42

Believe of sample household users on utilization of RWHT indicated that all farmers (100 per cent) positively percieved RWHT. Sampled households participation in the RWHT based on volunteer and compulsory basis were 86 and 14 per cent, respectively. Nevertheless, those who practiced irrigation using RWHT were only 58 per cent. The worth of covering RWHT structure cost, investing from their own only were 43 per cent of the sampled farmers, and the rest were not interested to invest. With respect to the worth of getting assistance for the RWHT structure, about 57 per cent were willing to adopt the RWHT(Table 7).

Social elements influencing RWHT

Table 8. Distribution of farmers to RWHT utilization.

RWHT utilization	User	
	N	Percent
Family use	27	27
Animal use	2	2
Sanitation	13	13
Irrigation	59	58
Total	101	100

Where the population has alternative sources of water, rainwater harvested has secondary quality and can be used for livestock, domestic non-drinking use and supplementary irrigation. The sampled household's RWHT of the ponded water used for animals was two percent, family 27 per cent, irrigation 58 per cent, and utilizations purpose of sanitation was 13 per cent. The linkages of RWHT with watershed management were more indirect than envisaged (Table 8).

However, women accessed with rainwater have social benefit such as improved health, income and saved time to undertake the social role and production activities. This gives power and opportunity to use their land to FHH's without entering share cropping with male-headed household. Moreover, utilization of rainwater for family, sanitation and irrigation increased as the rainwater availability is nearby to their residence than that far distance of their farmland.

Economic factors influencing RWHT

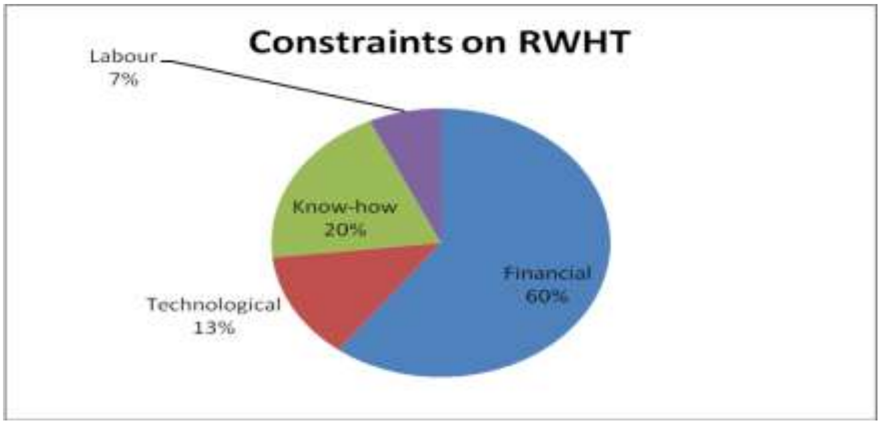


Figure 2 . Constraints on RWHT.

Sampled farmers explained that, the constraints for implementing the current RWHT structure were finance (60 per cent), Know-how (20 per cent), technical (13 per cent), and labour (7 per cent). (Fig 2). As compared to rain-fed agriculture and livestock, respondents believed that RWHT was better in terms of generating income that avoids risk & uncertainties, but rain-fed is preferred in terms of labor requirements. Farmers reported a number of problems associated with RWHT activities, lack of capital, technology, lack of skill, labour, and market problem.

Technological factors influencing RWHT

Many structures held water for some period during the past season. Variations in the design were observed in the field, which is derived because of the physical factors.

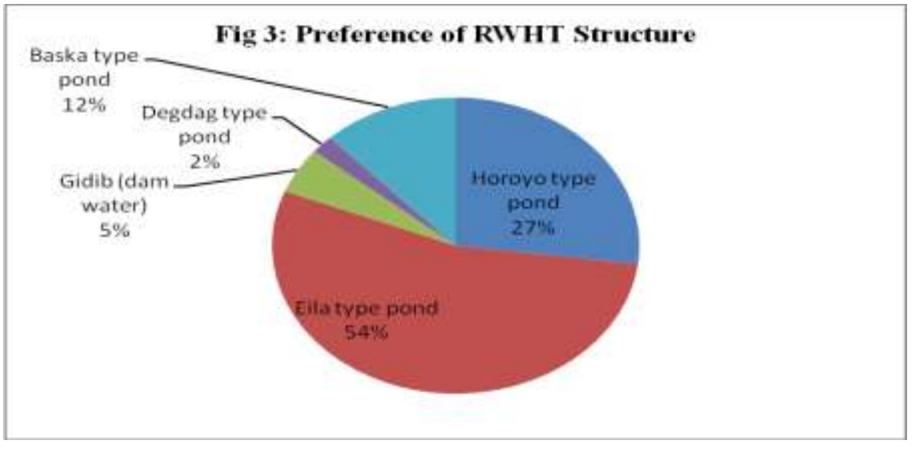
Inefficient utilization of the plastic and cement was observed which resulted from poor shaping of the ponds, irregular top width and lack of beams and over sizing of the plastic for the pond dimensions. Variation in water holding capacity also observed. This emanates due to variation in the construction quality of the pond.

Most of the clay blanketed and cemented pond are considered by farmers as ineffective in retaining water after the rainy season. Ponds closer to the houses receive good attention and follow up from the households who own them, especially from the women.

Those in the middle of the arable holding receive the same attention as the arable crops and this is neither effective for the vegetable production nor an efficient utilization of the water stored. Sampled households opinion regarding similarity of RWH designs, 62 per cent and 41 per cent respectively replied that the trapezoidal micro pond and percolated type pond as suitable for the location.

Almost all irrigated plots are located near the ponds, both upslope and down the slope. Most farmers were abstracting irrigation water for utilization directly from the ponds using old jerry and oil cans and applying the water either directly to the plants or via unlined furrows and basins. Few farmers do use tridle pump and drip irrigation. Some farmers have already developed their own labor saving devices using such devices as rope lining.

Physical factors influencing RWHT



Physical factors of RWHT, such as site selection are made before establishment. Ponds whose surface is not covered with cement, compacted clay or plastic were found to be ineffective because they lost water in few months.

For all site, ponds would store water collected during the wet season to be for supplementary irrigation and for use for multipurpose use including domestic water supply, livestock watering as well as small-scale irrigation. Farmer's preference and choice towards the RWHT structures in terms of important inclined towards *eala* (percolated pond) was 54 per cent, *horoyo* (trapezoidal pond with plastic) 27 percent, *baska* (rectangular pond) 12 per cent, *gidib* (dam water) five percent, and *degda*g (trapezoidal pond clay blanketed) two percent(Fig 3)..

In the sampled six Village of the study area RWH structures, 21 percent blanketed with plastic, seven percent cemented, 43 percent clay blanketed, 29 percent percolated pond type RWHT were established by the RWHT users.

All constructed ponds have trapezoidal cross section and square plan while the percolated ponds have the shape of the land escape. Seepage water loss from ponds was identified as one of the critical issues. This was overcome by the provision of cement, compacted clay lining and or installation of plastic sheeting.

The net result was that farmers did not believe that clay lined ponds will hold water and that, unless they are given plastic to line them, will not have confidence in the potential to hold water.

Environmental side-effects of RWHT

A number of incidents of drowning of people and animals in the ponds have occurred. Excavated infertile sub soil from pond area has been both deposited on agricultural land and also heaped near to the pond. This has on the one hand occupied rather scarce agricultural land and rendered unproductive by covering good topsoil. All of the ponds are uncovered and which aggravates incidences of malaria in the residential areas.

5. Acknowledgment

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6. Conclusion and Recommendation

Based on the finding of the study, the following points are suggested as possible policy implications in order to increase agricultural production and enhance effective utilization of RWHT.

RWHT that undermines the existence of psychological and social factors related to human aspect that influence the decision making of the household are not effective. Hence, RWHT should recognize the existence of difference in perception, opinion, attitude and decision in the RWHT utilization.

Training influences RWHT positively and significantly. Hence, in order to address the existing gap, linking basic education with technical training is highly recommended for better prospect of RWHT. Therefore in-order to address the shortcoming of the conventional extension education system, it is recommended that increased pluralism of service providing, decentralization of extension education service delivery and development of more client responsiveness extension education methodology to increase customer ownership and influence RWHT.

This study found out that availability of cash is significantly and positively related to RWHT utilization. Hence, this study recommends that favorable market and price policy, strengthening farmer organization, improving market infrastructure, providing market and price information could mitigate small holdersfinancial constraints.

The result of this study revealed that farm size is found to influence the utilization of RWHT positively and significantly. Hence, this study recommends development of alternative pond dimension as a menu of choice.The study highlighted that rainwater utilization for irrigation purposes in most cases are through flooding. Hence, this study recommends alternative abstraction techniques of which appropriate technologies such as tridle pumps and drip irrigation need to be examined in-order to improve rainwater utilization and to reduce irrigation time.

Hence in-order to mitigate the malaria problem spraying the ponds and disturbing impregnated mosquito nets to the nearby homestead .

One interesting outcome of this study indicated that where water harvested used for domestic purpose, real benefits should include improved health, reduced time spent for collected water particularly for women. Saved time can be used for productive activities such as agricultural production as a result of this, these ponds closer to the houses receives good attention and follow-up, especially from the women. Hence, addressing gender issue could be possible through gender mainstreamed RWHT promotion as a means of empowerment of the rural women.

In this respect, this study provides a base and point of departure for similar studies using a time series of data on the extent and intensity of RWHT utilization in the future.

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17. An Extent of Household Responses to Drought in Fentale Pastoral Woreda of Oromia Regional State, Ethiopia

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Abstract
Fentale pastoralists have been undertaking a set of responses to mitigate their livelihood sources from the adverse effects of the present day severe recurrent drought. However, the extent of household responses is poorly understood. The objective of this research was to investigate responses that are undertaken to drought effects by households in Fentale pastoral woreda of Oromia regional state, Ethiopia. A household survey was conducted with 134 households and this was complemented by interviews with informants and with in-depth focus group discussion. The results indicated that households have developed various response mechanisms to deal with the challenges of the present day severe droughts through pastoral and non-pastoral activities. An extent of household responses towards both pastoral and non-pastoral activities are various, in which the household characteristics, specifically, wealth in terms of livestock holding is the decisive factors for the engagement of the household in any one or more of a set of productive activities or response mechanisms. The extent of households' mobility and herd diversification has increased. In addition, households have started to partly practice crop cultivation. Other non-pastoral activities such as agriculture, daily labor, petty trade, fuel wood collection and charcoal selling contributed to about 35% of the total household income.

Keywords: Climate change; Drought cycle; pastoral and Agro-pastoral; Household responses; Fentale Woreda

1. Introduction

Pastoralism is a rational, adaptable, tried and tested production system uniquely suited to the dry lands. Pastoralism occupies a quarter of the world area, which is predominantly arid and semiarid. Pastoralism was developed autonomously across the world's dry lands from some 7000 years ago (Brooks, 2006). It is still widely practiced and remains a dominant feature of rural east Africa in which most households sustain their means of living from keeping domestic livestock (Anderson *et al.,* 2008). Pastoral and agro-pastoral population are about 60% in Somalia, 33% in Eritrea, 25% in Djibouti, 20% in Sudan and 12 - 15% in Ethiopia. Pastoralists in this region keep a significant part of the livestock wealth. For example, in Ethiopia 30% - 40% of the country's livestock is found in this area (Abdel *et al.,* 2002). However, pastoral areas are typified by high levels of uncertainty from one season to the next season. Drought is the major serious hazard for incessantly deteriorating pastoral households' livelihood sources in an alarming rate. In addition to drought, other important risks include uncertain access to grazing and water due to appropriation of dry season grazing lands by external land users, disease, raids, conflict, and price of livestock in relation to other commodities.

In the past, in most cases, in non-equilibrium systems, pastoralists spread drought risks through moving herds and flocks to make best use of the heterogeneous landscapes, restocking, and destocking. However, in the present day, in addition to the pastoral activities households seek economic diversification as a means of response mechanisms to severe drought through undertaking non-pastoral activities such as farming, wood cutting and trade; and in extreme cases reduced meal intake per days; and defend complex rights of access to grazing and water resources to support their livelihoods (Abera, 2010). Pastoralists kept a diverse mix of livestock in terms of species and class and undertake flexible responses to a diverse resource base to allow further drought risk reduction (Adopted from Jahnke, 1982; Perrier, 1988; Swallow, 1994). The increasing interaction and integration of livestock and crop activity has major implications for the efficiency of opportunistic pastoralism (Bayer and Water Bayer, 1991). Pastoralists demonstrate diverse range of adaptations to the risk and uncertainty they face in the daily life. At the same time, people's adaptations change as conditions alter, so that a snapshot of pastoral life today is in a sequence of moving images i.e. a continual adaptation and change (Adopted from Scoons, 1996). There is probably an inevitable 'shake-out' of people from the pastoral sector during each drought crisis, due to the deterioration of the pastoral households capacity by the recurrent and the severe drought of the present day that are resulted in failure of certain households to make positive response mechanisms.

