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The Role of Rain Water Harvesting for Food security in Ethiopia (A Review)

Abayneh Wubetu
College of Post Graduate Studies, Debre Markos University, PO box 269, Debre Markos, Ethiopia

Lists of abbreviations

ADLI	Agriculture development led industrialization
CSA	Central Statistics Agency
EIAR	Ethiopian Institute of Agricultural Research
ERDO	Emergency Relief & Development Overseas
FAO	Food and Agriculture Organization of the United Nations
FFW	Food-for–Work
FDRE	Federal Democratic Republic of Ethiopia
GDP	Gross Domestic Production
ICID	International Commission on Irrigation and Drainage
IFAD	International Fund for Agricultural Development
JICA	Japan International Cooperation Agency
Kebele	Smallest administrative unit in the Ethiopian structure
Mha.	Million Hectares
MMt.	Million Metric Tons
MoARD	Ministry of Agriculture and Rural Development
MOWR	Ministry of water resources
NAPA	Climate change national adaptation programme of action
NGO	Non-Governmental Organization
OARI	Oromia Agricultural Research Institute
OIDA	Oromia Irrigation Development Authority
RWH	Rainwater Harvesting
UNDP	United Nations Development Programme
UNFCCC	UN Framework Convention on Climate Change
Woreda	Administrative boundary comprising various Kebeles
WUE	Water Use Efficiency

Abstract
Ethiopia, a country with an area of 1.2 million km^2 is located in the region that is known as the Horn of Africa. Agriculture is the back bone of the country's economy and mainly practiced under rain-fed conditions. The main type of farming system was mixed farming that involves the production of crops and rearing of livestock mainly for subsistence. Ethiopia is the second most populous country in Africa with a total population estimated at 90 million with a growth rate of 2.6 percent and the majority of the population lives in the rural areas and depends on agriculture as their primary source of livelihood. Rain-fed agriculture in arid and semi-arid areas of Ethiopia is suffering from moisture stress due to drought which is a major limiting factor for successful crop production which intern results food insecurity. In Ethiopia recurrent drought, low productivity, population pressure, flooding, Rural-urban migration, poor saving trends, Lack of infrastructure, Poor rural asset base, Low education level were the factors for food insecurity. Surprisingly, Ethiopia is well-endowed with water resources. The total annual runoff is estimated at 110 billion m^3 however, much of which are carried away by trans-boundary Rivers. Groundwater reserves are estimated at 2.6 billion m^3. Even if these natural resource bases have a potential for supporting a far greater number of people than the current population food shortages and high levels of malnutrition continue to affect a large number of people in several parts of the country. Therefore, RWH is one option to use runoff in a better way by capturing and storing when rainfall is abundant for periods when water is scarce. So, different sources such as journals, proceedings, thesis works, symposium and annual reports have been reviewed in this paper to emphasize the role of RWH for food security in Ethiopia.
Keywords: Rain water harvesting, Food Security, Poverty, Ethiopia

1. INTRODUCTION

1.1. Background and Justification

Ethiopia, situated in the Horn of Africa, has a population of nearly 90 million and a surface area of 1.2 million square kilometers, of which 65% is suitable for arable farming. Agriculture is the country's largest economic sector, contributing about 43% of the country's GDP and employing more than 85% of the working population.

Production systems are dominated by smallholder farming under rain-fed conditions with little mechanization. Subsistence mixed farming with crop cultivation and livestock husbandry is practiced on most farms. Agriculture is highly dependent on rainfall, and hence the onset, duration, amount and distribution of the rainfall determines the performance of the agriculture sector and the economy of the country in general. More than 95% of the country's agricultural output is generated by subsistence farmers who, on average, own less than 1 ha of cultivated land with poor soil fertility as a result of continuous cropping and little input of nutrients to replace removal with harvest (K. Tesfaye Fantaye, 2015).

Ethiopia is known for its ecological diversity that ranges from tropical to temperate conditions. Altitude ranges from -126 meters below sea level in the Danakil Depression in the northeast to 4620 meters above sea level in the Ras Dashen Mountains in the northwest. In central highland plateaus, where major cereal crops are grown, elevation ranges from 1800 to 3000 meters above sea level with mean annual rainfall ranging from 950-1500 mm and mean annual temperature from 11-21°C. Ecological and socio-cultural diversity creates favorable conditions to support tremendous diversity of fauna and flora such that the country is a center of origin and biodiversity for many cultivated crops and their wild relatives. According to global agro ecological zone classification based on length of growing period (FAO, 2010), the major crop growing areas of the country are found in the sub-humid, humid and moist-semiarid climatic zones. On the other hand, the Ministry of Agriculture and Rural Development (MoARD, 2005) classified the country into 32 major agro-ecological zones and categorized about 51% of the total land area of the country under arid, semi-arid and sub-moist zones and the other half in moist to humid zones. From among 18 major soil types, Nitosols (23%), Cambisols (19%), and Vertisols (18%) comprise more than half the arable land area in the different agro-ecologies of the country (Paulos, 2001; K. Tesfaye Fantaye, 2015).

About 15% of the county's area is currently used for the production of major food crops. Major staple crops include cereals, pulses, oilseeds, roots and tubers, vegetables, fruits and coffee. According to the recent Ethiopian Central Statistical Agency report (CSA, 2013), grain crops (cereals, pulses and oil crops) are cultivated on 13.9 Million Hectare (Mha.) with annual production of 25.1 million metric tons (MMt). According to the same report, cereals, pulses and oil crops constituted 78, 15, and 7% of the cultivated area and 85, 12 and 3% the total grain production of the country, respectively in the main rainy season of 2012/2013. Cereals are the most important field crops and the chief element in the diet of most Ethiopians (K. Tesfaye Fantaye, 2015).

Principal cereals are teff (an indigenous principal staple crop), wheat, barley, maize, sorghum and millet. Wheat is grown mostly between 1,500 and 2,700 meters above sea level whereas maize, sorghum and millet are cultivated at lower elevations in the warmer areas of the country. Sorghum and millet, which are drought resistant, are grown in regions with low and uncertain rainfall. Maize is mainly grown between 1,500 and 2,200 meters above sea level and requires relatively higher seasonal rainfall to ensure good harvests. These major food crops are produced in almost all regions of the country but with large variations in terms of volume of production (K. Tesfaye Fantaye, 2015).

Ethiopia is one of the most famine-prone countries with a long history of famines and food shortages. In Ethiopia, food insecurity among the population is widespread, and most devastatingly, there have been famines that have cost the lives of about a million people. Ethiopia is one of the world's poorest countries with indicators suggesting low levels of development. Many Ethiopians live in conditions of chronic hunger with both a low average daily energy supply (kcal/capita/day) of 1880 and a very high (44%) prevalence of undernourishment (Adnew 2004; Anne van der Veen and Tagel Gebrehiwot, 2011). Frequent droughts are not the only factors contributing to Ethiopia's food security problems. Low agricultural productivity, poverty, food insecurity, and land degradation are pervasive and interconnected problems in the Ethiopian highlands (Holden and Shiferaw, 2004; Anne van der Veen and Tagel Gebrehiwot, 2011). Social factors such as population pressure, traditional farming systems and practices, and economic limitations like poor infrastructural services, shortage of farm land and other productive assets, are also factors responsible for households' food insecurity (Anne van der Veen and Tagel Gebrehiwot, 2011).

Food security is a concept that has evolved over time. According to Hoddinott (1999), there are approximately 200 definitions and 450 indicators of food security. In the mid-1970s, definitions of food security focused on aggregate food supplies at national and global levels, and analysts advocated production self-sufficiency as a strategy for nations to achieve food security. In the 1980s, the focus of food security shifted from global and national levels to household and individual levels. Definitions further underwent another round of evolution after the 1996 World Food Summit (Anne van der Veen and Tagel Gebrehiwot, 2011).

According to the refined definition of United Nations Food and Agriculture Organization (FAO) food security "exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". Poverty encompasses different dimensions of deprivation that relate to human capabilities and is thus closely intertwined with food security (ICID, 2012).

National food security is when there is a satisfactory balance between food demand and food supply at reasonable prices. But this is subject to the influence of the different factors which affect agricultural production, including for example natural phenomena, population increase and market volatility. For households to be assessed as foods secure their food consumption should be greater than their needs as defined by the aggregate of individual requirements. For an individual to be food secure, his or her food consumption should be greater than their needs as defined by physiological requirements and also the earnings, assets and position in the household (FAO, 2014).

Four dimensions of food security can be identified: physical availability of food, economic and physical access to food, food utilization and stability of these other three dimensions over time.

1. Availability of sufficient quantities of food of appropriate qualities, supplied through domestic production or imports (including food aid). Food availability addresses the supply side of food security and is determined by the level of food production, food stock levels and net trade;
2. Accessibility of appropriate foods for a nutritious diet is strongly determined by the level of available resources to acquire those foods. Concerns about insufficient food access have resulted in a greater policy focus on incomes and expenditure in achieving food security. Accessibility brings food security closer to poverty reduction;
3. Food security is also about meeting nutritional requirements. Though it was traditionally perceived as consuming sufficient protein and energy (food quantity), the importance of micro-nutrients for a balanced and nutritious diet (food quality) is now well appreciated. The converse of this is malnutrition, which is the condition that results from taking an unbalanced diet in which certain nutrients are lacking, in excess (too high an intake), or in the wrong proportions;
4. Stability dimension of food security is about maintaining all above conditions at all time and reducing the risk of adverse effects of a shock (e.g. an economic crisis or climatic extreme event) or cyclical events (seasonal food insecurity). Food insecurity appears whenever one of the above mentioned conditions is not met (ICID, 2012).