Drought in Ethiopia is not a new phenomenon. Crisis linked to famine and droughts have been traced back as far as 250 BC (Patrick *et al.,* 1992). Drought used to recur within 8-10 years in the highland areas and 4-6 years in the pastoral areas of Ethiopia. However, in the drought prone areas drought cycle has changed in the recent time and become more frequent, 2-3 years, giving no time to recover from the effects (Aklilu and Alebachew, 2009; Abera, 2010). This has resulted in economic, environmental, social, and cultural losses in the pastoral areas of east Africa (Bayer and Waters-Bayers, 1991). A total of at least 35 periods of food shortage with high human and livestock transience have been recorded. These events have been concentrated partly in the crescent of low lying pastoral and agro-pastoral areas of the country (Gufa, 1998). Unusual, severe, and recurrent drought of the present day has brought adverse effects on the pastoral household's livelihood basis: declining rangeland resources, productivity, and survival of livestock.

The *Kereyu*, who have been the indigenous inhabitants of the Metehara plain and Mount Fentale area are Oromo pastoralists. Drought is one of the major hazards frequently challenging the area and it is a natural recurring part of climate of the Fentale woreda. It has had implications on the predicament of pastoral and agro-pastoral households and their responses (UNDP field report, 2002). In the present day, households of Fentale pastoral woreda have employed a range of pastoral and non-pastoral activities to mitigate the adverse effects of recent severe droughts on their livelihood basis. In the present day, Fentale pastoral woreda households have been undertaking various responses to spread the risks of drought through pastoral and non-pastoral activities. However, the extents of responses are not identified. In addition, wealth of the local knowledge is not taken into consideration by external actors, no or little effort is undertaken to encourage responses that are undertaken by pastoralists to drought. Rather blue print planning development intervention i.e., only sedentary agriculture is taken as the final option to mitigate the adverse effects of recent severe drought. Even though it is a segment of an opportunity in responses taken to drought, changing the pastoral mode of life to sedentary life will require a long evolutionary process, and it is also a risky and difficult task under non-equilibrium environment with poor technology and capital (Abera, 2010).

According to Anderson *et al.* (2008) from many land uses in the drylands, pastoralism is the most resilient against climatic variability and change than others. Hence, to improve the resilient capacity of the Fentale pastoral woreda community, identifying the dimension of households' response mechanism is more fundamental for households and external agencies to employee appropriate response mechanisms. In the present day, adverse effects of drought is more aggravated due to lack of well-identified, appropriate and relevant local level response mechanisms. The objective of this research was to investigate response mechanisms that are undertaken by households of Fentale pastoral woreda to drought.

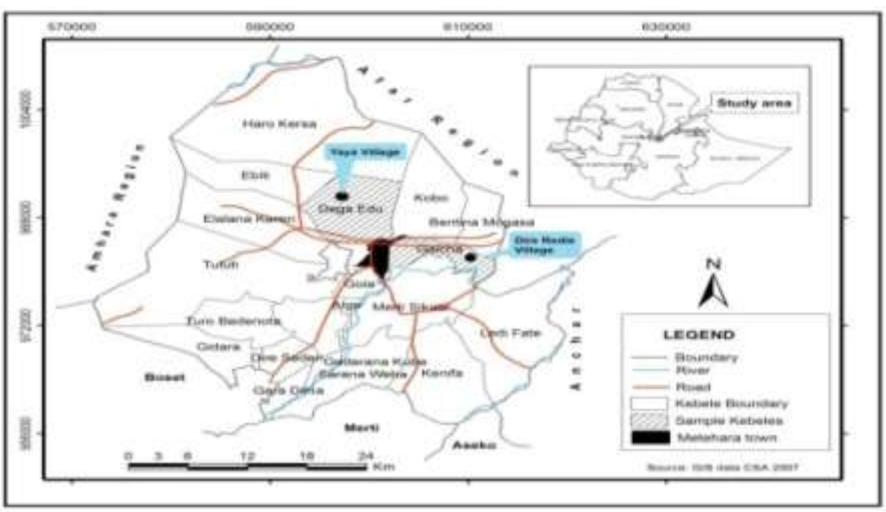
2. Research Setting

Despite the conventional superiority of probability sampling techniques, non-probability sampling techniques were used to select all the research subjects and so as to make easy the demeanor of the study. Regarding the context of the study, Fentale woreda of Oromia region was taken as a case due to the familiarity of the researchers to the area and due to frequent vulnerability of the woreda to the risk of drought. Out of 20 kebeles, two representative kebeles, namely Dhega Hedu and Gelecha, were purposely selected for the exploration of variables under the study. Dhaga Hedu is among the kebeles whose dwellers are mostly pure pastorallists while Gelcha is among the kebeles whose dwellers are agro-pastoralists. These two kebeles represent the other pastoral and agro-pastoral kebeles of the woreda with varying degrees in continuous distressing by the adverse effects of the natural and manmade factors.

Yaya village (YYV) of Dhaga Hedu Keble is predominantly inhabited by pure pastoral households. The total number of the households residing in the village was estimated at 70. Households in the village are members of the interconnected clanship family of Bacho, Dullacha and Ittu and they are living surrounding the foot of the mount Fentale to triumph over the effects of heavy scorching sun of the dry period through using the shades of the sparse indigenous tree and the scant pasture on the slant of the mountain.

Dire Redie village (DRV) of Gelcha Keble is inhabited by agro-pastoral households. The total number of the households residing in the village is estimated at 120. Similarly, households in the village are the members of the interconnected clanship family of Bacho, Dullecha and Ittu. The village is residing between the Awash national park and the Metehara sugar cane plantation and they are among the most seriously humiliating village due to the conversion of the traditional rangelands to other land uses by the outsiders and unremitting drought hazardous which forced them to engage in the opportunist farming in this non-equilibrium environment. The study is conducted on a purposely selected 75 % of households in both villages.

The information presented draws on data from 134 households, where 88 were purposely selected from YYV and 46 were purposely selected from DRV. Out of the total respondents, 29% (13% from YYV and 14.9% from DRV) were female. Households were interviewed with a baseline survey in March 2010 and data were complemented and triangulated with secondary sources and other qualitative data which was generated through interviews. . Discussions were also carried out with informants and focus groups to map out the timeline of drought events in the area. Quantitative data were compiled using some data analyzing facilities such as frequency distributions, comparisons of mean, and computation of percentages. Qualitative descriptive data, on the other hand, was compiled and summarized using qualitative data analysis techniques.



Source: AAU Cartography Lab, 2010.
Figure 1. The location of the study area.

3. What is meant by responses?

Pastoral household responses to drought are a set of people's activities or strategies which comprises pastoral and non-pastoral activities to declining food and/or declining livelihood sources abnormality entitlements in abnormal seasons and /or normal seasons or years (adopted from Davis, 1993). Until recently, pastoralists have been employing adaptive mechanisms that varied from mobility to herd diversification and exploiting micro environments. According to Sandford and Habtu (2000), mobile pastoralists that can optimally exploit spatial variation in rainfall and consequent vegetation, those who exploit patches of lands and vegetation suitable for their respective stocks, those who use the community network in times of severe crisis and those who maintain different species of herds have a high degree of sustaining droughts in the pastoral areas.

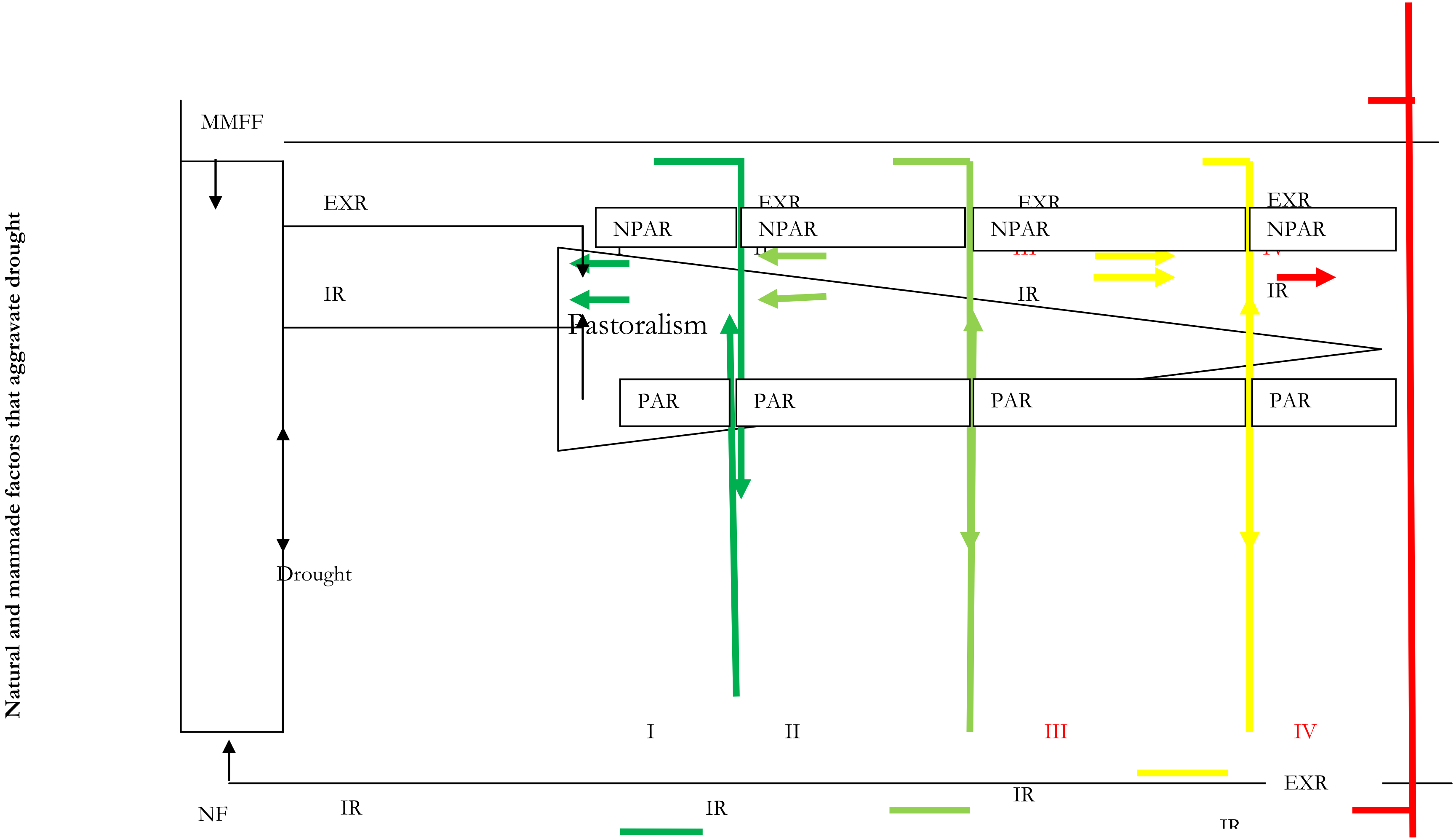
How can pastoralists live with such hard-to-live environments for a long time? Futterknecht (1997), for instance, stated that pastoralists living in marginal areas have much better to cope with drought periods than those who live in relatively better environments as the former ones used to live within little food for longer dry seasons of the year. In the present day, to mitigate their livelihood from drought and non-drought adverse effects, pastoral and agro-pastoral communities employ various coping strategies by undertaking a set of pastoral and non-pastoral activities. Pastoral activities include mobility, herd diversification, herd splitting, reduction of consumption, and social support. Non-pastoral activities includeopportunistic agriculture, collection and selling of firewood and charcoal, petty trade, causal labor, and use of wild fruits (Kinyangi, 2008; Aklilu and Alebachew, 2009; Abera 2010).

Response can lead to adaptation for groups that are able to protect and increase assets, but can be a vicious spiral towards poverty (destitution) for the poorer through scattered efforts in low-skilled, low-income, broad-spectrum casual employment (Adopted from Little, 2001; Homewood, 2008; Homewood and Chevenix-Trench, 2008). Often, returns are insufficient for the destitute pastoralists and agro-pastoralists to invest in rebuilding household assets (Homewood and Chevenix-Trench, 2008).

The combination of natural (increased climatic shocks like drought and others catastrophic) and manmade factors (conversion of pastoralists' dry season grazing land to other land uses), and a lack of other viable livelihood options pushe more and more pastoralists out of the system. Loss of livestock assets below a certain threshold translates into poverty in the absence of viable alternative livelihoods. Increased poverty, pressure on settlements and urban areas, displacement and conflict are common results of loss of livelihood without the option of viable alternatives (Little, 2001). As the result of differential in capacity of responses to drought as it is seen from Figure 2, pastoral livelihoods were in a flux (in dynamics). Those who were able to respond positively to drought were perpetuating in the pastoral mode of life and those who were not able to respond positively were on the extent of leaving the system and others were in transition (agro-pastoralists).

Figure 2 shows how the cumulative effects of natural and manmade factors reduced the inherent responsive capacity of pastoralists and lead to a depletion of pastoral livelihood system. Transition away from pastoralism can have different outcomes. Under the circumstances of drought that is aggravated by the climate change, there is increasing stresses on the system, the rate of destitution is likely to increase unless options which enable responses, adaptation and a choice of livelihoods which allows people to maintain or improve their conditions independent of livestock-keeping.

As it can be seen from Figure 2, the adverse effects of drought were aggravated by both natural and manmade factors on the pastoral households' livelihood system. Natural factors include climatic factors such as scarcity of rainfall, increased temperatures, wind pressure, loss of livestock by drought, natural resource/biodiversity degradation, and disease. Manmade factors mainly include development policy issues such as curtailment of mobility, conversion of traditional dry season grazing lands in to other land uses, poor infrastructure development, conflict and household characteristics. As it can be seen from Figure 2, Karrayu pastoralists were found at a varied stage of responses in which wealth of the household coupled with the external responses were the decisive factor to put the pastoralists in any one or more of the stages of the responses. In this case, those pastoralists who had undertaken appropriate responses to drought through pastoral and non-pastoral activity responses (PAR and NPAR) were mainly found in the firsts (I) and second (II) stages of responses. Pastoralists in I and II stages were those who had asset and the capacity to undertake appropriate response mechanisms to mitigate their livelihood from the adverse effects of drought. However, the Karrayu pastoralists who lack capacity to undertake appropriate response mechanisms to drought through both pastoral and non-pastoral activities were mainly found in III and IV stages of responses. Pastoralists in these stages were those in great tension or in pressure because of drought and its related effects. Pastoralists in stage III were those who reached the asset disposal stage due to loss of livestock by drought and sell for exchange of grain. Mainly household in this stage were those with livestock holdings below threshold level. Unless appropriate external responses are facilitated for these groups, their responses only (internal responses) are not well enough to mitigate them from adverse effects of drought and to rebuild asset. Those pastoralists who reached the IV stage of responses were the destitute who totally lost their assets due to drought and related effects and those who were out of any viable productive responses. These clearly showed that as the dimension of the pastoral mode of live of study area pastoralists are in a continuum fluxes or dynamics due to responses to drought and related adverse effects that is aggravated by the recent climate change (Abera, 2010).

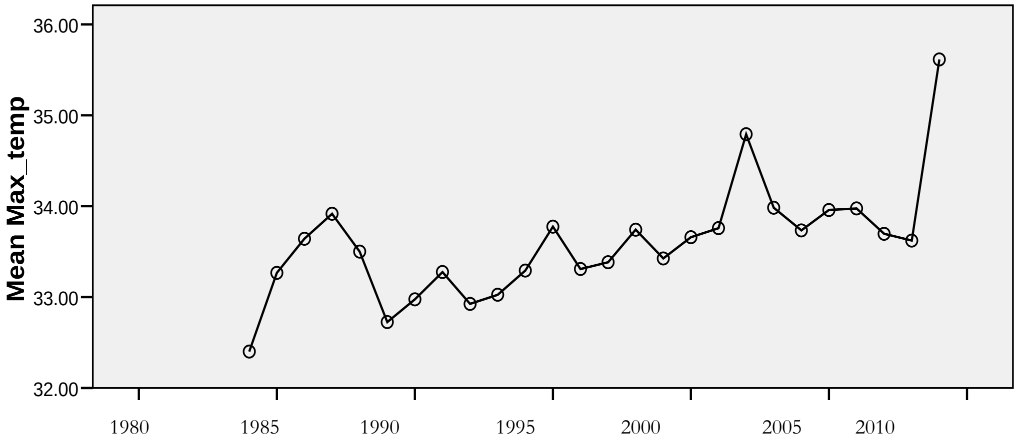


Keys: NF-natural factors; MMF- Manmade factors; EXR-external responses; IR-internal responses; PAR-pastoral activity responses; NPAR-non pastoral activity responses; I-IV-stages of responses.Source: Abera (2010)

Figure 2. Conceptual Framework

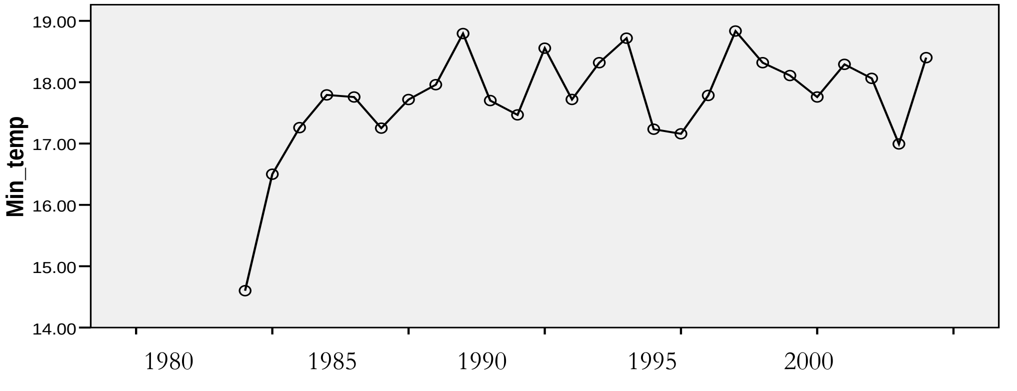
4. Severity of Drought in the Study Area: Magnitude of Hotness and Wind Speed

As it can be seen from Figures 3 and 4, which is based on the data obtained from NMSA (2010), an average annual temperature of the study area in 2009 was 27.01^{0}C. In the last 10 years, temperatures of the study area have shown an increasing trend. For example, there is a difference between the average temperatures of 1994 - 2001 which was 25.71 ^{0}C and the average temperatures of 2002 – 2009 which was 26.13^{0}C. There is also great intra- and inter-annual variation in temperature of the area.



Source: NMSA, 2010.

Figure 3. Annual maximum temperatures in the study area (1984 – 2009)

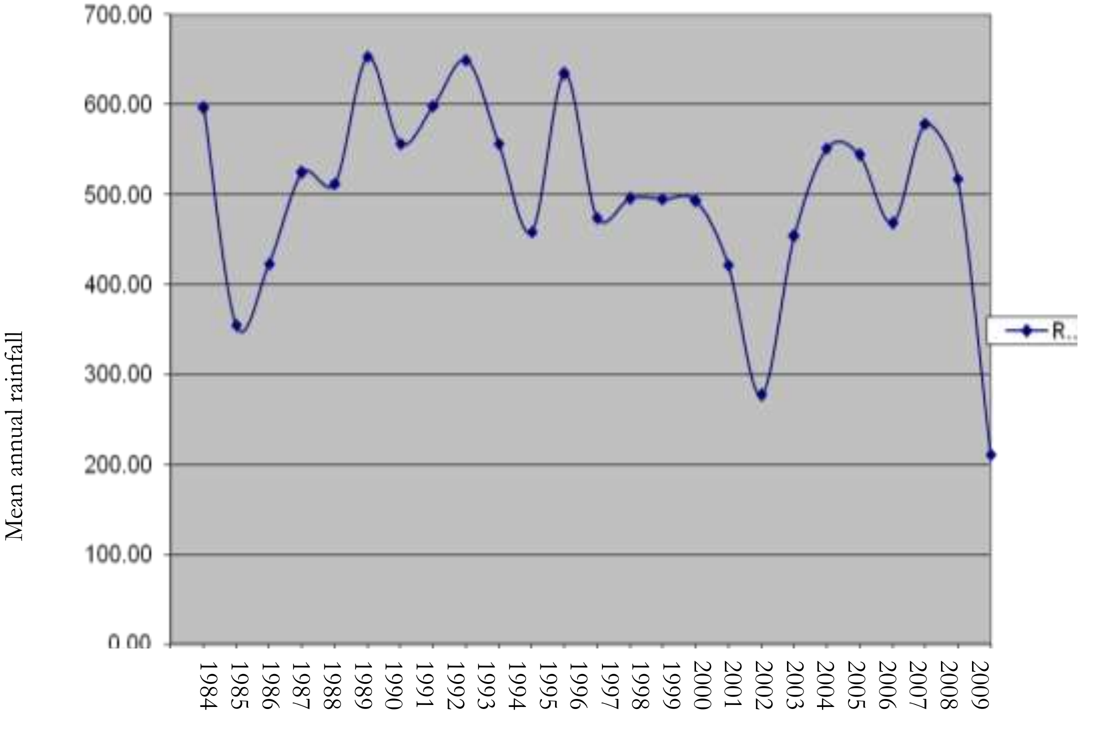


Source: NMSA, 2010.

Figure 4. Annual minimum temperatures in the study area (1984 – 2009).

5. Rainfall Characteristics of the Study Area

As it can be seen from Figure 5, amount of rainfall in the study area had decreased in an alarming rate from year to year. There is a great variation in amount of annual rainfall and amount of annual rainfall before 10 years in the study area. For example, the average amount of rainfall between 1990 – 1999 was 556.9 mm and the average amount of rainfall between 2000 –2009 was 451.3 mm. Magrath (2008) stated that the rain oscillation is becoming bigger, rainfall distribution is becoming poor and planning on seasonal rain is becoming harder and harder in the dry land areas. This phenomenon is the reality that is seriously challenging Fentale pastoralists through its adverse effects on the livelihood source. Prolonged drought resulting in loss of pasture, drying up of borehole and cisterns and increased intensity of rainfall within a short time caused soil erosion and degradation of rangelands in the study area.



Source: NMSA, 2010.
Figure 5. Annual rainfall of the study area (1984 – 2009).

6. Household Responses to Drought

Responses are set of activities that are undertaken by households to mitigate and to minimize adverse effects of usual and present day severe drought and/or other livelihood risks that is aggravated by climate change through pastoral and non-pastoral activities. Household responses are divided into two major categories, pastoral activity responses and non-pastoral activity responses. The pastoral activity responses are divided in to sub categories such as mobility, herd diversification, herd splitting, forced selling, social supports and reduction of meal per day. Even though most of these responses are traditionally adapted by pastoralists in order to live in the harsh environment and to overcome the effects of normal drought of arid and semi-arid lowland areas, Kerreyu households have modified extent of their response mechanisms to withstand effects of recent severe drought that is aggravated by climate change. For example, extent of mobility and herd diversification as modified responses to climate change are increased as compared to the past; and selling of livestock, especially, cattle including cow and livestock products are developed as a new response to severe drought that is aggravated due to climate change by households (Abera, 2010).

The non-pastoral activity responses are also divided in to sub categories as opportunistic agriculture, collection, burning and selling of fuel wood and charcoal, trade (petty trade and small microenterprise), causal labor, and use of wild food. Even though most of these activities were started in a response to severe drought of 1980s by the households, extent of this response is becoming high as a response to severe drought that is aggravated by the climate change and resulted in loss of the dominant livelihood (Abera, 2010).

6.1 Pastoral activity responses

As described above, pastoral activity responses are traditional responses that are used by pastoralists to minimize adverse effects of drought on their livelihoods. In the present day, in the study area more functional pastoral activity responses are mobility, herd diversification, selling of livestock and livestock products, traditional natural resource management, and meal reduction.

Mobility

Mobility, allowing pastoralists to respond quickly to fluctuations in resource availability and thereby to maintain their herds and other assets as well as their productivity, enables pastoralists to inhabit areas of harsh and volatile climate and to transform seemingly unproductive wastelands into assets. It allows tracking changes in the dramatic fluctuations in feed supply, avoiding areas where forage is insufficient and mopping up surpluses where they are abundant (Sandford, 1983; Behnke and Scoons, 1993, cited in Behnke, 1994). Pastoralists are specialists, they respond to and use, even choose and profit from variability. Highly variable, unpredictable and often scarce rainfall dictates where, when, and how much vegetation is available for their livestock to graze (Adopted from Behnke, 1994). The exchange of services and negotiation of land access between pastoralists and farmers have allowed pastoralists to adapt climatic variability.

Although in the past, an extent of mobility outside of their boundary was low, Karrayu households had moved more in their boundaries in accordance of spatial and temporal variation of pasture and water availability that were based on the rainfall seasons which are *ona*[134] *Ganna*, *ona Birra* and *ona Arfasa* before appropriation of kaarryu dry season grazing land for other land uses by other external bodies. Households have undertaken this mobility to track fresh pastures, avoid overgrazing and evade disease, conflict, and drought condition. When the scarcity of pasture and water are observed in the area of *ona Ganna* settlement, households move their livestock with their whole families to the other potential settlement to the *ona Birra* and also to the *ona Arfasa*. The cycle of mobility continuous in the past unless during extreme drought; Karrayu households seldom move to other distant area in search of pasture and water.