Drought and environmental degradation are important natural factors that make households vulnerable to food shortage. If the agricultural sector is nearly totally dependent on rainfall and any weather fluctuation or rainfall failure means loss of a major livelihood source that always accentuates food deficit. Von Braun (1991), for example, reported that a 10% decline in rainfall below its long average results in a 4.4% reduction in national food production (Anne van der Veen and Tagel Gebrehiwot, 2011).

Water needs are directly proportional to population growth. Agriculture still accounts for at least 70%of the world's total water usage. Whenever the demand for freshwater increases, a competition among municipal, industrial, and agricultural sectors, often results in a decreased allocation to agriculture and threatens food security. Water harvesting and water conservation techniques have been successful in improving food security in some developing countries through an ecological approach that requires collective action at the local level, as well as the participation of governmental and non-governmental organizations (Rosegrant and Cline, 2003; Komariah and Masateru Senge, 2013). The importance of interdisciplinary and integrated approaches was revealed through detailed impact assessment and economic evaluation of rainwater harvesting studies. It was shown that these approaches have various functions, e.g., water supplementation, flood prevention, water table recharge, and water erosion control (Ouessars et al., 2004; Komariah and Masateru Senge, 2013).

1.2. Statement of the problem

Poor distribution of rainfall due to dry spells together with low nutrient input during critical growth stages lead to low yields or crop failure; hence there is a need for dry spell mitigation by improving water productivity in sub-Saharan Africa (Komariah and Masateru Senge, 2013). As in other sub-Sahara African countries, Ethiopia is one of the most famine-prone countries with a long history of famines and food shortages that can be traced back to 250 BC (Webb and von Braun 1994; Fitsume Y. et al., 2014).

In Ethiopia, food insecurity among the population is widespread. Serious food shortages and high levels of malnutrition continue to affect a large number of people in several parts of Ethiopia. On the other hand the country is known as the Water-tower of North-Eastern Africa for its source of 12 big River Basins including the Blue Nile. The country is currently economically unable to optimally utilize its large rivers for different development purposes in line with national/regional/local interest. The only water resource available is rainfall as a local source and this is why rain water harvesting is extremely necessary.

Even though the country has huge water resources; 12 river basins with an annual runoff volume of 122 billion cubic meter of water with an estimated 2.6 billion m^3 of ground water potential, the effort made so far to exploit these resources is extremely low (Awulachew et al., 2005; Fitsume Y. et al., 2014).

A decline in productivity, a scarcity of arable land, irrigation expansion limitations, erratic rainfall, and frequent dry spells are the challenges faced by small-scale farmers in Ethiopia, hence there should be increased adoption of new rainwater harvesting (RWH) technologies to enhance water productivity for the rain-fed agriculture.

1.3. Objective

The main objective of this work was therefore, to review the different efforts done, achievements obtained and roles played by promotion of rain water harvesting technologies in sustaining agricultural production during the previous decade and to its future roles on food security in Ethiopia.

2. MATERIALS AND METHODS

For the success of this term paper, different sources such as journals, proceedings, thesis works, Symposium and annual reports related to rain water harvesting have been reviewed. The history, definition, classification, components, benefits, roles, policy constraints, previous research results, success and achievements in rain water harvesting have been properly presented. In addition, determinants, causes, status, demographic and socio-economic aspects of food security will be rationally examined and documented.

3. LITERATURE REVIEW

3.1 History of Water Harvesting

Storage of water in small ponds, tanks or cisterns has been practiced widely throughout the world for millennia. Water stored in ponds or tanks is used for a variety of purposes in North Africa since the Roman times. Some of these are reported to be in operation in Tunisia and Egypt (Gharp, 2003; Fitsume Y. et al., 2014). In some of the very earliest agriculture, in the Negev Desert of Israel, water-harvesting systems dating back 4000 years or more have been discovered (Evanari et al., 1971; Fitsume Y. et al., 2014). A growing awareness about the potential of rainwater harvesting for improved crop production was observed in Africa during the 1970s and 1980s when there was a wide spread droughts that resulted in crop failures. A number of rainwater harvesting projects were constructed in sub-Saharan Africa during the past three decades which costed considerable amount of money, time, and efforts. Their objective was to combat the effects of droughts by improving plant production and rehabilitating abandoned and degraded land (Critchley and Reij; 1989 Fitsume Y. et al., 2014).

Rainwater harvesting in Ethiopia has a long history with strong attachment to the ancient Orthodox churches (Habtamu, 1999; Fitsume Y. et al., 2014). Getachew and Habtamu (1999) indicated that the history of rainwater harvesting in Ethiopia date back to pre Axumit period (560 BC) (Fitsume Y. et al., 2014). During this period rainwater was harvested and stored in ponds and tanks for agriculture and water supply purposes. The remains of an ancient roof- water harvesting system is still visible in the oldest palaces in Axum. Other evidences include the remains of one of the old castles in Gondar, constructed in the 15 and16th century and Lalibela Rock hewn churches (over 800 years ago), including a pool that was used to store water used for religious rituals. Rainwater harvesting systems in monasteries like Mahbre Selassie in Gondar and Debrekerbie in Shoa can be mentioned as examples. In south of the country, the Konso people have had a long and well established tradition of building level terraces to harvest rainwater that is used to produce sorghum successfully under extremely harsh environment characterized by low, erratic and unreliable rainfall (Gharp,2003; Fitsume Y. et al., 2014).

In the Ogaden (Eastern Ethiopia), Brikass are used to store rainwater. People in North Omo (Gatto Valley), Eastern Hararghe, and other parts of the country have been practicing the art of conserving soil and water (Habtamu, 1999; Fitsume Y. et al., 2014). The promotion and application of rainwater harvesting systems as an alternative to address water scarcity were started in Ethiopia through government initiatives of soil and water conservation programs in response to the 1971-74 droughts with the introduction of the Food-for–Work (FFW) program. The initial rainwater harvesting activities included construction of ponds, micro dams, micro basins, bunds, and terraces in most parts of the drought affected areas (Kebede, 1995; Fitsume Y. et al., 2014).

3.2 Definition and Classification of Water Harvesting

There are a dozen different terminologies of WH and classifications of WH techniques used at the regional and international levels that have not yet been standardized. The commonly used are listed below:-

- ✓ Water harvesting is "The collection and management of floodwater or rainwater runoff to increase water availability for domestic and agricultural use as well as ecosystem sustenance" (IFAD, 2013). It is the collection of runoff and its use for irrigation of crops, pastures and trees, and for livestock consumption (Finkel and Finkel, 1986; IFAD, 2013).
- ✓ Rainwater harvesting is the collection and concentration of rainfall to make it available for domestic or agricultural uses in dry areas where moisture deficit is the primary limiting factor (Liniger et al., 2011; IFAD, 2013).
- ✓ In-situ rain water harvesting is collecting of the rainfall on the surface where it falls (Lakew Desta, 2006).
- ✓ Ex-situ rain water harvesting is collecting of runoff originating from rainfall over a surface elsewhere (Lakew Desta, 2006).
- ✓ Water can be collected from catchments, rooftops, courtyards and similar compacted or treated surfaces.

Therefore, based on the water source RWH can be classified in to:-

A. Flood water harvesting can be defined as the collection and storage of ephemeral channel flow for irrigation of crops, fodder and trees, and for groundwater recharge (IFAD, 2013).
B. Macro/Micro-catchment RWH is a method of harvesting runoff water from a large/small natural catchment such as the slope of a mountain or hill (IFAD, 2013).
C. Roof top RWH: Harvesting of rainwater can be from roofs of private, public or commercial buildings using different over ground storage structures (IFAD, 2013).
D. Courtyard RWH: Rainwater is collected from compacted, paved surfaces or where plastic sheeting has been laid out ground surfaces using over ground or underground storage structures (IFAD, 2013).

3.3. Components and benefits of rain water harvesting

The important components of the physical design elements for water harvesting are precipitation, soil type, soil characteristics, runoff area ratio, runoff efficiency, and vegetation type (Komariah and Masateru Senge, 2013). The development and selection of a water harvesting technique should consider all available water sources and options for collection, storage, treatment and use, and should take into account the availability of local materials and equipment's. The best choice will also take into account socio-cultural, political, legal, environmental, economic, management and organizational aspects (NWP, 2007; Komariah and Masateru Senge, 2013).

All WH systems must have the following components:-

1. Catchment area/run-off area, varying from a few square meters (micro-catchment) to as large as several square kilo-meters (macro-catchment): the part of the land where a portion or all of the precipitation which falls on it runs off its boundaries. It can be agricultural, rocky or marginal land, or even a rooftop or a paved road.
2. Storage facility: the place where the run-off water is held from the time it occurs until it is utilized by crops, animals, human beings and/or other uses. Storage can be: (i) above the soil surface as in surface reservoirs or ponds; (ii) in the soil profile as soil moisture; and/or (iii) underground in cisterns or as groundwater in aquifers.
3. Target or use: the beneficiary of the stored water. In agricultural production, the target is the plant or the animal, whereas in domestic use, it refers to human beings and their needs (T. Oweis and A. Hachum, 2009).

Water, is probably the strategic entry point, for reducing risk of crop failure due to water scarcity. Improved rain water harvesting may result in improved crop yields, food security and better livelihood among households (Nyamadzawo et al., 2013; Komariah and Masateru Senge, 2013). Water harvesting is a promising technique that is widely accepted throughout the world and is used to cope with water scarcity problems in agricultural production. Micro- and macro-water harvesting techniques are implemented in arid, semi-arid, and tropical regions depending on the purpose and the circumstances. The implementation of a water harvesting system has been shown to have a positive impact on agricultural production by providing irrigation water during critical growing stage of crops, hence increasing the yields. A water harvesting system also helps to reduce runoff velocity and soil erosion, and thus, contributes to groundwater recharge (Komariah and Masateru Senge, 2013).