According to key informants, in the present day, extent of mobility of households in search of water and pasture to a distance area is high. The increase in frequency and severity of drought left the pastureland barren and drying up water points. These subjected the households to move their camel up to Hosa'ina[135] (SPNN), Shashamane, Modjo[136] and Adama[137] area; and their cattle up to Bosat[138] woreda. Even during the data collection for this study, no any livestock including lactating cows is available around the village.

According to woreda pastoral development office's views, an extent of mobility is highly increased and even children and the elderly could not obtain milk due to the reason that all cows are stayed at a far distance outside of the woreda for more than six month in a year in search of pasture and water. As it is seen from Table 1, 90 % of Yaya and 70 % of Dirre Redie respondents confirmed that extent of mobility this days is higher than that in the past.

Table 1. Percentage of an extent of mobility in response to drought to distant places.

Extent of mobility	Yaya		Dirre Redie		Total	
	Past	Present	Past	Present	Past	Present
Low	2		10		6	
Medium	98	10	90	30	94	20
High		90		70		80

Source: Household survey, 2010.

Herd Diversification

Karrayu pastoralists have been raising different species and breeds of livestock to make optimum use of different ecological niches, particularly in the dry season when resources are scarce. Traditionally unlike other Oromo pastoralists, karrayus rear different livestock compositions such as cattle, shoats, camel and some equines. They also consume milk of cow, camel, sheep and goats. Unconsciously, in the past, Karrayu households reared large amount of shoats and even do not discern their numbers and reckoning only shoats which started giving birth. In the past, households invest much on fertile female cows, to build up herd size as an insurance against

[134]The Karrayu's settlement pattern that was entitled by the name of the rainfall season such as summer, autumn and Spring

[135]It is more than 200 km from the Fentale woreda and it is found in the southern nations and nationalities regions of Ethiopia,

[136]More than 85 kms from the Fentale pastoral woreda.

[137]More than 65 km from the Fentale woreda.

[138]Found in Neighboring of Fentale woreda

drought, disease, and raiding and are reluctant to sell reproductive cows. According to OPADC (2009), cattle and sheep are predominantly grazers, feeding on grasses. The capacity of Karrayu breeds to rapidly put on weight after the rains (compensatory growth or recovery in short period of time) is admirable. Camels and goats can survive in harsher environments of Karrayu rangelands by browsing leaves, feeding pods and fruits of trees.

In the present day, households sale small stocks to cover all their basic necessities such as grain, garment, house utensils, health expenditure and for social obligation. However, they highly recovered from effects of forced selling due to their high birth rate that are undertaken within a short time interval. Hence, households called small stocks *Lubbu Dhaqabo*[139]. For example, shoats give birth in an interval of 5 – 7 months and urgently solve the household cash problem. In addition, small stocks provide milk in the drought period more than large stocks without significant variation from the normal years. Karrayus also give more emphasis to camel since camel tolerate draught for long period of time, move to far distances, produce high amount of milk both during normal time and drought year, use different plant variety as a feed sources, and also used as a pack animal in the rural areas. However, it requires high initial capital and hold mostly by the medium and richer wealth group of the community.

According to FGD participants, in the past, when drought was normal, households had specified herd structures to maintain an ideal portfolio of livestock and to meet their long and short term objectives in which adult cows were needed to produce milk in the short term and give births to calves that later will grow in to adults. Thus, ensuring the future survival of the family, adult steers are needed for sale or major ceremonial purposes, a bull is needed to inseminate cows, heifers are needed to replace cows while young steers to be fattened for future sale. Sufficient supply of small stock (sheep and goats) was also essential to the families for more routine needs without resorting the sale of the cattle and camel herd, which represent the main resource of the family while donkeys and camel are critical for providing transport. Karrayu households rear different types of livestock by pastoral households as a response to drought risk reduction. Currently, households inclined more towards small stocks and camel as a modified response mechanisms to minimize adverse effects of climate change and to diversify livelihood source bases. Especially, browsers feed different varieties of natural pasture and bushes found in the rangelands and less affected by drought when compared by grazers. For example, according to Fantale pastoral development office, from the present total livestock number of 545,909 of the district, share of small stocks is high which is more than 51 % (sheep is 131,829 and goats are 147,535) and the share of camel is 15 % (camel is 81,204).

In the present day, Karrayu households have given more emphasis to camel, shoats and cattle in decreasing order depending on their drought escaping and drought tolerant capacity; unlike in the past in which wealth was determined by the number of cattle. According to the results of the household survey (Table, 2), 82% of households confirmed that their extent of herd diversification is becoming high for the purpose of minimizing drought risks in the present than in the past. An extent of herd diversification is high among pastoralists as compared to agro-pastoralists. However, extent of herd diversification of both villages is high in the present day than in the past.

Table 2. Percentage of households' Extent of Herd Diversification in Response to Drought.

Extent of herd diversification	Yaya		Dirre Redie		Total	
	Past	Present	Past	Present	Past	Present
No	2				1	
Low	10	3	20	6	15	4.5
Medium	78	7	65	20	71.5	13.5
High	10	90	15	74	12.5	82

Source; Household survey, 2010

[139] means indemnity during critical time and solve households problem

Selling of Livestock and Livestock Products

Pastoralists sell their livestock rarely. Since livestock number is socially valued, they rather prefer to keep as much livestock as possible (Aklilu and Alebachew, 2009). District livestock experts explained that in the past, karrayyu households were traditionally reluctant in selling cattle and livestock products. They usually sell weak cattle and rarely sell reproductive livestock, especially, except during special social ceremony like marriage. Karrayu households sell small stocks (shoats) to cover basic household expenses such as salt, spice, fuel, garment, etc. In the past day, livestock and livestock products were sufficient for the household consumption and hence the extent of livestock selling as a response mechanism to minimize adverse effects of drought was low. In the present day, however, average livestock holding per capita is becoming below threshold level due to loss that is caused by recurrent drought. Lack of water and pasture that is caused by rangeland degradation, conversion of dry season pasture lands to other land uses, invasion of pasture lands by unpalatable exotic and indigenous shrubs and bushes, eradication and depletion of palatable herbaceous, grasses and bushes by severe drought (degradation of pasture biodiversity and genetic deterioration due to both natural and manmade factors which requires independent study in the future) resulted in declining of household herd size.

This in turn has resulted in reduction of production and productivity from livestock, forcing pastoral households to undertake forced selling for the purpose of purchasing grain. Especially, since 1984 devastating and debilitating drought, households have started unusually selling of livestock including cows and livestock products as a modified response mechanisms to minimize loss/death of livestock by drought and also for exchange of grain. According to the information obtained from informants, in the present day, on average households sale one to five small stocks per month; and yearly three to six cattle and one camel in a normal year for exchange of grain, other basic household necessities and for social and economic obligation. In the past, Karrayus were also reluctant to sell livestock products such as milk and butter, but in the present day they have selling meager available milk and milk products as a newly developed response mechanisms to drought and as a means of diversifying a source of income.

Household survey result also revealed that 77% of the households confirmed that, in the past, extent of selling of both livestock and livestock products were low. About 85% of the households confirmed that the extent of selling livestock and livestock products as a response mechanism to drought, which is aggravated by climate change, is becoming high in the present day than in the past. In the past, extent of selling livestock and livestock products were low in YYV than DRV but in the present day it is high in YYV than DRV.

Social support

According to informants, traditional Karrayu Oromo system encourages and supports sharing of resources and mutual assistance mechanisms that serve as a risk spreading tool among households, and communities. Pastoralists who are victims of calamities have the right to seek support in kind and in cash. In the past there was no destitute in the community; when somebody loss livestock due to natural or manmade factors, the relatives donate lactating cows for the handicapped for a defined period. This was undertaken not only for the purpose of overcoming short term problem but also in expectation of rebuilding the asset for the future; where at the end, the owners are expected to return back the cows. In a range of one to two years, a person will be able to fully recover his herd. In addition, in Karrayu tradition, there is a type of loaning animals ''surplus" to subsistence requirements to family and friends to help them rebuild their herds and develop social relations as a form of social capital as hedge against drought and other risks which allows them to maintain a functional balance between herd and family size. Furthermore, partiality was not known and every one shares from each other and some body's (neighbor) resource was considered as each other's resources. Because of this extended and bonded traditional background, karrrayu households strongly believe each other and split their herds among different relatives to overcome the scarcity of pasture and water in certain locality and also to reduce overgrazing. But consultation and agreement of household members are reached prior to making gifts, transfers, and loans of any type of livestock including small ruminants.

However, in the present day the extent of social support gradually declined due to depletion of asset by recurrent drought that resulted in increasing of destitute pastoralists. FGD participants reflected that in the past karrayus support each other, holding asset is only for the sake of social value and those who had no livestock equally use without any partiality from their neighbors. But this situation is not expected today, almost all are equal, the numbers of destitute are increasing from time to time due to an increase in the occurrence of severe drought. Through household survey, all respondents from both villages also confirmed that the extent of social support is low in the present day when compared to the past.

Natural resource management

Pastoralists employ a number of highly specialized risks spreading strategies to safe guard their herds in the face of unpredictable and some time extreme climatic events, disease out breaks, and social unrest. These strategies are the rational use of the natural resource base on which the herds depend and also build strong social networks (Hesse and MacGregore, 2006). Grazing management can contribute to biodiversity and promote biomass production. Dry land ecosystem health is better where mobile pastoralism continues to be practiced effectively (Redriguez, 2008).
It appears that the drylands in rural belongs to no one in particular, and that communal land means free for all grazing where pastoralists try to outdo each other in terms of herd size to ensure that individual persons or groups benefit the most from this assumed 'open access' resource. Such open access is expected to eventually lead to exhausted and degraded pasture (Behnke, 1994). However, drylands which are under communal land tenure are not 'open access'. They are divided up between groups, and rights to the use of these areas are defined and redefined through negotiations, communications, and other means. Strict rules are put in place to maintain these rights (Behnke 1994; little, 2001). In this way, pastoralists ensure that pastures can be sustained and allowed to replenish. Traditionally, Karrayu households manage their pasturelands through different techniques including mobility, identifying dry and wet season grazing location, and burning the rangelands to facilitate the regeneration of grasses at the onset of rainfall. Karrayu households also burn the rangelands for controlling the effects of pests such as ticks and for facilitating balanced germination, regeneration, and growth of grasses, bushes, shrubs, trees and herbaceous pasture in the rangeland ecosystem. Each Karrayu clans have their own rangelands in which the right to use the pasture was restricted (only the clan members have free right to access to the pasture) to reduce the pressure on rangelands. However, during uncertainties through negotiation they may allow other clan members for a defined time period. Mobility directly benefits rangeland management in a number of ways. It removes dead biomass and paving the way for fresh grass to sprout at the onset of the rains, prevent the liter plant (risk of colonization by unpalatable tree), disperse plant seeds, facilitating the germination of certain hard species that requires physical dispersal, breaks up hard soil crusts (facilitate infiltration and seed burial).

According to the woreda rangeland expert, Karrayu households undertake natural resource management activities such as terracing, resting of the rangelands, reforestation, reseeding of grasses, water harvesting as a response mechanisms to mitigate the effects of drought. According to the results of the household survey, 60 % of the households responded as they were undertaking reseeding of grasses, reforestation and terracing on their private closure areas; and 51 % undertake cut and carry system of grasses and agro-forestry practices; and 67 % of the households undertake water harvesting, management of water points and controlled grazing systems on their farmlands, private closure area and communal grazing lands and water points. In general, when we compare the present and past natural resource management practice of the households, more households undertake natural resource management practice in the present day than in the past as a response to minimize adverse effects of climate change.

Management of water points and controlled grazing system were undertaken more by pure pastoralist households (Yaya Village). Cut and carry system of grasses, agro forestry practice, reforestation and reseeding of grasses were undertaken more by DRV households than YYV households. It was found that in the present day rangeland burning was not practiced at all by the groups from both villages. The shortage of grasses by recurrent drought and degradation of the land deter the households from undertaking the rangeland burning as a means of conserving a meager available shrub, bushes, grasses, and herbaceous pasture. According to the woreda pastoral development office's 2001 annual report, more than 500,000 different types of forest seedling was planted by the pastoral community on their farmland, communal grazing land, and on the private closure areas.

Reduction of Consumption and use of Wild foods

Reduction of consumption and changing of composition of diet is also undertaken by karrayu pastoralists as a final resort or response to drought. According to Coppock (1994, 163) during the drought pastoralists take more cereals than milk and reduce their food intake. FGD participants revealed that in the past an extent of reducing consumption, as a response to conventional drought, was low but in the present day consumption is reduced even during the normal period to only one time per day. The effects of present day drought are multidimensional in the study area; it also eradicates many bush products that pastoralists used in the past during critical time such as grasses, berries, and roots. They also explained that drought eradicates wild plants that are used by human and livestock during drought – this also highly reduced food intake rate of pastoral households during the present day drought. According to informants, in drought period not only quantity of food is decreased but also the quality is dropped due to lack of milk, especially, for children and elder resulting into a dangerous health effect. Through household survey, 63 % of respondents confirmed that there was no meal reduction as a response mechanism to conventional drought in the past.