Besides the increase in agricultural productivity, RWH technologies were also found to bring benefits in enhancing household food security and rising incomes (Mutekwa and Kusangaya, 2006). Specifically, Vohland and Barry (2009) concluded that in-situ rainwater harvesting practices improved hydrological indicators such as infiltration and groundwater recharge, soil nutrients were enriched, biomass production increased, and soil temperatures improved (Li et al., 2000; Komariah and Masateru Senge, 2013).

Rainwater harvesting practices are known to enhance floral diversity, modify the spatial structure of the ecosystem, and increase the animal biodiversity as more biomass becomes available for food and shelter (Rockström et al., 2004; Komariah and Masateru Senge, 2013).

The implementation of RWH increases the irrigation area, which changes more "blue" water into "green" water. This has a positive impact on groundwater recharge but decreases stream flow downstream, therefore increasing the resilience and sustainability of the groundwater system (Glendenning and Vervoort, 2011; Komariah and Masateru Senge, 2013). Water harvesting can be attractive to farmers because it reduces the risk of crop loss from spatial or temporal drought, provides more options by extending the growing season, supplies more " rainfall " to offer a wider selection of crops to grow, and allows "abandoned" land to be cultivated (Tabor, 1995; Komariah and Masateru Senge, 2013).

3.4. Factors for Rain Water Harvesting site selection

Proper implementation including area selection and design could improve the performance of RWH and improve the livelihoods of many poor. The identification of potential areas suitable for RWH is therefore the key for a successful RWH intervention. One of the main reasons for failure of RWH structures is the lack of scientifically verified information which could be used to identify areas where RWH can be applied and for which type of RWH techniques. The potential of areas for RWH depends on a multitude of parameters, either physical factors like rainfall, land use, soil and topography and/or the combination of the physical factors and socio-economic factors (Girma Moges, 2009).

FAO (2003) lists six key factors to be considered when identifying RWH sites: climate (rainfall), hydrology (rainfall–runoff relationship and intermittent watercourses), topography (slope), agronomy (crop characteristics), soils (texture, structure and depth) and socio-economic (population density, work force, people's priority, experience with RWH, land tenure, water laws, accessibility and related costs) aspects. For relatively small areas, the critical factors can be assessed by field surveys. However, for larger areas the application of GIS can be helpful for a first suitability screening with less time, cost and labor (Girma Moges, 2009).

3.5. Determinants and causes of Food Security

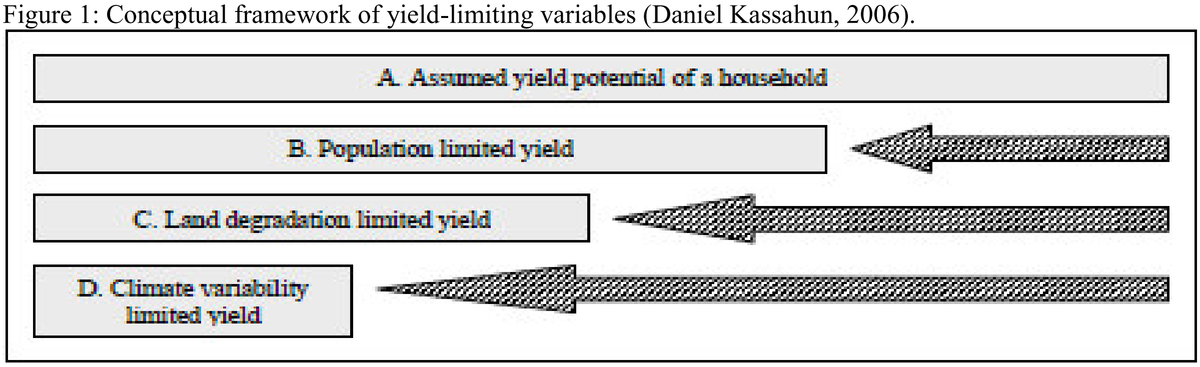
Factors that affect household food security in various developing countries especially in Africa have been documented in some literature and these factors or determinants are most often than not location-specific (i.e. different study areas were found to have variant attributes as food security determinants with some attributes recurring). According to the studies conducted in Ethiopia, ownership of livestock, farmland size, family labor, off farm income, market access, use of improved technology, education, health, amount of rainfall and distribution, crop diseases, number of livestock and family size are identified as major determinants of household food security. Household size and age of the household head have positive and significant effect on household food insecurity; whereas, educational status of the household head, asset possession, credit access and access to employment have negative effect (Birara Endalew, et al. 2015).

The other study conducted in Ethiopia, identified different factors that cause food insecurity. These are: deterioration of food production capacity (due to drought and land degradation), population pressure and instability and armed conflict. Poor soil fertility, land shortage, frost attack, chronic shortage of cash income, poor farming technologies, weak extension services, high labor wastage and poor social and infrastructural situation have caused the problem of food insecurity. Hence, a combination of factors has resulted in serious and growing problem of food insecurity in Ethiopia. These will have cumulative effects on household level food security status (Birara Endalew, et al. 2015).

3.6. Coping and Adaptive Strategies Practiced in Ethiopia

Household's response to food insecurity is classified into two: coping strategies and adaptive strategies. Coping strategies are responses made by households to improve the declining situation of households food security while adaptive strategies involve, a permanent change in the mix of ways in which food is required, irrespective of the year in question and it refer to long term adjustment. The most commonly practiced coping strategies during abnormal season include short term dietary change, changing intra household food distribution like skipping adults to feed children, limiting size and frequency of food, borrowing and gifts from relative and friends, mutual support mechanism, selling of livestock and fire wood, cash for work and relief assistance, etc. while the commonly used adaptive strategies include risk minimization, food and income diversification mechanism, planting damage resistance crop, cultivating marginal soils, etc.…(Birara Endalew, et al. 2015).

Figure 1: Conceptual framework of yield-limiting variables (Daniel Kassahun, 2006).



3.7. Policy Constraints of RWH in Ethiopia

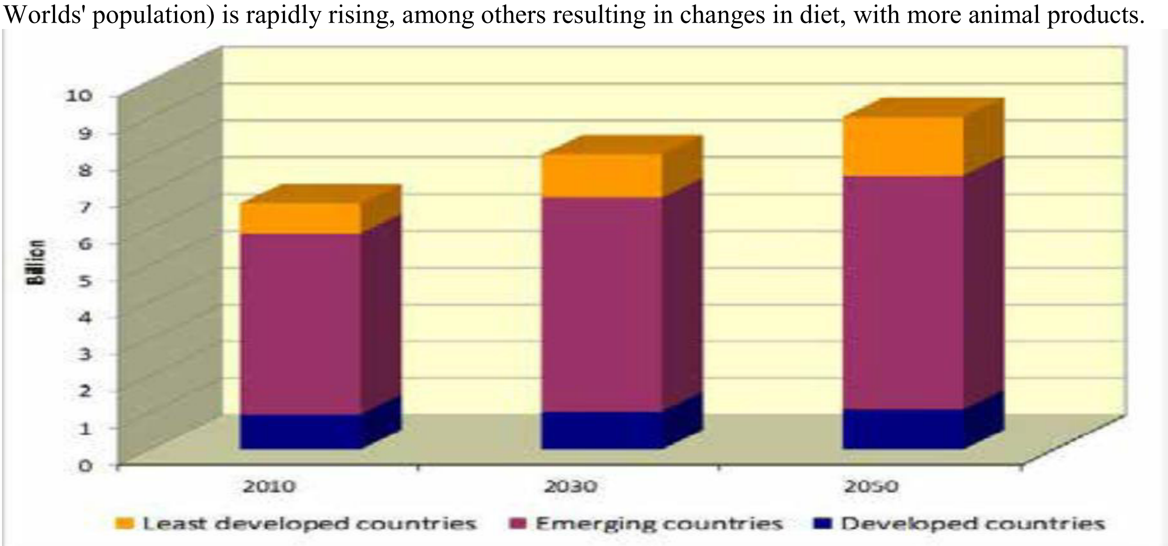
According to the study conducted by Daniel Kassahun (2006) in Central Ethiopia, the following policy issues were found critical to affect the success of RWH :-

3.7.1. **Poor Targeting:** While RWH was primarily targeted to address the poorest of the poor, but the findings of the research was quite the opposite. It was those who are better informed and those who have better resources who grabbed the advantages of RWH.

3.7.2. **Biases in Approaches:** Most RWH practices in Ethiopia have biased towards semi-arid areas. This is due to the misconception that RWH could turn arid and semi-arid into agricultural lands. However, humid areas, which receive "adequate" annual rainfall, suffer significantly from crop failure due to the erratic nature of rainfall. The other RWH bias is the higher propensity to utilize RWH for horticultural than cereal crops.
3.7.3. **Disoriented Subsidy Policy:** Currently, the Ethiopian government has decided to withdraw its financial and material support for the expansion of RWH ponds. On the contrary, soil and water conservation activities are still heavily subsidized, which might be due to the long term economic and environmental return. During the group discussion at Bati district, several farmers challenged the decision of the government, through the question "which comes first: rehabilitation of degraded land or ensuring food production through expansion of ponds"? Farmers argue that the government should continue to support RWH making.
3.7.4. **Poor Linkages:** RWH is a crosscutting issue and various forms of linkages, i.e., institutional, professional, and the like are mandatory. It stipulates the active engagement of professionals such as civil engineers, agronomist's, health practitioners, crop protectionists, economists, environmentalists, etc. Likewise, the strong linkage within sectors of the government (e.g., Agriculture, Water Resources, Health, etc.) and cooperation with NGOs and research institutions is imperative. However, those linkages were absent in the survey areas. Currently, RWH is new to many farmers of the survey areas where the available micro-credit services have not been tuned to the expansion of RWH. Hune (2004), too, noted that the availability of credit facilities for RWH in Ethiopia has been limited (Daniel, 2006).
3.7.5. **Inadequate Knowledge Base:** Before the launching of RWH, prior experiment was conducted in the Nazareth area, which is characterized by erratic rainfall, sandy soil, deep water table, etc. The technology generated from this area was diffused to the rest of the country. The approach followed was "one size fits all". There have been two practical limitations. First, the area selected for experimentation was not representative enough for the diversified nature of the whole country including the study area. The second limitation was that the generated knowledge was mainly engineering (mainly structural) and cost-benefit analysis. Information on water lifting, irrigation scheduling, irrigation amount, crop protection, storage systems of crops, the maintenance of ponds, etc., were not addressed.

3.8. State of Food Insecurity in the World

The Worlds' population is expected to grow from 7 billion in 2012 to 9 billion by 2050. This growth is especially expected in the urban areas of the emerging and least developed countries, while no growth is expected anymore in the developed countries. In addition the standard of living in the emerging countries (almost 75% of the Worlds' population) is rapidly rising, among others resulting in changes in diet, with more animal products.



Graph1. Population and population growth in the least developed, emerging and developed countries (data UNDP Population Reference Bureau, 2015).

The World population growth combined with the expected rise of living standards will require a substantial increase of cereal production to ensure sustainable food security. Various organizations estimate that a 70 - 100% increase in cereal production is required over the next 25 - 30 years. At present 55% of the food comes from areas with a form of water management and 45% from the areas without any (only rain-fed) water management system. At the cultivated area of about 1,500 million hectares most of the cultivation takes place under rain-fed conditions without any water management system (i.e. 1,100 million ha) (ICID, 2012)

The global food challenge is huge and it will be a challenge to feed the additional 3 billion people by 2050(Conway 1997). About 95% of this population growth will occur in developing countries and this is a developmental challenge as most of their economies are agricultural based. The majority or two thirds of the poorest people in the world are found among the 1.1 billion farmers who make their living from agriculture (Rockström 2002; G. Nyamadzawo et al., 2013). For reference, the Food and Agriculture Organization has estimated that in 2006, the number of people undernourished globally was 820 million. In order to feed the larger, more urban and partially richer population, it is estimated that in the forthcoming 25 - 30 years food production (net of food used for bio-fuels) would have to increase by 70 - 110% at global level and at least double in the emerging and least developed countries (ICID, 2012).

Agricultural production is sensitive to a range of influencing factors. Among these factors are developments in the sector, introduction of innovations in practice, market fluctuations, production conditions, flooding and in case of rain-fed agriculture inter-annual variability of climate, especially the occurrence of drought and environmental degradation. Given the wide range in the projections of changes in climate and a possible increase in climate variability, increases in the frequency, severity, or duration of extreme climatic events and environmental shifts may have significant impacts on the production of rain-fed food crops (ICID, 2012).

Droughts have been occurring more frequently because of global warming and they are expected to become more frequent and intense in Africa, southern Europe, the Middle East, most of the Americas, Australia, and Southeast Asia. Their impacts are aggravated because of increased water demand, population growth, urban expansion, and environmental protection efforts in many areas. Droughts result in crop failures and the loss of pasture grazing land for livestock (Ding Y. et al., 2011)

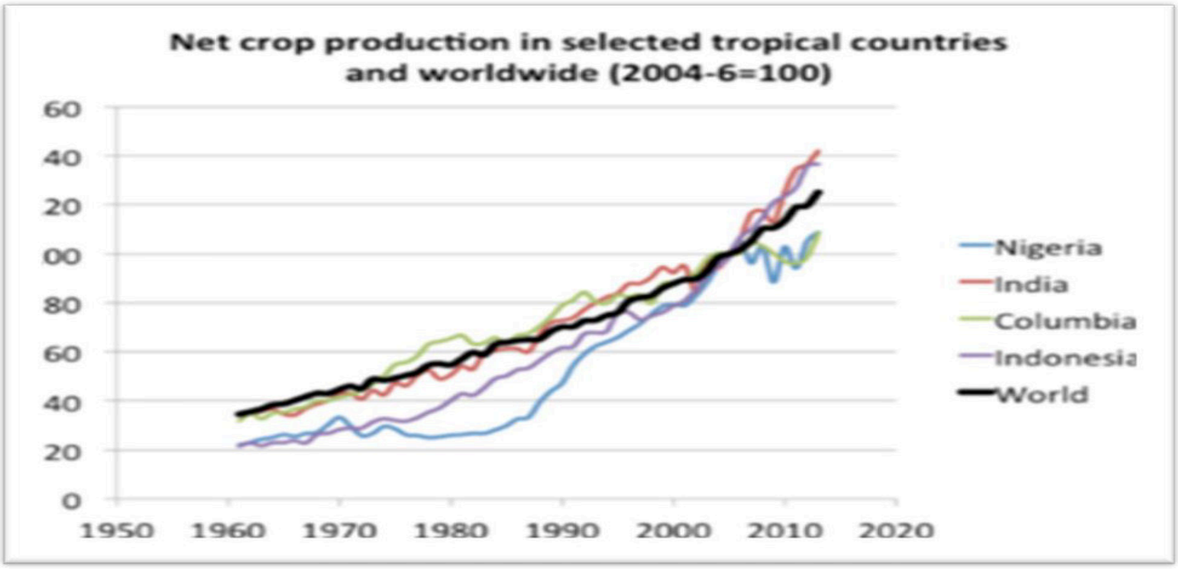
For instance, Evan Fraser has conducted a number of studies which show that the socio-economic context of farming may play a huge role in determining whether a drought has a major, or an insignificant impact on crop production. In some cases, it seems that even minor droughts have big impacts on food security such as what happened in Ethiopia in the early 1980s where a minor drought triggered a massive famine (Fraser, E. et al., 2008).

Rainfall does not infiltrate properly due to a combination of human-induced land degradation and high-intensity rainfall events. In addition, most of the rainfall received in semi-arid regions is lost as runoff, and very little water is harvested for plant growth or future use. In general, water harvesting has its largest potential in semi-arid to dry sub-humid regions where crop water requirement is higher than supply due to low annual rainfall, high evapotranspiration, uneven seasonal distribution and/or rainfall variability. In these regions, the result of rainfall scarcity and/or high spatial and temporal variability is a high risk for annual droughts and inter-seasonal dry spells. In sub-Sahara Africa, it has been estimated that 44% of the land surface is subject to high risk of meteorological drought (SIWI, 2001).

Currently, of the 1.5 billion hectares of cropland worldwide, more than 80 percent depend on rainfall alone, contributing to at least two-thirds of global food production (FAOSTAT, 2005). While the coverage of rain-fed agriculture varies regionally, in developing regions including Latin America and Sub-Saharan Africa more than 90 percent of cropland is rain-fed. But recent global precipitation patterns have been changed due to climate change and will likely continue to do so, and rainwater harvesting systems have been regarded as an important measure in climate change adaptation strategies (Komariah and Masateru Senge, 2013).

Table1. Approximate percent of cropland that is rain-fed (FAOSTAT, 2005)

Region	%
Latin America	90
Middle East and North Africa	75
East Asia	65
South Asia	60
Sub-Saharan Africa	95



Graph 2.Net crop production worldwide and in selected tropical countries. Raw data from the United Nations (Wikipedia, 2015)

3.9. Status of Food security in Ethiopia

Ethiopia is generally characterized by extreme poverty, a high population growth rate, severe environmental degradation and recurrent drought. As a result, agriculture, from which 85% of the country's population derives its livelihood, has performed so poorly over the last few decades that the country cannot adequately feed its population from domestic production alone. This has manifested in both chronic and transitory food insecurity, which have almost become a structural phenomenon and the way of life for a significant percentage of the population (Messay Mulugeta, 2009).

In the last three decades food production in Ethiopia has been insufficient to render the population food secure. For example, the food gap rose from 0.75 million tons in 1979/80 to 5 million tons in 1993/94, falling to 2.6 million tons in 1995/96 despite a record harvest. This clearly shows that over the last 20 years this cycle of food insecurity has repeated itself, and each time the number of people affected gets larger, and the resulting amount of human suffering and disease increases. (Mihret Jember and Tesfahun Asmamaw, 2014)

Drought and famine have become an everyday reality in Ethiopia. The country has faced three major famines and numerous famine-like situations in the past three decades. The recurrent of famine in 1970s, 80s and 90s has affected significantly the country's food production. During the period between 1958 and 1977 over 25 million people were directly affected by famine and drought. The number of death was estimated between three and five million people. The 1984/85 famine alone had taken the lives of 300,000 people. It was estimated that close to 58 million were affected by famine between 1973 and 1986 (Berhanu Gutema, 2001).

The percentage of people in rural areas who are unable to attain a minimum nutritional requirement is estimated at 52%, and the prevalence of child malnutrition is very high. Perhaps the greatest challenge that the country faces is that of ensuring food security. Serious food shortages and high levels of malnutrition continue to affect a large number of people in several parts of Ethiopia. Many Ethiopians live in conditions of chronic hunger, with a low average daily energy supply and a very high prevalence of malnutrition, estimated at about 44% of the total population (Mihret Jember and Tesfahun Asmamaw, 2014).