6.2. Non Pastoral Activity Responses

In the present day, more and more pastoralists are desperately looking for additional sources of income including non-pastoral subsidiary activities which generate additional revenue during normal years and spread risks at times of insecurity. Such activities may range from opportunistic farming, causal labor in urban areas, and commercial farms to selling of charcoal, firewood, and wild fruits collection (Akliliu and Alebachew, 2009). During the pre -1980s severe drought, extent of responses to non-pastoral activity was almost nil by the Karayu households and they were devoted extremely on the pastoral activities. In the past, livestock and livestock products were sufficient for household consumption requirements. However, in the present day due to loss of livestock by drought, pastoralists in the study areas have engaged in agriculture, collection and selling of firewood and charcoal, serving as a causal laborer and trade as response mechanisms to drought (Abera, 2010).

Crop cultivation

With change in the climate condition and uncertainties surrounding livestock production, more and more pastoralists are shifting towards agro-pastoralist. In the present day, crop cultivation is spreading to rangelands and areas that have never been under cultivation (Akliliu and Alebachew, 2009). As a response to drought events and food insecurity, Karrayus engaged in crop cultivation. In the past, cultivation was considered as an activity of distressed; poor pastoralists when they have been ejected from pastoral systems, they engage in farming because of livestock loss to drought or disease. Informants indicated that Karrayus have started rain fed agriculture during the Derg regime after the 1977 severe drought. But the extent and coverage has increased more after 2002 as modified responses to drought that is aggravated due to climate change.

Through household survey, out of 134 targeted sample households, 109 of them have started (engaged in) agriculture as a response to drought. It was found that the objective of crop production varies across wealth group. Informants indicated that the wealthy appeared to cultivate for avoiding of livestock liquidation to purchase grain, where as the poor cultivated to deal with food security. The land cultivated and the rate at which it expands may not pose serious problems to Karrayu pastoralism in comparison to the quality of land it encroaches. According to OPADC (2008), from the total area of the woreda (133,963.6 hectares) the total cultivated area in 2008/9 under rain-fed agriculture was 2021 hectares and under irrigation agriculture was 202.25 hectares which means < 2% of the total area of the woreda. But after the completion of the Fantale large scale irrigation project, the area that is cultivated through irrigation may rise up to 18,000 hectares. Although it is on a progress, the construction of the irrigation canal was not installed up to the villages where this study was undertaken.

Karrayu pastoralists were eagerly waiting the completion of irrigation canal and expecting as it will resolve their current food security problem. Through household survey, it was identified that in the last season 45 %, 52 % and 5 % of households from YYV cultivated 0.5, 0.6- 1, 1.1-2 hectares of maize, respectively, under rain fed agriculture. On the other hand, 20%, 54% and 26% of the households from DRV cultivated 0.5, 0.6-1, 1.1 -2 hectares of maize under rain fed agriculture. Regarding the yield 40%, 56% and 4% of the YYV households produced <3, 4-6 and

7-9 quintal, respectively. Similarly, 36%, 55% and 9% of households from DRV produced <3, 4-8, and 9-12 quintal, respectively, in the last season. Average farm holding and engagement in agriculture is high in the agro-pastoral village than pure pastoral village. An expert of woreda crop production explained that in both villages, cultivation of other crop type was not practiced due to the soil type and duration of the rainfall of the area. In addition, pastoralists claimed that full sedentary agriculture is difficult in the area. For example, on a certain plot of land, crop is not grown for more than a season without resting due to salt deposition. This indicated that crop farming is not the sole solution as a response to drought. Instead, it is an opportunity and help pastoral households as a means of supplementatiing income from pastoral activity.

However, respondents claimed that since 2006, there has not been harvest from rain fed agriculture because of late initiation, and early cessation of rainfall, lack of soil fertility, pest outbreak and effects of salt deposition. For example, Ganna crop was completely devastated in 2008 by the army worm, ball worm, cutworm, and stock borer breakout that is caused by variation in daily temperature and by the late initiation and the early cessation of Ganna rainfall. Even though the irrigation is an opportunity for the karrayu households in production of supplementary feed for the livestock and crop, it is too difficult to entirely depend on it because of the soil characteristics (deposition of salt in arid and semi-arid lands, stunting plant growth on the second season of production) and climatic condition of the area.

Through household survey, 78 % of the household respondents confirmed that they did not use agriculture as a usual response to drought in the past and 22 % of them responded that their extent towards agriculture as a response mechanism to usual drought was low in the past. But in the present day, 63 % of the households responded that as their extent towards agriculture as a newly developed response mechanisms to drought that was aggravated by climate change is becoming high.

Collection and selling of fuel wood and charcoal

The disposal of livelihood asset due to drought and related shocks forced pastoral households to collect and sell of fuel wood and charcoal. Both key informant interview and focus group discussion participants revealed that in the past Karrayu gave proud for the nature; nobody was cutting tree from the base (it was prohibited by the Gada system).

But depletion of asset by recurrent and prolonged drought (climate change) and lack of alternative livelihood option have led Karrayu pastoralists to destruction of meager indigenous trees, collection and selling of firewood and charcoal. They explained their fear that, in the present day, an extent of households towards this activity is high; the deforestation of tree for this purpose may lead to severe degradation of natural resources. The respondents confirmed that, in the past, none of them had participated in selling of firewood and charcoal. But in the present day, 57 %, 19 %, 7 % and 17 % of respondents from YYV confirmed that their extent of selling firewood and charcoal as a modified responses (forced response) to drought is no, low, medium and high, respectively. on the other hand 40%, 20%, 17% and 23% of respondents from DRV confirmed that their extent of selling of firewood and charcoal in the present day is no, low, medium and high, respectively. An extent of selling of charcoal and firewood was high in DRV than YYV households. This indicated + the increasing severity of present day drought. According to informants from woreda finance and economic development office, in the present day, all wealth groups of the woreda are involved in making charcoal and collection of fuel wood for selling. Especially, female-headed households are entirely depending on this activity for their daily consumption due to disposal of asset by drought and lack of other alternative income for exchange of cereals.

Causal Labor

Traditionally, Karrayus give priority, emphasis and proud to their pastoral activities, manage their livestock and when uncertainties happen to any of their member they wire each other. But in the present day, drought reduced herd size, deteriorated social support, led households to destitute, and forced them to engage in causal labor. According to informants, slashing of the railway side, temporary daily labor in sugar cane plantation, compilation and loading of sands were among labor activities that were undertaken as a means of income generation by Karayu pastoralists due to loss of livestock and lack of other alternative viable livelihoods. According to the results from the household survey, all respondents confirmed that none of them used causal labor as a response to a conventional drought in the past. But 10 % and 17 % of respondents from YYV confirmed that their extent towards causal labor is medium and high in the present day, respectively. And 15 % and 25 % of respondents from DRV confirmed that their extent towards causal labor is medium and high in the present day, respectively, due to the complete disposal of livelihood asset (livestock). An extent towards causal labor is high in agro-pastoral village than pastoral village.

Trade

As Sandford and Habtu (2000) argued, pastoralists in Ethiopia in general have low level of earning income from non-pastoral activities like petty trade. Similarly, Karrayyus give less attention to non-pastoral activities and their participation in trade is also almost nil. According to the FGD, participants until today have had no any small, medium and big business centers from the woreda town in Matahara[140]. However, as a response to drought in the present day, households have started petty trade and livestock trade in the village (buying and retailing after sometimes within the village or selling in the woreda town) and women have started selling of butter and milk when available to purchase household utensils. In the present day, 65 % of the households from DRV and 43 % of the households from YYV confirmed that their extent of involvement in trade is high. However, they had no any intentions to involve in trade in the past.

Asset disposal

In the past, livestock represents wealth and to a large extent considered as insurance of food security (livelihood) and description of social value among Karrayu pastoralists. But now days, due to increased climatic shocks (severe drought), some pastoralists reached the stage of destitution because of complete asset disposal (loss of livestock by drought). According to Little *et al.,* (2008), loss of livestock assets below a certain threshold translates pastoralists into poverty in the absence of viable alternative livelihoods. According to the data obtained from the woreda food security office, in the present day, 13 % of the woreda population is identified as destitute and treated through direct support of safety net pregame due to complete loss of physical capital (livestock) by drought and related shocks. About 17% of households confirmed that in the past they did not loss their entire asset because of responses to drought but in the present day they become destitute and completely loss their entire asset through undertaking responses to current climatic shocks.

As it can be seen from Table 3, in the present day, almost all wealth groups of the Karayu pastoralists households have been undertaking both pastoral and non-pastoral activities in a varied extent as a response mechanisms to drought. The responses of the households are categorized at different stages and individual households have engaged in different types of activities. Very few old pastoralists have limited themselves to the first stage and modifying their extent of response mechanisms through undertaking pastoral activities such as increasing an extent of mobility, increasing an extent of herd diversification, etc. But majority of the study area pastoralists engaged simultaneously in the pastoral and non pastoral activities as a means of response mechanisms to drought risk reduction. The third stage of response was asset disposal. The pastoralists who reach this stage were those who lost their livestock by both drought and selling for exchange of grains and/or those who could not be able to respond to drought due to their livestock holding is below threshold level. Those who disposed their asset and could not get other productive livelihood option are now employed in non-secure activities and some loss moral and out of any dimension of pastoral activities and addicted to chewing *khat.* Extents of responses of the households to a set of pastoral and non-pastoral activities vary. For example, an extent of mobility and herd diversification is higher in the present day than in the past. Herd splitting and social support is high in the past and low in the present day. An extent of households towards agriculture, collection and selling of firewood and trade is high in the present day than the past.

[140] Fentale woreda town

Table 3. A simple model of an extent of households' response mechanisms to drought in Yaya and Dire Redie villages of Fentale Pastoral woreda in the past and in present day.

Stage of responses	Type of livelihood responses	Type of household activities (modified household activities)	Before 10 years an extent of responses to conventional drought	Now- an extent of modified responses to drought due to [141]CC
1	Pastoral activity responses	Mobility	Medium	High
		Herd diversification	Low	High
		selling of large stocks and livestock products	No	Medium
		Herd splitting	High	Low
		Selling of small stocks	Medium	High
		Assistance from the relatives and communities(Social supports)	High	Low
		Collection of wild foods and meal reduction	Low	High
2	Non pastoral activities	Agriculture	Low	High
		Collection and selling of fuel wood and charcoal	No	High
		Petty trade	No	High
3	Asset disposal	Loss of asset (selling of whole livestock and household tools)	No	medium
4	Destitution	Causal labor, migration and employment on non secured activities and lack of moral	No	High

Source: extracted and summarized from household survey responses, key informant interview and FGD, Participants (Abera, 2010)

Household income

Table 4 displayed the households' average annual income and its respective sources. It is found that more than 65 % (10,000 birr) of the average annual income of the households of both villages were generated from the pastoral activities through the sale of livestock and livestock products. This indicates that livelihood of the study area is highly dependent on pastoral activities.

Table 4. Household annual income.

	Yaya	Dire Redie	Total
Average pastoral activity income	5854	4146.0	10,000.0
Average non-pastoral activity income	2226.9091	3697.3	5924. 2091
Average income from food aid	548.4783	657.2	1205.6
Total income (average)	8414.3478	8485.3	17,129.7

Source: Household survey, 2010.

The share of non-pastoral activities income to households of both villages were large which was 34.6% (5924.2091 birr) and is modified and developed as a response mechanism against severe drought that is aggravated by climate change.

6.3. External Responses

External responses are the responses that were undertaken by the external agents such as Government and NGOs to reduce the adverse effects of the drought on the pastoral households of the study area. Even though it is beyond the objective of this article, currently, government and non-governmental organizations are undertaking emergency aid, livelihood diversification, and

[141] climate change

expansion of social and economic infrastructure, early warning, conflict management and resolution in the Fentale pastoral woreda to spread the drought risk and to improve the resilient capacity of the households (Abera, 2010).

7. Conclusion and Recommendations

7.1. Conclusion

Though the Fentale pastoral woreda households have been undertaking a set of responses to mitigate their livelihood sources from the adverse effects of the present day severe and recurrent drought, extent of household responses are poorly understood. However, as a response to drought, in the present day, households are undertaking a set of pastoral and non-pastoral activities to mitigate their livelihoods and to spread adverse effects of the present day severe droughts. Responses of the households' are categorized at four different stages of livelihood activities and individual households are occupied in different stages of the responses such as pastoral activities, non-pastoral activities, and asset disposal and destitution stages. In general, in the present day, an extent of responses towards mobility and herd diversification is higher by households. In addition, households have started to partly practice crop cultivation. Other non-pastoral activities such as agriculture, daily labor, petty trade, fuel wood collection and charcoal selling contributed to about 35% of the total households' income in the study area.