Majority of the Ethiopian rural population has been chronically suffering from mass poverty in more severe situations than the urban dwellers. Under-nourishment and malnutrition are common in rural Ethiopia and very large proportion of the peasants lives under absolute poverty. Moreover, landlessness, lack of means of production, and large family size (majority of which are dependent) are the major characteristics of the Ethiopian peasants at present (Messay Mulugeta, 2009)

Patterns of food consumption and dietary level in Ethiopia vary from place to place. Cereals such as maize, teff (only grown in Ethiopia), barley, sorghum, wheat and millet are the main food source in most part of the country. Nevertheless, the per capita consumption of cereals has shown a down ward trend since 1960s, for instance in 1966 the per capita consumption was estimated to be 138.4 kg., whereas in 1984 the figure had fallen to 94.5 kg. This figure is 50 percent less than the normal consumption ratio. The consumption level of a large segment of the population is less than the average estimates and this depicts the prevalence of hunger among many millions of people (Berhanu Gutema, 2001).

The Government of Ethiopia/UN Framework Convention on Climate Change (UNFCCC) NAPA process identified arid, semi-arid and dry sub-humid areas of the country as being most vulnerable to drought. Agriculture was identified as the most vulnerable sector and, in terms of livelihoods, small-scale rain-fed subsistence farmers and pastoralist were identified as the most affected. The NAPA process has identified and prioritized 11project areas that address the immediate climate change adaptation needs in the country, focusing on: human and institutional capacity building; improving natural resource management; enhancing irrigation agriculture and water harvesting; strengthening early warning systems and awareness raising (Eva Ludi, 2009).

Food insecurity is a structural problem in many parts of rural Ethiopia. 32% of Ethiopians suffered from malnutrition in 2015; and as late as 2014 Ethiopians' daily food calorie intake stood at 2,100, below the standard 2,200 required to sustain life, according to FAO statistics. The root cause of the problem cannot, therefore, be addressed by short term crisis response measures. It requires moving beyond the immediate triggers such as extreme weather events (drought and erratic rainfall) into the underlying causal factors (Urgessa Tura, 2015).

Experts, who extensively studied Ethiopia's food policy, observed that 'Ethiopia is the world's most food aid dependent country', and since the 1980s it had annually received between 200,000 to 1.2 million metric tons. In 2016 alone, it is estimated that Ethiopia needs two million metric tons of food aid to feed its starving people. Thus, maximizing food aid has become a standard policy response for food emergency situation in the country. However, this is a very dangerous approach as it distracts the government from addressing structural problems that perpetuate this vicious cycle of food insecurity in the first place (Urgessa Tura, 2015).

These days, early warning systems alert the government when famine threatens, and in 2015, these kicked into action after the spring and summer rains failed, leaving herders trapped in desert pastures and farmers with extensive crop failures across the north and east of the country (USGS, 2016).

A climate disaster linked to a major “El Nino” weather pattern is moving across much of Africa. Ethiopia is the hardest hit with an estimated 10.2 million people needing food because of crop failure. The World Health Organization estimates “400,000 Ethiopian children will face severe malnutrition in 2016”. The typical summer rains were severely affected this year, which has resulted in the worst drought the country has seen in decades. This came immediately after failed spring rains, which has resulted in mass food insecurity and malnutrition in impacted regions across the country. In addition to the wide-spread food crisis, water wells are drying up and schools are starting to close in the worst-affected areas. Children are missing out on education, and mothers are forced to walk for hours to find water (ERDO, 2016).

At first, some in the Ethiopian government claimed the country could handle the drought itself. But as the numbers of needy increases skyrocketed, authorities issued an appeal. In December, they said about 10.2 million people were in need of $1.4 billion in aid, with 400,000 children severely malnourished. This is in addition to 8 million people supported by the government safety net even before the drought. To date, 46 percent of the appeal has been met, and the worst could be yet to come (USGS, 2016).

4. RESULTS AND DISCUSSION

4.1. Previous Research Results

Analysts have used several techniques to evaluate the economics of water harvesting. The simplest approach is to compare the yields of a particular crop obtained using water harvesting and traditional cultivation practices under the same set of experimental conditions typically applying the same type and quantity of fertilizer to similar soil conditions. Tabor (1994) conducted one such study for millet and sorghum. In this study yields for both millet and sorghum under water harvesting increased as compared to traditional cultivation, but the increase in yield depended on whether it is a dry or wet year (Rodney B.W. Smith et al., 2011).

Several studies improved upon this analysis and compared the yields of a given crop under four different scenarios: traditional practices, water harvesting only, fertilizer use only, and a combination of water harvesting and fertilizer use. These studies examined maize (Barron and Okwach, 2005; Rodney B.W. Smith et al., 2011) and sorghum (Fox and Röckstrom, 2003; Rodney B.W. Smith et al., 2011) production under the above scenarios. The general finding was that water harvesting alone can boost yields, but the greatest increase in yields occurs when water harvesting is combined with fertilizer use. As with Tabor (1994), these increases depend on the total rainfall realized during the growing season. The exception to these results is Carsky et al (1995), who find that water harvesting alone boosts yields more than when combined with fertilizer use. Finally, Zougmoré et al (2004) compared sorghum yields from two separate water harvesting techniques under three scenarios: water harvesting without fertilizer use, fertilizer use without water harvesting, and the combinations of water harvesting and fertilizer use. They concluded the combination of water harvesting and fertilizer use increases water use efficiency and increases yield (Rodney B.W. Smith et al., 2011).

The research conducted to estimates a quadratic production technology for millet and white sorghum mono-crops, and a directional output distance function for joint production of white sorghum and cowpea, with water harvesting use as an input in Burkina Faso indicates that in millet mono-cropping and white sorghum mono-cropping, water harvesting typically increases yields by at least forty percent. Water harvesting also has a positive effect on sorghum and cowpea multi-cropping. These results provide useful insight on the economic benefits of water harvesting, and on the potential of water harvesting as a poverty reduction strategy throughout sub-Saharan Africa (Rodney B.W. Smith et al., 2011).

Macro and micro-catchment rainwater harvesting systems have shown a variable but positive impact on soil moisture regimes and crop yields (Walker et al., 2005; Mupangwa et al., 2006; Komariah and Masateru Senge, 2013). Li and Gong (2002) and Tian et al. (2003) found that micro-water harvesting of ridges and furrows with plastic mulch increased the tuber yield of potatoes by 158 -175% for two years (Wang et al., 2008), and the corn yield by 1.9 times (Li et al., 2000) because of the higher water use efficiency (WUE) (Li et al, 2004; Komariah and Masateru Senge, 2013).

Aftab et al. (2012) concluded that rainwater harvesting systems were shown to be a relatively low-cost option for temporal access to a water source. RWH minimizes some of the problems associated with irrigation, such as the competition for water between various uses and users, low water use efficiency, and environmental degradation. RWH is a simple, cheap, and environmentally friendly technology that can easily be managed with limited technical skill (Ngigi, 2003; Komariah and Masateru Senge, 2013). Supplemental irrigation during dry spells with micro-catchment rainwater harvesting could improve the soil water content of the rooting zone by up to 30% (Biazin et al., 2012; Komariah and Masateru Senge, 2013). Harvested water from a small pond increased sorghum harvests by 41%, and when combined with added fertilization, by 180% (Fox and Rockström, 2000; Komariah and Masateru Senge, 2013).

Experimental plots by Abu-Zreig and Tamimi (2011) of in-situ rain water harvesting with a sand-ditch proved that runoff and sediment loss were significantly reduced, by 46% and 60%, respectively, and infiltration and soil moisture were increased. Rainwater harvesting techniques such as jessr or jessour in Tunisia and the Middle East decreased the amount and velocity of the runoff and consequently reduced soil erosion, and ameliorated the soil water storage capacity and soil fertility (Schiettecatte et al., 2005; Komariah and Masateru Senge, 2013).

The study conducted in urban and rural areas of Amhara regional state of Ethiopia by Mesfin Welderufael (2014) showed that about 48 % of the households were not able to meet the daily recommended caloric requirement and the percentage of food consumption needed to bring the entire food insecure population to the food poverty line is 18percent while 8.7% sample households were most food insecurity households groups in the study area. Further, the descriptive statistics shows that there was evidence of location and rural households were likely to suffer more insecurity than urban households (Mesfin Welderufael, 2014).

4.2. Water Harvesting Achievements in Ethiopia

The ministry of water resources (MOWR, 2002) reported that about 67% of the country's landmass was categorized as arid and semi-arid which are characterized by acute water shortage because of erratic rainfall distribution and resulting in recurrent drought and famine. Excluding the purely pastoralist areas, more than 90 Districts/woredas with a total of more than 2 million households in the country are drought prone and regularly hit by severe water shortages. This seriously threatens the lives of more than 12 million people (Hugo, 2003; Fitsume Y. et al., 2014). The major factors contributing to the current food insecurity include widening gap between the level of food production and the rapid population growth, degradation of natural resource base and dominance of cereal based farming system which is exclusively dependent on the erratic and unreliable rain fall (Fitsume Y. et al., 2014).

Rain water harvesting during the surplus periods for use during the critical periods has become a feasible strategy in different parts of the world. This is to bridge dry spells through supplemental irrigation of rain fed crops in smallholder farming systems to improve the lives of rural people at low cost and with minimal outside inputs. This could be achieved with water harvesting system, which involves collecting runoff in small storage structures. Water harvesting can reduce the risk of crop failure by facilitating early planting which allows the maximum use of the rainfall, thereby insuring the crop against rainfall irregularities. Efficient collection and storage of rainwater is critical in food insecure areas with increasing pressure on land. Capturing of more runoff from rainfall and the efficient storage and use of the water has become the component of the national strategy in combating drought and famine (OFS, 2002; Fitsume Y. et al, 2014).

Intensive and high amount of rainfall during the wet season in the highlands is the major cause of degradation particularly soil erosion. The rain/runoff washes down the nutrient rich soil, seed and applied fertilizer. Big gullies are acting as permanent drainage ditches thus depleting soil moisture regime. During the dry season water is a major constraint in many parts of the country and women, children and livestock have to travel distant places to get it. In this respect it is like that a blessing is changed into curse. Peak hydrograph during wet season and absence of any flow over dry seasons, high rainfall variability of unreliability that results in significant runoff variability, erosion and sedimentation problem jeopardizes availability of water. This needs to be changed through effective watershed treatment and various RWH interventions (Lakew Desta, 2006).

In the country's Agriculture development led industrialization (ADLI) policy and food security programs water is considered as one of the three pillars (land, labor and water) for development. Although the total surface and groundwater potential of the country is estimated at more than 120 billion cubic meter, there is a serious problem in terms of access. Out of the total 4.25million hectare irrigation potential it is only 247,500ha (5.8%) that is developed in small, medium and large-scale irrigation programs. Of this developed 55% is traditional. Oromiya region comprises the highest irrigation potential, which is 32% of the country. To harness the available potential effectively financial, physical and human capitals are not adequately available. Obviously there are a number of physical, technical and socio-economic problems (Lakew Desta, 2006).

The government of Ethiopia has recently formulated the Water Policy of the country. Basin wide integrated master plan studies which envisage development activities over the coming 30 to 50 years have been undertaken for most of the major rivers. Other option to increase water productivity at production system was also proposed as a main pillar in the national food security strategy (FDRE, 2012; Fitsume Y. et al., 2014).

At the national level, the planned target in the water sector particularly through household level water harvesting, micro and small irrigation is 400,000 ha in each of the short term (2002-2006), medium term (2007-2012) and long term (2013- 2016) planning phases (EIAR, OARI, OIDA and JICA, 2006).

In Amhara region (North western part of the country) from the total completed water harvesting structures, reaching 242,000 in number, over 42,000 have started production. And as a result 21,194 ha of land is under irrigation and 148, 244 farm households are benefiting. Of these 14% (21,194) are women headed households. Irrigated area in the region is primarily aggregated from shallow well, river diversion and spring development. (Lakew Desta, 2006)

Total irrigated land with water harvesting in Oromiya region (central eastern and western part of the country) is 65,508ha, when the plan was 68,565ha (95.5% achievement). By this 343,953 (92%) households have become beneficiaries. Again 379 hectares traditional irrigation through river diversion is under establishment on top of 31,311ha that already exists. Of the total planned 216,290 pond 75% is in food insecure Districts and the remaining 25% is in non-food insecure Districts. The stored water apart from drinking and crop production farmers have used it by selling, making mud for house construction, making soil blocks and raising seedlings at the nursery(Lakew Desta, 2006).

Table 2: Summary of achievements of four regions in 2003/2004 physical year (Lakew Desta)

No	Type of technologies	Achievements	Beneficiary Households	Estimated area of land
1	Shallow wells (hand dug wells) construction	308,338	308,338	18,500
2	Shallow wells improvement	850	850	51
3	HH trapezoidal surface ponds	205,787	205,787	6,173.61
4	Cisterns/tanks	5,632	5,632	168.96
5	Cisterns improvement	877	877	26.31
6	Community ponds	49,311	-	-
7	Spring development	32,727	-	-
8	River diversion in ha^2	37,020	148,080	37,020
9	Runoff diversion in ha	31,386	62,772	31,386
Total			732,336	93,326

So far within the country 732,336 schemes reaching 93,236 households means 3.7 million people will benefit assuming 5 members per household. Therefore, this is believed to contribute to household food security. Along with the storage facilities low cost water lifting and family drip equipment's/systems have been and are being promoted. This includes treadle pumps, watering cans, family drip kits and tie-ridges. However, the amount required with respect to the number of schemes is far below the requirement. Hand lifting and watering using cans to the root of each plant is time and labor consuming too many farmers (Lakew Desta, 2006).

Historically Haffir dam in Somali region was introduced from Sudan through UNHCR in the refugee camps of Aware. As of its original design it was meant to collect water only for human consumption. However, Hope for the Horn a local NGO closely working with pastoralists had been continuing to modify the technology by accommodating some of the feedbacks of the pastoralists. The Haffir dams made by machinery were to serve both livestock and human beings. The main dam and the silt trap were supplemented with outlet canal attached to two shallow wells where water is pumped to the elevated distribution cistern and further through gravity distributed to the livestock troughs and human collection points (Yohannes G/M., 2015).

The cost of constructing an average Haffir dam with a capacity of 60,000 cubic meters of water accounts about 1.4 million Ethiopian Birr (one dollar is about 8.5 Birr). It is assume such volume of water is sufficient to supply up to 20,000 people and their animals for four or three months. As a system, the Haffir dam is integrated with environmental rehabilitation where the command area is closed, afforested and complemented by site specific soil and water conservation techniques like micro basins, soil bunds and check dams were applied (Yohannes G/M., 2015).

Therefore, the biological and physical measures were facilitating as a silt trap and fodder banking. The check dams were made from the locally available materials of dead branches and living trees. The nurseries were also producing dominantly indigenous multi-purpose trees (fodder, fruit and medicinal values) and few fast growing exotic pants were also introduced to the system. The water and environmental committees which consists elders, women and youth are established on the onset of the Dam construction (Yohannes G/M., 2015).

Currently there are a total of 17 Haffir dams constructed across the 400 kms, with an average distance of 60 kms from each other. These dams which serve as a blue (water) and green (fodder) belts cover the five districts of Gashamo (5 Haffir dams), Aware (5 Haffir dams), Harshen (3 Haffir dams), Kebrebehyah (3 Haffir dams) and Jigiga (1 Haffir dam). The spatial distribution of the blue and green belts is based on the consideration of different factors, such as the distribution of other sources of water (natural, traditional and Birkas), clan and sub-clan distribution, mobility patterns and reciprocity among the clans with territorial fluidity (Yohannes G/M., 2015).

The water harvesting system is only economically viable if it is combined with improved soil fertility management (Fox et al., 2005). The combination of micro-catchment with agroforestry, known as the run-off agroforestry system, provided sufficient water to grow both woody and herbaceous plants for the supply of fodder in Ethiopia (Abdelkadir and Schultz, 2005; Komariah and Masateru Senge, 2013).

4.3. Constraints encountered during rain water harvesting

Water in an agricultural production system can be lost due to evaporation from the soil surface, surface runoff (which simultaneously causes erosion) and through deep percolation / drainage, which sometimes can be later recovered for irrigation elsewhere (IFAD, 2013)

The micro-water harvesting system requires a large area to collect water, and thus, its construction requires more labor. The plastic used to mulch the ridges also poses environmental problems; therefore biodegradable plastic film should be used (Wang et al., 2008; Komariah and Masateru Senge, 2013). Ngigi (2003) stated that the impacts of a RWH system in Ethiopia, Kenya, Tanzania, and Uganda were still marginal because the adoption rate is low in spite of the success of a number of RWH systems (Rockström et al., 2001; Glendening and Vervoort, 2010; Komariah and Masateru Senge, 2013).

With some variation among regions, soil storage and watershed treatment aspects of RWH are missing primarily due to capacity reasons. Hand lifting and watering by cans is time and labor consuming resulting in wastage of stored water. High seepage and evaporation losses (estimate of 24 and 6liters/day.m2, respectively), high sediment in the ponds, losing productive land to surface ponds, cost versus benefit for cisterns being of excessive payback period, technical capacity limitation at the grass-root level during implementation and insufficient extension follow up on already established schemes, concern on malaria and inadequate local market in view of the targeted high value horticultural crops are to be mentioned (Lakew Desta, 2006).

4.4. The role of rain water harvesting for food security in Ethiopia

With more than 90 million people, Ethiopia is the second most populous country in sub-Saharan Africa and has one of the fastest-growing economies in the world. The foundation of its economic growth is agriculture, which employs 80 percent of the population. Ethiopia could potentially reach middle-income status by 2025 with an emphasis on boosting domestic saving rates, private sector development and improving the trade logistics, according to the World Bank. In recent years, Ethiopia has made development strides despite the regular cycle of droughts in parts of the country. The number of emergency beneficiaries has dropped from 15 million in 2003 to 5.6 million due to the support of international donors and the government of Ethiopia's national food safety net. Emergency preparedness and response have improved substantially with the assistance of USAID (Care USA, 2014).

According to UN officials, Ethiopia is among the nine countries of Africa which possess great potential for RWH. It is estimated that the country could meet the needs of six to seven times its current population, that is, equivalent to 520 million people (Daniel, 2007). The application of water harvesting technique however, although potentially high, is still low in Ethiopia (Aziz Shikur and Tesfaye Beshah, 2013).

In Ethiopia, there are four major categories of productive use of water in agriculture:-

(1)For 'rain-fed agriculture',
(2) For 'supplementary irrigation',
(3)For 'irrigated agriculture', and
(4) For 'livestock production'; but rain-fed agriculture is relatively the major one.

In most sample households, the agricultural produce suffices for a maximum of nine month consumption. The remaining months would fall short. This is the period in which most Ethiopian farmers adapt different coping strategies, such as cutting trees for charcoal making, selling livestock, off farm activity in nearby urban centers, etc. One of the great merits of RWH-based agriculture is therefore to fill the food gap in such critical periods, especially through vegetables production (Daniel Kassahun, 2006).