7.2. What is to be done?

The recurrence of severe drought is a cause of human suffering and a major blockage to pastoral and agro pastoral systems in Fentale pastoral woreda. Hence, identifying more viable and productive pastoral and non-pastoral activities that are well suited to the agro-ecological condition of the area is the decisive factors to reduce vulnerability of the households to the increasing rate of recurrent drought. Mobility and herd diversifications are among the pastoral activities that requires due attention to minimize adverse effects of drought on pastoral households. In addition, perseverance have to be made to make use of unexploited local wealth potentials of non-pastoral activities such as agriculture (irrigation and rain fed agriculture), trade, micro enterprise, and tourism as a development strategies. In this case, identification and characterization of the distribution and composition of the livestock resources among the wealth group is mandatory to design appropriate and plausible interventions that are based on the household wealth characteristics. Traditional rangeland management and drought risk spreading strategies should be strengthened, and go along with scientific rangeland and the drought cycle managements. It is best to think about increasing the level of community participation in relation to each of the main components of drought management. Identification of the potential and degraded rangelands, species composition, productivity status, and types of management intervention are advisable.

In this case, since the indigenous pasture on the rangelands is the primary feed source for livestock of the pastoralists, giving attention is needed for its improvement by applying rehabilitation intervention: dry season reserve areas should be better protected, unwanted plant species should be better controlled and the management and utilization of the feed source should be improved. Furthermore, natural and social science research institution should give due attention and priority to find drought tolerant and drought escaping forage, livestock, and crop varieties to strengthen pastoralists' adaptation to recent severe drought that is aggravated by climate change. Continuum of emergency intervention and livelihood development is required from pastoralists and external agencies instead of only focusing on life saving at the onset of drought; to improve the resilient of pastoralists in sustainable basis. In general, it is better to promote holistic development approach that comprises both pastoral and non-pastoral activities, and improvement of social and economic infrastructure to undertake sustainable responses to drought instead of only giving blue print development approach (sedentary agriculture) as a final option to adverse effects of drought.

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18. Climate Change/Variability, Perceptions and Livelihood Strategies by Pastoral Community in *Karrayu* Area, Oromia Region, Central Ethiopia

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Abstract

Climate change and variability has continued to become one of the most formidable challenges of human beings. The pastoral and agropastoral communities are among those most vulnerable to such changes and variability. The adverse effect of climate variability and change is accelerating the already existing pastoral livelihood insecurity. Improving resilience of communities and households to effects of the impacts of climate change requires understanding of the existing local practices. Perceptions and strategies of these communities should be understood for building a sustainable future. The current paper reports the major climate change/variability, and their perceptions and livelihood strategies devised by Karrayu pastoralists in Fenatale Woreda, Oromiya Regional State. Meteorological reports of Metehara (1968-1984) and Awash (1985-2007) stations were used for preliminary assessment of the change and variability. These data were substantiated by 120 randomly selected sample households using semi-structured questionnaire, key informants' interview, and focus group discussions. Rainfall coefficient, least square regression models, Standardized rainfall anomalies and coefficient of variations were used to assess pattern, distribution and variability in temperature and rainfall. The result showed that there has been an increase in the maximum and annual average temperature and a decline in the minimum annual temperature from 1965-2007. Rainfall declined at an average of 0.26mm per decade in the stated period. According to the values of rainfall coefficient, eight months (FMAMJJlAS) were rainy months while the remaining four months (ONDJ) were dry months as their values were <0.6 and >0.6mm, respectively. Three of the wet months (MAS) were with moderate concentration while two of them (JlA) were with big concentration of rainfall. From these, it can be concluded that there are climate change and variability and also extreme weather events like drought in the area. Cognizant of such events, large proportion of pastoral community of Karrayu area devised numerous livelihood strategies including use of fewer amounts of water and food, dependence on Participatory Safety Net Program, migration with their camels to areas ranging from the vicinity of Metehara Sugar Factory to other distant areas, and collection and sale of fire wood and charcoal. Despite these facts, the gaps of adequate meteorological data and information requested for further investigation in the area of climate change/variability. Moreover, it was recommended to have proper use and management of water harvesting technology as well as environmental management mechanisms to integrate local initiatives towards disaster and risks due to such extreme weather events as drought. Furthermore, local and regional early warning systems should be integrated to enable pastoral community get strengthened in their Ex-post- and Ex-ante disaster and risk management mechanisms.

Keywords: Climate Change/Variability; Drought; Karrayu; Livelihood Strategies; Pastoral

1. Introduction

Pastoralism has a great share in national and regional economies for several poorest countries of the world. It serves as a base for local livelihoods and provides multi-directional ecological services (Nori *et al.,* 2008). Pastoral and agro-pastoral societies inhabit in the arid and semi-arid environments, which are characterized by high probability in the frequency and intensity of drought and flood occurrences (WISP, 2007; Birch and Grhan, 2007). Climate variability and change is one of the major issues for the future of pastoralism. The adverse effect of climate variability and change is accelerating the already existing pastoral livelihood insecurity (Tagel and Veen, 2015). Knowledge of people's perceptions and adaptation measures are crucial to inform future actions and thereby minimize impacts of climate change. Improving resilience of communities and households to effects of the impacts of climate change requires understanding of the existing local practices (Smucker and Wisner, 2008).

The pastoral areas of Ethiopia cover over 60% of total landmass inhabiting 10 million people (Beruk, 2008). These are known for inadequate and erratic rainfall to meet the physiological water requirements of biotic system. This phenomenon is aggravated by high temperature and strong dry winds leading to high evapo-transpiration, which in turn accelerates water scarcity to its climax (Mesfin, 2000). There are few local level studies on climate change and variability regarding the arid and semi-arid areas of Ethiopia (Gebre, *et al.,* 2013; Nega, *et al.,* 2015). As there are spatio-temporal variations in the degree of climate change and variability as well as their resilience capacities, informative studies at local level are crucial for reliable data and for decision actions. The current study is based on *Karrayu* pastoral area in Fentale *woreda* of Oromia region where there has been frequent climate induced disasters, such as drought, flood, and resultant livelihood insecurity. It aimed at evaluating the trend and variability of major climatic element; assessing the perception of local pastoral community toward; and identifying major livelihood strategies to livelihood insecurity associated with climate change and variability.

2. Materials and Methods

2.1. Descriptions of the Study Area

Karrayu land (administrative fall under Fentale *woreda*) is astronomically located from $8^0$42'to $9^0$00'N Latitudes and $30^0$30' to $40^0$11'E Longitudes in East Shewa Zone of Oromia, Central Ethiopia. Metehara, the capital of the *woreda*, is located at about 200km south east of Addis Ababa, along the Addis Ababa-Djibouti road and rail ways. The neighbours of Fentale woreda are the Afar Debine in the north, Arsi Oromo in the south, Awash National Park in the east, the *Ittu* of west Hararghe and the *Argoba* in the west, and Bereket and Shenkora and Minjar *woredas* in the south west (Fig.1). It is situated in tectonically active Main Ethiopian Rift (Goerner, *et al.,* 2009) with topographic features of flat, undulating plains, hills and mountain ridges, and altitude ranging from 900 to 2700meter above sea level (FWARDO, 2007).

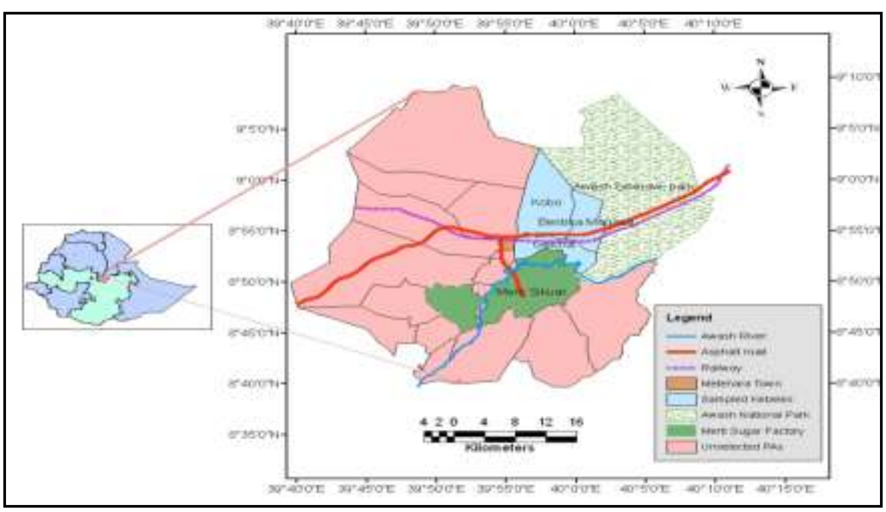


Figure 1. Location map of Fentale *woreda* and the selected *kebeles* of Fentale *woreda.*

The average monthly and annual temperatures are 25^{0}c and 26^{0}c, while the average annual minimum and maximum temperatures are 17.3^{0}c and 32.5^{0}c, respectively. The highest rainfall occurs in the Ethiopian summer (*Kiremt*) season (JJlAS) followed by four to eight consecutive months (ONDJFMAM) that are water deficit in the area (Haji, *et al.,* 2015). Its total annual rainfall ranges between 400 and 700 mm and being categorized under semi-arid (*kolla)* agro ecological zone or dry/arid climatic zone (lower *kolla*) (Ayalew, 2001; MOA/FAO/UNDP, 1983). Awash River and Lake Beseka are the main hydrologic elements in the *Karrayu* areas.

The soils in *Karrayu* area are dominated by Andosols and Leptosols, having reddish colour, silt clay to sandy loam texture, and low organic matter content. Its dominant tree species are *Acacia senegali* (colloquially known as *Burquqqee*), *Acacia tortolis* (*Xaddacha*) and *Acacia etaica (Ajo*). Among these, *Acacia senegali* and *Acacia tortilis* are highly deforested for firewood and charcoal production (OIDA, 2007; FWARDO, 2007). The area is a habitat of a variety of birds, fishes, crocodiles and other aquatic species from Lake Beseka and plays an important role in the wildlife ecology as it is located in the northern vicinity of Awash National Park (Eleni, 2009).

It is one of the most drought prone areas in the East Showa Zone of Oromia Region inhabited largely by *Karrayu* pastoralists (FWARDO, 2007). The total population of Fentale *woreda* was 82255, of which 53% and 47% are male and female, respectively. Rural and urban dwellers constitute about 75% and 25% of the total population, respectively (FWARDO 2007). *Karrayu* has two major tribal divisions namely *Dullacha* and *Basso* (Haji, *et al.,* 2015) and is inhibited as a single dominant group in Fentale *woreda* until 1950s and 1960s. Since then, *Ittu* Oromo and the Somali community continually have permanent settlements in *Karrayu* area (Ayalew, 2001). Pastoral system is the dominant livelihood base of the area, including rearing cattle, goats, sheep and camels. Agro-pastoral livelihood system began after the 1980s following the severe scarcity of feed, grazing land and water. Agro-pastoral households cultivate maize, sorghum, groundnut and onion (FWARDO, 2007).

2.1. Data Collection and Analysis Methods

Multi-stage sampling procedure was used to select sample pastoral *kebeles* based on their accessibility and representativeness to the features of pastoral and agro-pastoral livelihood system. In the second stage, stratified random sampling technique was used to select 120 sample respondents from three kebeles, namely: Gelcha, Kobo, and Banti Mogassa. Primary data was gathered through semi-structured interview, focus group discussion (FGDs), key informants interview, and field observation. The secondary data were obtained from archives of the National Meteorological Service Agency, Fentale *woreda*, regional and national governmental and non-governmental institutions. In addition, consecutive meteorological data (1985-2007) of Awash and Metehara (1965-84) Stations were used.

The descriptive quantitative analyses were made using SPSS software. The rainfall variation and distribution was analyzed and interpreted on the basis of daily, monthly, seasonally and annual time duration. For the available daily rainfall data, the number of wet days and corresponding amounts and probability of wet days were calculated by taking a daily rainfall amount of > 0.1 mm as a threshold to identify a rainy day (like used by Bewket and Conway 2007). The probability of wet day is computed as:

$P(w) = \frac{n}{N}$ Where P (w) is probability of wet day

n is number of wet days

N is total number of days (both wet and dry days

Following Bewket and Conway (2007), inter-annual variability is evaluated by calculating standardized rainfall anomalies using:

SRA = (Pt-Pm)/ σ

Where SRA= Standardized Rainfall Anomaly

Pt= rainfall amount of a given period

Pm=is Long term mean rainfall over a period of consideration

σ=is standard deviation of rainfall over a period of observation.

Non parametric Spearman's rho and linear regression are used to quantify trends and their statistical significance, respectively while patterns and trends of climate change and variability are presented using graphs, tables and charts.

3. Results aAnd Discussions

3.1. Trend and Variability of Major Climatic Elements

3.1.1. Temperature variation and distribution

The study area experienced decreasing average monthly minimum temperature for almost all months of a year during 1985-2007 as compared to that of 1965-1984. Except slight monthly record variations, the least average annual minimum temperatures were recorded in December, January, and November from 1965-2007. November was the second coldest month preceding December (Fig.2). Similarly, the perception of local community identified December as the coldest month.

The mean monthly minimum temperature for the period 1985-2007 was relatively lower than that of 1965-1984, which implies a gradual decrease in the minimum temperature. Conversely, the mean maximum monthly temperature indicated increasing trend for both periods, with the exception of the months of July and August (Fig.2). With regard to annual linear trend, there was increase in the maximum and annual average temperature for the periods 1965-84 and 1985-2007, while a declining trend was observed in the minimum annual temperature from 1965-2007 (Table 2).

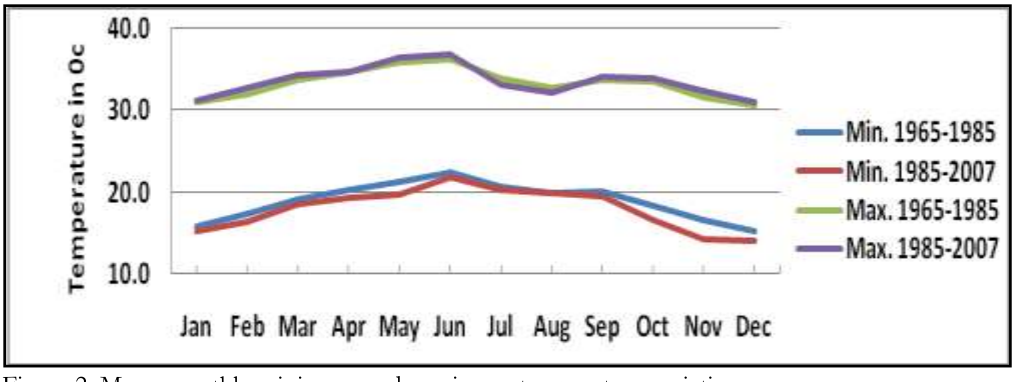


Figure 2. Mean monthly minimum and maximum temperature variation.

Table 2. Annual Mean Minimum, Average and Maximum Temperature Variations.

Years	Annual Mean(in °c)			Standard Deviatioons			LT (in °c per decade)		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
1965-1984	18.8	33.3	26.1	0.7	0.6	0.5	0.76	0.46	0.61
1985-2007	17.9	33.6	25.7	0.6	0.5	0.4	0.46	0.4	0.43
1965-2007	18.34	33.44	25.89	0.8	0.5	0.5	-0.11	0.12	1.02

Source: Computed from NMSA Data.

3.1.2. Rainfall variation and distributions

i. Annual and seasonal rainfall variability and trends

For the period between1965-2007, the mean annual rainfall of the study area was 512.5 mm, with over half (58%) of it received during *Kiremt* followed by nearly a third (33%) in *Belg* seasons and it has bimodal rainfall distribution (Table 3). The mean seasonal rainfall *bega* followed by *Belg* indicated variability. As indicated in Fig 3(A–D), the rainfall of annual total and all three seasons showed decreasing trend. Likewise, the pastoralists' perception also identified that of *arfaasaa* (*Belg*) period alone as had been decreasing in the study period. According to the rho analysis, there are significant decrease trends in Belg and Bega seasons but not significant decrease in *Kiremt* and annual mean rainfall (Table 3).

Conversely, the regression analysis showed not significant decrease in both the seasonal and annual rainfall, as the r value is below 0.5 (Table 3). In general, there is decrease in the mean annual rainfall during the aforementioned period by about 0.26 mm every decade. Significant decreasing trend was also identified in the mean *Belg* season and the mean annual rainfall (Table 3) that goes in line with significant decline in the annual rainfall distribution in the eastern and south eastern Ethiopia from 1982 to 2003 report by Yilma and Zanke (2004). Despite these facts, it is essential to conduct further study on trend analysis of the dominant climatic elements using other methods and data from the study area to come up with representative conclusion on status of significance of seasonal variability of these elements.

Table 3. Annual and Seasonal Rainfall Amount and Percentage and Linear Trend (1965 - 2007).

Variables	Mean Rainfall		Decadal Linear Trend	Calculated rho	Regression Trends	
	Amount (mm)	(%)			R^2	R
Kiremt	321.22	58.16	-0.13	NST	0.029	0.17
Belg	184.78	33.46	-0.21	DST*	0.072	0.27
Bega	46.30	8.38	-0.09	NST	0.014	0.19
Annual	552.3	100	-0.26	DST*	0.106	0.33

Source: computed from NMSA (nd) data; NB: is significant at 0.05 level; NST- not significant trend; DST – decreasing significant trend.*

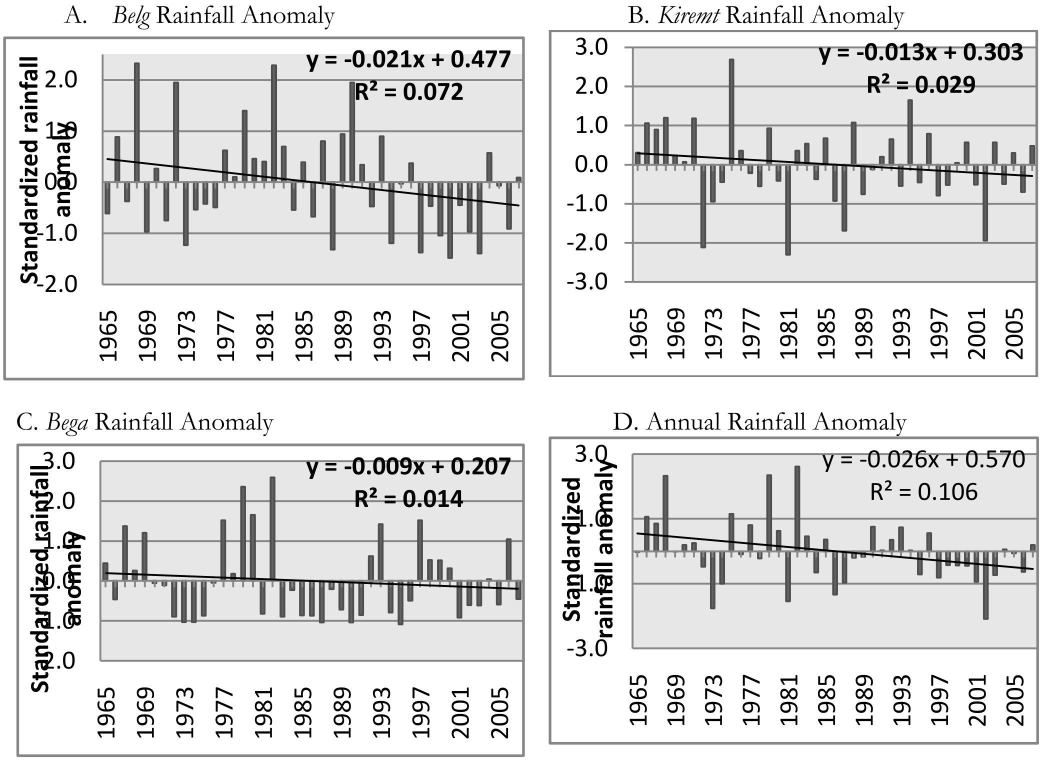


Figure. 3. Annual and seasonal rainfall standardized anomalies and trends (1965 – 2007).

ii. Monthly rainfall

The mean monthly rainfall amounts received by almost all months in the years 1965 – 2007 were almost uniformly distributed among the months whereby July and August are with the highest records (Table 4; Fig 4). The annual mean total rainfalls of 1965-1984 and 1985-2007 were 598.1mm and 512.50mm, respectively (Table 4). According to the values of rainfall coefficient, eight months (FMAMJJlAS) were rainy months as their values were <0.6 and >0.6mm, respectively while the remaining four months (ONDJ) were dry months. Three of the wet months (MAS) were with moderate concentration while two of them (JlA) were with big concentration of rainfall. This may request proper use of water harvesting technology to use and manage the concentrated rainfall. Moreover, early warning systems and integrate environmental management measures are required to minimize/avoid disaster and forward possible remedial actions.

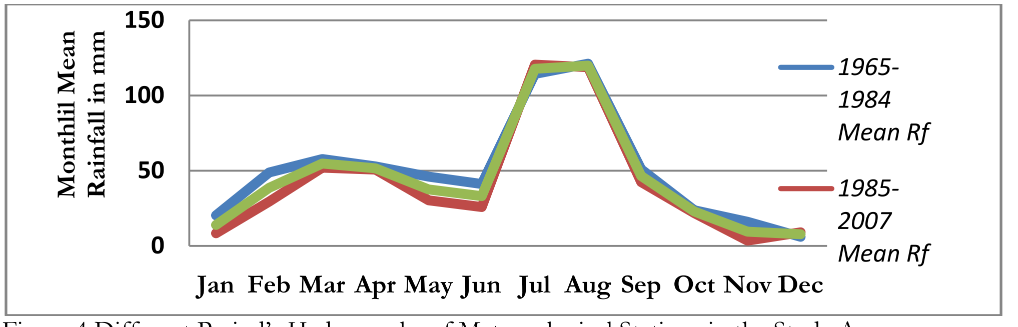


Figure 4 Different Period's Hydrographs of Meteorological Stations in the Study Area.

Table 4. Monthly and annual mean rainfall, Coefficient of Variation and Rainfall Coefficient (RFC) for the decades 1965- 1984, 1985 -2007 and 1965- 2007.

Variables	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Period of 1965-1984													
Mean RF[1]	20.2	48.7	57.6	52.7	46.0	41.1	114.2	121.1	50.8	23.7	15.9	6.0	598.1
C.V.[2]	1.9	1.4	0.9	0.8	0.6	0.9	0.4	0.5	0.5	1.2	1.5	1.8	0.3
RFC.[3]	0.4	1.0	1.2	1.1	0.9	0.8	2.3	2.4	1.0	0.5	0.3	0.1	
Period of 1985- 2007													
Mean RF[1]	8.3	29.5	52.0	50.7	30.2	25.8	120.6	118.9	42.3	21.8	3.4	8.9	512.5
C.V.[2]	1.5	1.5	0.7	0.7	1.0	0.8	0.4	0.3	0.5	1.4	1.5	1.9	0.2
RFC.[3]	0.2	0.7	1.2	1.2	0.7	0.6	2.8	2.8	1.0	0.5	0.1	0.2	
Period of 1965-2007													
Mean RF[1]	13.8	38.5	54.6	51.6	37.5	32.9	117.7	119.9	46.3	22.7	9.2	7.6	552.3
C.V.[2]	2.03	1.48	0.78	0.75	0.83	0.90	0.41	0.42	0.51	1.28	1.94	1.94	0.24
RFC.[3]	0.3	0.8	1.2	1.1	0.8	0.7	2.6	2.6	1.0	0.5	0.2	0.2	

Source: Computed from Meteorological Data; NB: [1]RF= Mean Rainfall; [2] CV= Coefficient of Variation; [3]RFC= Rainfall Coefficient.

iii. Amount, variation and trends of rainy days

From the points of view of hydrology, and soil and conservation, the duration, intensity and amount of rain that falls within a given area are very significant (Daniel, 1977). Accordingly, the mean annual number of rainy days was 84.93 with 23.27% probability of wet days. This implies that about 76.73% of the annual mean days from 1993-2007 were of dry days (Table 5). In all the cases, there was relatively smaller variability in the number of rainy days as the CV values of below 0.5 (i.e. 0.32). Concerning the rainfall amount of the rainy days, there was high variability in *Bega* (with CV=0.80) than those of *Belg* and *Kiremt* seasons and also annual mean (CV=0.45, 0.25 and 0.18, respectively).

Table 5. Mean Probability of Wet Days (W), Coefficient of Variation (C.V.), Linear Trend (LT) of Number of Rainy Days and Rainfall Amount for Belg, Bega and Kiremt (1993-2007).