Research reports (Hussien and Hanjra, 2003) have confirmed that RWH directly boosts yields and gives farmers the 'water security'. This implies that RWH users could be engaged in enhancing productivity inputs (Daniel Kassahun, 2006).

Also, according to agriculture sector review undertaken in Ethiopia to tackle the problem of food insecurity and rural livelihoods it is recommended that investment need to be made on rainwater harvesting. To insure food availability water centered development is required (Lakew Desta, 2006).

More than 214 Districts of the country are said to be food insecure. The major factors contributing to the current food insecurity include widening gap between the level of food production and the rapid population growth, degradation of natural resource base and dominance of cereal based farming system which is exclusively dependent on the erratic and unreliable rain fall (Fitsume Y. et al, 2014).

On average to produce one kilogram of marketable crop (grain) 1000 - 3000 liter of water is required (Isaya, V.S., 2001; Lakew Desta, 2006). Of course, rainwater harvesting should be promoted where irrigation is not a viable option. For crop production rain water harvesting has two purposes in Ethiopia; first to raise horticultural and short duration crops during the dry period and to provide water as supplementary irrigation whenever there is a shortfall in wet seasons, especially to the time of maturity (Lakew Desta, 2006).

According to reports of UN officials, Ethiopia is among the nine countries of Africa which possesses great potential for RWH. It is estimated that the country could feed 520 million people through RWH. Though the technology dates back to the Axumite period (560 BC) (Fattovich 1990), it was only after 2003 that the Ethiopian government recognized its importance and promoted it on on-farm rainwater ponds. From a total of ten regional states of the country, close to one million RWH ponds were constructed in four major regional states. Almost all RWH Users utilized their pond water for horticultural crops. However, multiple functions of RWH were observed in the study areas, i.e., for domestic purposes, beef fattening ,tree nursery, selling domestic water, cultivation of chat, and bee-hiving (Daniel Kassahun, 2006).

Daniel Kassahun (2006) stated that currently, a shift of land use type, from cereals to horticulture, is taking place in the study area (Amhara and Oromia Regional States). One factor could be due to the fact that cereal farms are located at far away distances from residential units and ponds. The other factor could be due to the intensive labor requirement for cereal crop irrigation. Between 2003 and 2005, about 20,000 ha of land were irrigated from RWH ponds. By resolving the biophysical, socioeconomic and policy constraints, it is safe to conclude that the situation of millions of poor farmers could be improved through RWH, via the reduction of vulnerability to crop failure, malnutrition and seasonal food deficits (Daniel Kassahun, 2006).

Yihun Taddele et al, (2013) based on their research results conclude that, there is evidence that water harvesting practices can fulfill the criteria for sustainable intensification by
1) Improving water availability for dry spell and drought proofing,
(2) Improving agricultural yield for food security,
(3) Rehabilitating degraded lands to restore biodiversity,
(4) Minimizing use of external inputs that has adverse effects on the environment,
(5) Sequestering carbon in terrestrial landscape to mitigate climate change, and
(6) Reducing downstream riverine pollution from release of nutrients from upstream agricultural lands, and thereby strengthens the specific resilience of the social–ecological system.

Water harvesting is a promising technique that is widely accepted throughout the world and is used to cope with water scarcity problems in agricultural production. Micro- and macro water harvesting techniques are implemented in arid, semiarid, and tropical regions depending on the purpose and the circumstances. The implementation of a water harvesting system has been shown to have a positive impact on agricultural production by providing irrigation water during critical growing stage of crops, hence increasing the yields. A water harvesting system also helps to reduce runoff velocity and soil erosion, and thus, contributes to groundwater recharge. However, poor design, poor management, and poor communication between designers, the government, and farmers can lead to the failure of a water harvesting system. The potential of a rainwater harvesting system to sustain agricultural production should be supported by other technologies, specifically Information Technology (IT). Soil and nutrient management, as well as a consideration of the farmers' social and economic condition during implementation, can be used to ascertain the success of the water harvesting system in improving local agricultural production (Komariah and Masateru Senge, 2013).

Small irrigation systems with gravity or lift canals using rain water harvesting techniques result in beneficial use of runoff. Micro schemes can be very small (lift or gravity type) feeding areas of less than 50-100 ha. Since runoff erratically occurs in semiarid and arid areas and for a limited period, storage becomes essential in most cases. The structures have to be designed and constructed using sound engineering principles and practices. It should, however, be emphasized that micro or small schemes should be designed within a drainage basin approach and should form part of comprehensive watershed planning (Alemayehu Mengistie; 1997).

5. Summary, Conclusion and Future Prospects

Several factors were identified by different studies for the deteriorating situation of food security in Ethiopia. These are population pressure, drought, shortage of farmland, soil erosion, deterioration of crop production capacity, outbreak of plant and animal diseases, poor soil fertility, frost attack, poor farming technologies, weak extension services, high labor wastage and poor social and infrastructural facility and pre and post-harvest crop loss. To cope the problem, the households should respond to the problem of food insecurity through soil and water conservation, agricultural employment, afforestation, small scale trading, institutional and societal saving and credit systems, limiting family size and through rain water harvesting.

To improve food security situation in Ethiopia, the following action should be taken. The household head and members of the household should engage in different income generating activities for means of living, coping mechanism and to escape from hunger and under-nourishment; the government of Ethiopia should incorporate different research outputs to design programs for food insecurity intervention; the farmers should develop soil conservation measures to reduce soil erosion and the habit of using rain water harvesting to alleviate problems caused by shortage of rain fall and irrigation scheme will be the crucial activities.

Rain water harvesting can have an important role in achieving the food security of Ethiopia. It helps as a bridge at the dry times between the rainy season to the benefit of human and livestock consumption and for crop production through irrigation. So aspects of catchment/watershed treatment, seepage and evaporation control, soil and water conservation, conservation tillage, and integration of low cost water lifting techniques and family drip systems are also should be applied for the success of efficient rain water harvesting.

The design, type of technology, inputs, size and cost are also factors contributing to success and failure of rain water harvesting schemes. So the implementation of different types of technologies should consider the geology and the geography of the target areas. The most important problem, seepage has to be resolved with low cost and effective lining materials that convince the user's economy and satisfy environmental requirements. In addition the research system has to take part in further improvement of the rain water harvesting technologies. In addition, there should be a follow up on already established rain water harvesting schemes and their maintenance should be planned and targeted each year.

Since Ethiopia has huge water resources, i.e. 12 river basins with an annual run-off volume of 122 billion cubic meter of water with an estimated 2.6 billion m^3 of ground water potential and ample human labor, there will be better implementation and utilization of rain water harvesting in the future for the success of the country's food security.

6. REFERENCES

A. Inocencio, H. Sallyand D. J. Merrey. (2003). Innovative Approaches to Agricultural Water Use for Improving Food Security in Sub-Saharan Africa. Colombo. Sri Lanka.

Ambe Emmanuel Cheo, Emmanuel Amankwah and Prosper Somah Techoro. (2014). Water Harvesting: A Potential Means for Water Security in the Far North Region of Cameroon. NAAS (National Academy of Agricultural Sciences)

Alemayehu Mengistie. (1997). Land surface water harvesting techniques and their application for drought mitigation measures. Continental Consultants Plc, Addis Ababa, Ethiopia.

Anne van der Veen and Tagel Gebrehiwot. (2011). Effect of Policy Interventions on Food Security in Tigray, Northern Ethiopia. Ecology and Society 16(1): 18.

Anteneh Girma, Menale Kassie, Siegfried Bauer, and Joachim Aurbacher. (2014). Integrated Rainwater Harvesting Practices and Household Livelihood: Evidence from a Counterfactual Analysis in Northeast Ethiopia. JLU Giessen.

Arbo Feyisa. (2013). Technical and Socio-economic Study of Using Small Ponds Water Harvesting Systems for Supplemental Irrigation in Gumara-Maksegnit Watershed, Ethiopia. Wageningen University. Netherlands.

Awulachew, S.B., Yilma, A.D., Luelseged, M., Loiskandl, W., Ayana, M., Alamirew, T. 2007. Water resources and irrigation development in Ethiopia. Working paper 123, International Water management.

Awulachew S., Merrey, D.J., van Koopen B., Kamara A., Penning de Vries F., Frits, Boelee E. (2006). Roles, Constraints and Opportunities of Small Scale Irrigation and Water Harvesting in Ethiopian Agricultural Development: Assessment of Existing Situation. International Water Management Institute (IWMI).

Aziz Shikur and Tesfaye Beshah. (2013). Analysis of influencing factors in adoption of rainwater harvesting technology to combat the ever changing climate variability in Lanfuro Woreda, Southern region, Ethiopia. Wudpecker Journal of Agricultural Research.

Bancy M. Mati, Maimbo Malesu and Alex Oduor. (2005). Promoting rainwater harvesting in eastern and southern Africa. World Agroforestry Centre. Nairobi. Kenya.

Binyam Alemu and Desale Kidane. (2015). Rain Water Harvesting: An option for dry land Agriculture in arid and semi-arid Ethiopia. International Journal of water resource and environmental Engineering.

Birara Endalew, Mequanent Muche and Samuel Tadesse. (2015). Assessment of Food Security Situation in Ethiopia. World Journal of Dairy & Food Sciences.

Berhanu Adenew. (2004). The Food Security Role of Agriculture in Ethiopia. Ethiopian Economic Policy Research Institute. Addis Ababa. Ethiopia. E-mail: berhanuad@yahoo.com

Berhanu Gutema. (2001). Food Insecurity in Ethiopia: the Impact of Socio-political Forces. Aalborg University. Den Mark.