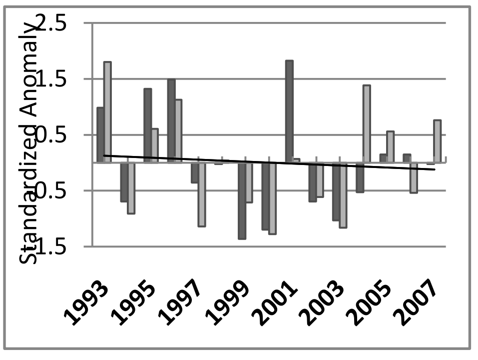
Periods	Number of Rainy Days				Rainfall Amount of Rainy Days			
	Mean	P(w)	C.V.	LT(day /decade)	Mean	% of annual	C.V.	LT (mm/ decade)
Belg	21.13	17.61	0.28	- 0.57*	141.03	27.98	0.45	- 0.17
Kiremt	46.60	38.20	0.18	- 0.60	306.67	60.85	0.25	- 0.32
Bega	17.2	13.98	0.43	-0.40	56.31	11.17	0.80	- 0.35
Annual	84.93	23.27	0.32	- 0.93	504.01	100.00	0.18	-0.56*

Source: Computed from Meteorological Data; NB: is significant at 0.05 levels.*

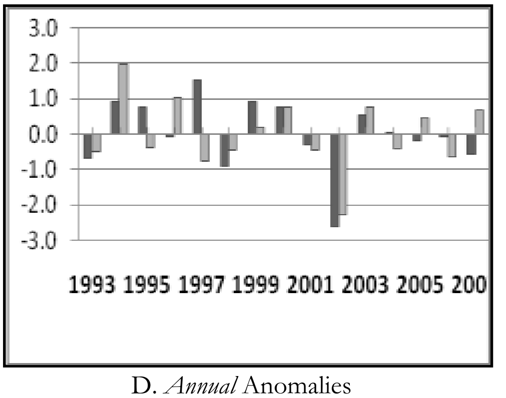
As disclosed in (Table 5 and Fig. 6 (A-D)), both numbers of rainy days and amount for annual and all season's rainy days showed decreasing trend and show negative anomalies for the aforementioned years. These are found significant at 0.05 levels for the *Belg* and annual, respectively. For the *Kiremt* season (Fig. 6B and Table 6) numbers of rainy days have been decreasing at faster rate (0.32mm/decade) than *Belg* (0.17mm/decade). Similarly, Yilma and Zanke (2004) also concluded that *Kiremt* rainy days in the eastern Ethiopia show a significant decline (at 5% level) since 1982 compared to that of 1965-81.

In a nutshell, the overall conditions of annual, seasonal and monthly and daily rainfall characteristics of the study area showed decrement during the study periods. Moreover, there were continued rise in the minimum and maximum temperature of the study area. Yet, this requires proper meteorological data of the contemporary period to come up with sound suggestions recommendations vis-a-vis climate change adaptive and coping strategies for the life and livelihood of the *Karrayu* community in particular and the region at large.

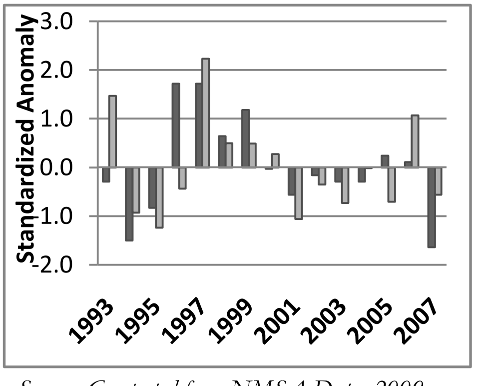
A. *Belg* Anomalies



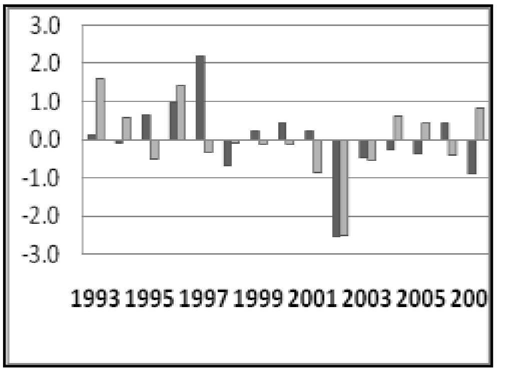
B. *Kiremt* Anomalies



C. *Bega* Anomalies



D. *Annual* Anomalies



Source: Computed from NMSA Data, 2009.

Figure. 6. Standardized seasonal and annual anomalies of number of rainy days (black bar) and rainfall amounts on wet days (white bar), (1993-2007).

3.2. Pastoralists' Perception of Climate Change/Variability and Drought

As revealed in Table 6, about 68.3% and 42.5% of sample respondents perceived increment in the mean maximum temperature and decrement in the mean minimum temperature, respectively. Similarly, the annual rainfall total is perceived decrement by 65% of sample respondents while about 57.5% of them indicated decrement in the annual distribution of rainfall. Furthermore, participants of FGDs and key informants' interviews indicated the presence of variations in the average temperature and rainfall. As per their perceptions, the periods of high and low temperatures were clearly known and demarcated. For instance, very high daily temperature was in June and the low temperatures were in December and January. Hence the local pastoral community adapts and acts accordingly during old periods. But, recently there are variations in low temperature that started as of September while high temperature occurred from April through July on irregular basis and that made resiliencies difficult.

Table 6. Pastoralists' Perception of Temperature and Rainfall Variations by Sample Respondents.

Climatic Elements	Pastoral Perceptions									
	Increases		Same		Decreases		Unknown		Total	
	No	%	No	%	No	%	No	%	No	%
Max. Temperature	82	68.3	21	17.5	10	8.3	7	5.8	120	100.0
Min. Temperature	35	29.2	14	11.7	51	42.5	20	16.7	120	100.0
Rainfall Intensity	27	22.5	16	13.3	77	64.1	-	-	120	100.0
Rainfall Variation	30	25.0	16	13.3	69	57.5	5	4.2	120	100.0

Source: Field Survey (2009).

In the case of rainfall during past years, pastoralists underlined that the rainfall was relatively ample and less variable as it occurred during two rainy seasons: small rainy season (*arfaasa*) and big rainy season (*ganna*). The former extends from March to May while the latter cover from June through September. In such a way, the rainfall period was extended from March to September. Within those months, the amount of rainfall was ample to be deposited in different ponds and used throughout several months. But recently the *Karrayu* area received rainfall either in July and /or in August for only one to two months. Unlike past years, water collected and deposited in ponds and surface depressions get dry up and that in turn resulted in severe water scarcity.

3.3. Livelihood Strategies by Pastoralists towards Climate Change/Variability and Drought

During drought period, pastoralists encounter shortage of food and/or finance to purchase food. The price of livestock on local market decreased and that of grain increased. In addition to these, the product of livestock like meat, milk, etc get deteriorated. Under such scenario, pastoralists developed numerous livelihood strategies including strategies concerning food, income, family and livestock related affairs (Table 7).

Over half percent of sample respondents pastoralists in the *Karrayu* area identified major livelihood coping and survival strategies to climate change and resultant drought including use less amount of water (76%), settling around Metehara Sugar Factory (73%), dependence on PSNP (72%), eat less amount of food (64%), migration with their camels to other areas (62%), and sale of fire wood and charcoal (57%). There are also other strategies that are responded by in-negligible percent of sample pastoralists including generation of food storage devices (15%), destocking by selling of old/weak livestock before drought (38%), borrowing cash from 'the haves' or relatives (34%), splitting family (32%) and migration to urban areas (31%). Regarding the dependence on PSNP it is variable among percentage of population of the pastoral communities in different *Kebeles* that benefited from the program. It ranges from <20% Haro Kersa *Kebele* to >50% by pastoralist in Tututi, Kobo, Debiti and D/Saden *Kebeles* (Fig. 7).

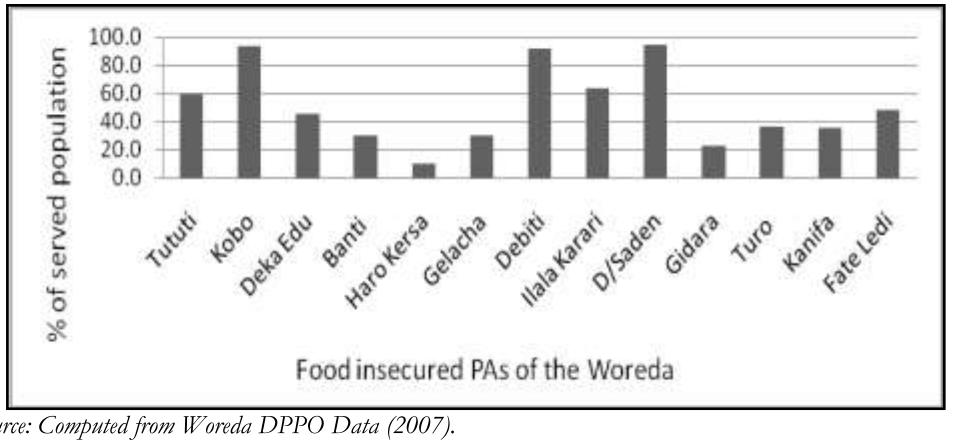
Table 7. Major Livelihood Strategies to Climate Change and Variability by Sampled Respondents.

Major Livelihood Strategies		Respondents	
		No	%
I. Coping/ Adaptive Strategies			
Food			
1	Use less amount of water	91	75.8
2	Eat less amount of food	77	64.2
3	Chewing chat	57	47.5
4	Borrowing food grain	52	43.0
5	Generating food store	18	15.0
Livestock			
1	Settling around Metehara Sugar Factory	87	72.5
2	Selling old/weak livestock before drought	46	38.0
Livelihood Diversification of Income			
1	Depending on Productive Safety Net Program (PSNP)	86	72.0
2	Sale fire wood and charcoal	68	57.0
3	Storage of butter until the price is high	57	47.5

4	Selling skins and hides of dead animals due to drought	54	45.0
5	Borrowing cash from 'the haves' or relatives	41	34.0
II. Survival Strategies			
Family			
1	Migration to other areas with their camel	74	62.0
2	Splitting family	39	32.0
3	Migration to urban areas	37	31.0

Source: Field Survey (2009); NB: Each option is out of the total percent of the sample respondents.

As per discussion with *woreda* key informants, the beneficiaries of the program are identified as those fall under food insecurity based on committee representative of all stakeholders in the area to select the beneficiaries based on guideline and data base proper. The selected beneficiaries get access to the program during dry months (from January to June). Most of the food aid is given according to their participation in the development works identified in the area: namely, participation in public work like de-silting and digging pond, constructing flood protection dams, road etc. Such beneficiaries are required to work five times per a month and are given 40 birr/head/month for three months (January to March) and 15 kg of grain/head/month for the next three months (April to June).While children, elders and pregnant women are given priority of getting access to the PSNP. In such conditions, beneficiary pastoralists' in the study area rely on the PSNP during dry period as their main coping strategies.



Source: Computed from Woreda DPPO Data (2007).
Figure. 7. Percentage Distribution of People Served by PSNP.

According to the opinion of participants of FGDs and key informants during past years, the *Karrayu* relied on only livestock products like milk, meat, butter, etc. They do not have permanent settlement areas; they migrate together with their cattle between "*ona gannaa*" (wet grazing area) and "*ona bona*" (dry grazing area). During old days, there was no scarcity of grazing land and hence pastoralists do not know about farming and culturally it is not accepted to be farmer. But, there are dynamics in the situation in the *Karrayu* area. Owing to all these dramatic changes since 1980s, *Karrayu* have exercised two major livelihood modifications against recurrent drought: from mobile to sedentary and from pastoral to agro-pastoral livelihood system.

A. From mobile to sedentary: - Owing to the aforementioned dramatic change in the *Karrayu* area, currently, they have started to settle at permanent places. Their former temporary settlements were abandoned and replaced by sedentary settlements in the study areas.

B. From pastoral to agro-pastoral:- the negative repercussions of CCV are reflected in frequent drought, dwindled grazing land, expanded land degradation, and decrement in the number and varieties of livestock in *Karrayu* area. The cattle and sheep holdings of most key informants decreased as compared to the past. As the quality and quantity of livestock deteriorated, the pastoralists were forced to practice rainfed and irrigated crop production.

A woman HHH key informant explaining the benefit of irrigation farming and showing the source of water for irrigation in their farm village

One of elder key informants, narrating the difference between the present and past year's livelihood in *Karrayu* area and how he has started this irrigation farming

Source: Field Survey (2009).
Figure 8. Pastoralists Practicing Irrigated Crop Production at Ajotere Village.

4. Conclusion

The analysis of meteorological data of Awash and Metahara stations and the perception of pastoralists in *Karrayu* area revealed steady increment and decrement in the amount and patterns of temperature and rainfall, respectively. Number of rainy days and amount of rainfall for all seasons and mean annual periods show decrement in the decades of the study periods. There are four distinct months of dry periods known for water deficit and resultant drought as extreme weather events in the area. Cognizant of the prevailing climate change and variability and extreme weather events, over half of sample respondents from pastoral community of *Karrayu* area devised numerous livelihood strategies including use of fewer amounts of water and food, migrating to settle around Metehara Sugar Factory, dependence on PSNP, migration with their camels to other areas, and sale of fire wood and charcoal.

Despite these facts, there are gaps of proper data to confirm about climate change and variability and forward possible suggestion regarding disaster risk management and early warning system applicable to the pastoral community of *Karrayu* area in particular and others in general. It is also recommended to have proper use and management of water harvesting technology as well as environmental management mechanisms to integrate local initiatives towards disaster and risks due to extreme weather events of drought and/or flooding. Furthermore, local and regional early warning systems better devised to enable pastoral community get strengthened in both ex-post and ex-ante disaster and risk management devices.

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