Care USA. (2014). Achieving food and nutrition security in Ethiopia. Washington Dc. USA.

Critchley, W.; Reij, C.; Seznec, A. 1992. Water harvesting for plant production. Volume II: Case studies and conclusions for Sub-Saharan Africa. World Bank Technical Paper.

CSA (Central Statistics Agency). (2013). Agricultural Sample Survey 2012/2013 (2005 E.C.). Volume I. Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Statistical Bulletin 532, Addis Ababa. Ethiopia.

CTA (Centre for Agricultural and Rural Cooperation). (2010). Integrated Water Management for Sustainable Agriculture. Annual seminar Johannesburg. South Africa. Website: www.cta.int

Daniel Kassahun Waktola. (2006). “Rainwater Harvesting In Ethiopia: Capturing Realities and Harnessing Opportunities.” Forum for Social Studies. Addis Ababa, Ethiopia. Email: daniel.kassahun@gmail.com.

Ding Y.; Hayes M. J. and Widhalm, M. (2011). "Measuring economic impacts of drought: A review and discussion". Disaster Prevention and Management 20 (4): 434

EIAR, OARI, OIDA and JICA. (2006). Experience of water harvesting technology in East Shewa and Arsi Zones. Proceedings of a Workshop. Melkassa Agricultural Research Centre. Ethiopia.

ERDO (Emergency Relief & Development Overseas). (2016). Ethiopia Food Emergency.

Eva Ludi. (2009). Climate change, water and food security. Overseas Development Institute. London.

FAO (Food and Agriculture Organization of the United Nations). (2014). State of Food Insecurity in the World. Rome. Italy.

FAO, WFP and IFAD. (2012). The State of Food Insecurity in the World. Rome. Italy.

FAO (Food and Agriculture Organization of the United Nations). (2010).The state of food insecurity in the world: addressing food insecurity in protracted crisis. Rome.

FAO (Food and Agriculture Organization of the United Nations).2005. Irrigation in Africa in figures. AQUASTAT Survey. http://www.fao.org/nr/water/aquastat/dbase/index.stm

FAOSTAT. (2012). Crop production statistics. Online at: www.faostat.fao.org

Fitsume Yemenu, Tilahun Hordofa and Yiferu Abera. (2014). Review of Water Harvesting Technologies for Food Security in Ethiopia: Challenges and Opportunities for the Research System. Journal of Natural Sciences Research. E-mail: http://www.iiste.org/journals/

Fox John and Yohannes G/M (2002). The management of natural resources in the pastoral areas of Ethiopia, Knowledge building process (consultancy work for Oxfam international May 2002). Addis Ababa, Ethiopia.

Fox P, Rockstrijm J, Barron J. (2005). Risk analysis and economic viability of water harvesting for supplemental irrigation in semi-arid Burkina Faso and Kenya. Agricultural Systems 83, 231-250.

Fraser, E.; Termansen, M.; Sun, N.; Guan, D.; Simelton, E.; Dodds, P.; Feng, K.; Yu, Y. (2008). "Quantifying socio economic characteristics of drought sensitive regions: evidence from Chinese provincial agricultural data". Comptes Rendus Geosciences340: 679–688.

George Nyamadzawo, Menas Wuta, Justice Nyamangara and Douglas Gumbo. (2013). Opportunities for optimization of in-field water harvesting to cope with changing climate in semi-arid smallholder farming areas of Zimbabwe. SpringerPlus.

Getachew Alem. (1999). Rain Water Harvesting in Ethiopia: an over view. Addis Ababa. Ethiopia.

Girma Moges. (2009). Identification of potential rain water harvesting areas in the Central Rift Valley of Ethiopia using a GIS based approach. Wageningen University. Netherlands.

Glopolis. (2010). Ethiopia's Food Insecurity: Europe's Role within the Broader Context of Food Flows, Climate Change and Land Grabs. **www.glopolis.org**

Hatibu N, Senkondo EM, Mutabazi K, Msangi ASK. (2004). Economics of Rainwater Harvesting for Crop Enterprises in Semi-Arid Areas. In 'New directions for a diverse planet: Proceedings of the 4th International Crop Science Congress'. Brisbane, Australia.

Hiwot Yirgu. (2014). Determinants of Food Security in Rural Farm Households in Ethiopia. International Institute of Social Studies (ISS).

ICID (International Commission on Irrigation and Drainage). (2014). Food Security by Optimal Use of Water Synthesis of Theme 2.2 of the 6th World Water Forum. Marseille, France.

IFAD (International Fund for Agricultural Development). (2013). Water Harvesting Guidelines to Good Practice. Rome. Italy.

Ines Beernaerts. (2003). Water harvesting for improved rainfed Agriculture in sub-saharan Africa: potential, constraints and opportunities. XI IRCSA conference – proceedings.

K. Tesfaye Fantaye. (2016). Description of cropping systems, climate, and soils in Ethiopia. Global Yield Gap Atlas.

Kebede, T. (1995). Experience in Soil and Water Conservation in Ethiopia. Paper presented at Agri-service Ethiopia's Annual Technical Meeting. Wondo-Genet, Ethiopia.

Kifle Woldearegay. (2015). Water Harvesting and Climate Change Adaptation; the experience of Tigray region in Ethiopia. Mekelle University, Ethiopia; Email: kiflewold@yahoo.com

Komariah and Masateru Senge. (2013).The development of water harvesting research for agriculture. Reviews in Agricultural Science.

L. Desta. (2004). Concepts of Rainwater Harvesting and its Role in Food Security – the Ethiopian Experience (MOARD). Addis Ababa. Ethiopia.

L. Desta. (2006). Keynote Speech. In 'Workshop on the Experience of Water Harvesting Technology in East Shewa and Arsi Zones'. Melkassa. Ethiopia.

Mesfin Welderufael. (2014). Determinants of Households Vulnerability to Food Insecurity in Ethiopia: Econometric analysis of Rural and Urban Households. Journal of Economics and Sustainable Development. E-mail: getmesafint@gmail.com

Messay Mulugeta. (2009). Causes of rural household food insecurity: a case from kuyu district, central Ethiopia. Journal of Sustainable Development in Africa (Volume 11, No.4)

Mihret Jember and Tesfahun Asmamaw. (2014). Understanding Food Security. Disaster Risk Management and Sustainable Development Department, Bahir Dar University. Bahir Dar. Ethiopia.

MoARD (Ministry of Agriculture and Rural Development). (2005). Major Agro-ecological Zones of Ethiopia. Forestry, Land Use and Soil Conservation Department. Addis Ababa, Ethiopia.

MOFED (Ministry of Finance and Economic Development). (2002). Ethiopia: Sustainable Development and Poverty Reduction Program. Federal Democratic Republic of Ethiopia (FDRE). Addis Ababa. Ethiopia.

Munir A. Hanjra and M. Ejaz Qureshi. (2010). Global water crisis and future food security in an era of climate change. Elsevier Ltd.

Ngigi, S.N., G. Savenje, and F. Gichuki. (2005). Land use changes and hydrological impacts related to up-scaling of rainwater harvesting and management in upper Ewaso Najro River basin, Kenya.

Rodney B.W. Smith, Laura A. Hildreth and Kimsey Savadago. (2011). Evaluating the Economic Impacts of Water Harvesting in Burkina Faso.

Rosen, Stacey, B. Meade, and A. Murray. (2015). International Food Security Assessment. U.S. Department of Agriculture (USDA).

Shumete Gizaw Woldeamanuel. (2009). Poverty, Food insecurity and Livelihood strategies in Rural Gedeo: The case of Haroressa and Chichu PAs, SNNP. Proceedings of the 16th International Conference of Ethiopian Studies. Ethiopia.

SIWI (Stockholm International Water Institute). (2001). Water Harvesting for Upgrading of Rainfed Agriculture. Report 11. Stockholm. Sweden.

T. Oweis and A. Hachum (2009). Water Harvesting for Improved Rainfed Agriculture in the Dry Environments. CAB International.

UNEP/United Nations Environment Programme/ SEI/. (2009). Rainwater Harvesting: a lifeline for human well-being. Report.

Urgessa Tura. (20150. Ethiopia's Persistent Food Insecurity: What went wrong?

Von Braun and Olofinbiyi. (2007). Famine and Food Insecurity in Ethiopia. Cornell University, Ithaca, New York.

Vurayai Mutekwa and Samuel Kusangaya. (2006). Contribution of rainwater harvesting technologies to rural livelihoods in Zimbabwe: The case of Ngundu ward in Chivi District. Zimbabwe University. Harare.

WFP. (2006). Climate risk and food security in Ethiopia: Analysis of climate impacts on food security and livelihoods.

Worku Endale, Zelalem Birhanu Mengesha, Azeb Atinafu and Akilew Awoke Adane. (2014). Food Insecurity in Farta District, Northwest Ethiopia: a community based cross–sectional study. BMC Research Notes.

Yenesew Sewnet. (2015). Causes and coping mechanisms of food insecurity in rural Ethiopia. Madawalabu University. Ethiopia.

Yihun Taddele, Louise Karlberga, Melesse Temesgenc and Johan Rockström. (2013). The role of water harvesting to achieve sustainable agricultural intensification and resilience against water related shocks in sub-Saharan Africa. Agriculture, Ecosystems and Environment. Elsevier B.V. Ltd.

Yohannes G/M. (2015). Water harvesting technologies in assuring food security: Lessons from the pastoral areas of Somali Region, Ethiopia. (Rainwater harvesting symposium 1st-12th June 2015). Ethiopia. Email: yohannesgmichael@yahoo.com