Achievements, challenges and opportunities of rainwater harvesting in the Ethiopia context: a review

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ABSTRACT

Rainwater harvesting (RWH) is a novel way for developing countries to construct and maintain long-term water supply systems. As a result, this review paper draws on actual findings and lessons learned from various places in Ethiopia to assess the country's achievements and opportunities when it comes to RWH, as well as to guide future alternatives toward its sustainability. RWH acts as to help throughout the rainy season's dry spells, as a potential asset for the dry season, aiding human and livestock consumption as well as crop production through irrigation. So, for successful well-organized rain water collection, watershed treatment, seepage and evaporation control, soil and water conservation, conservation tillage, and integration of low-cost water lifting techniques and family drip systems should all be undertaken. Given that the country has not been significantly modernized, it has outdated experience in the operation and exploitation of RWH systems. Aside from financial inadequacies, historical and political instability, lack of understanding among farmers, and resistance to new technologies, the country has opportunities and has made some progress on RWH systems. In general, RWH could enable smallholder farmers to diversify their crops, thereby enhancing household food security, dietary status, and economic return. In addition, the much-needed green revolution and climate change adaptations should combine RWH ideas with agronomic principles in the country. More work is needed to strengthen indigenous practices and share best practices to a larger scale.

Key words: Ethiopia, rainwater harvesting

HIGHLIGHT

Given that Ethiopia has not been significantly modernized, it has outdated experience in the operation and exploitation of RWH systems. Aside from financial inadequacies, historical and political instability, lack of understanding among farmers, and resistance to new technologies, the country has opportunities and has made some progress on rainwater harvesting systems.

1. INTRODUCTION

The goal of enhancing food production to maintain food security for the world’s continually growing population, particularly for nations in ecologically susceptible areas like Sub-Saharan Africa (SSA), will be the major issue for future decades (ICSU 2002).

The human population in SSA grows at a rate of 3% per year, yet yields of main food crops only grow at 1% per year, signifying a decline in precipitant food supply (Dyson 1999; Rockström 2003; Sachs et al. 2004). More than 41% of Africa’s population lives in drylands, which cover roughly 43% of the continent (UNEP 2009).

Due to severe fluctuation in rainfall, extended dry seasons, and periodic droughts and dry spells, water is a major barrier for food production in drylands. The majority of hungry and poor people reside in areas where water scarcity is a major limitation to food production (Kooohafkan & Stewart 2008). Africa’s rainfall variability is twice that of temperate regions, making agricultural droughts more common than anywhere else on the planet (World Bank 2004). Droughts have primarily afflicted the horn of Africa and the Sahara regions (IPCC 2013; L’Hôte et al. 2002), although they can affect any dryland in SSA.

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Agriculture is Ethiopia’s economic mainstay, accounting for the majority of GDP, export trade, and earnings, and employing 84% of the people (Teshome 2006). Agriculture, on the other hand, is the most volatile industry, owing to its reliance on rainfed systems (about 97% of agricultural land is rainfed) and the periodic seasonal shocks (Awulachew et al. 2007).

By 2050, the country’s freshwater availability per capita will be less than 1,000 m$^3$ per person per year, making it one of the world’s most water-scarce countries (Fischer & Heilig 1997; Wallace 2000). Arid, semi-arid, and dry sub-humid areas make up about 65% of Ethiopia’s total landmass (about 700,000 km$^2$) and 46% of all arable land is in this state (Yonas 2001). Semi-arid zones, in particular, cover 301,500 km$^2$ (27% of the country) and are the crop-producing zone most affected by moisture stress (Ephraim 2001).

Seasonal and annual rainfall in Ethiopia is very unpredictable and varied, with a higher risk of crop failure in arid and semi-arid regions due to a lack of water during the growth seasons (Gissila et al. 2004; Tesfaye & Walker 2004). During the years 1994–2003, the production of main grains in Ethiopia’s northern region had statistically significant relationships with seasonal rainfall variations (Bewket 2007). Because rainfed agriculture accounts for the majority of Ethiopia’s GDP, annual GDP growth was connected with annual rainfall variance from 1983 to 2000 (World Bank 2015). Rainwater loss through non-productive channels adds greatly to water scarcity in rainfed agriculture, in addition to the unpredictability and unreliability of annual and seasonal rainfalls. Surface runoff might lose anywhere from 10% to 40% of the rainfall (Welderufael et al. 2008; Araya & Stroosnijder 2010). Soil evaporation may reach 50% of the rainfall in dryland regions (Daamen et al. 1995; Rockström et al. 2009; Stroosnijder 2009).

As a result, in drylands, the percentage of rainfall utilized for plant transpiration might be as low as 15% of total rainfall (Stroosnijder 2009). Dryland soils that have deteriorated have little infiltration and water holding capacity, shallow depth, and are vulnerable to crusting (Hoogmoed 1999). Farmers in Ethiopia have to do repeated tillage techniques before seeding cereal crops due to insufficient ploughing with the traditional Maresha ard tool, causing the soil to be severely crushed (Temesgen 2007). As a result, the soil structure deteriorates, reducing rainfall penetration and increasing surface runoff generation.

The demand for water is proportional to the expansion of the human population. Agriculture still consumes more than 70% of all water on the planet. When demand for freshwater rises, there is often a competition among municipal, industrial, and agricultural sectors, resulting in a reduction in agricultural allocation and threats to food security (Awulachew et al. 2008). Water harvesting and conservation strategies have been successful in enhancing food yield in some poor nations through an ecological strategy that needs collective effort at the local level, as well as engagement from government and non-government groups (Rosegrant et al. 2002; Komariah & Senge 2013). Rainwater harvesting (RWH) research with extensive impact assessments and economic evaluations demonstrated the significance of interdisciplinary and integrated techniques. It has been demonstrated that these methods may be used for a variety of purposes, including water supplementation, flood prevention, water table recharging, and erosion control (Ouessars et al. 2004; Komariah & Senge 2013).

Low yields or crop failure are the result of poor rainfall distribution caused by dry spells combined with low nutrient input during crucial growth phases; thus, dry spell mitigation in SSA must improve water productivity (Komariah & Senge 2013). Ethiopia, like the rest of SSA, is prone to famine, having a long history of famines and food shortages dating back to 250 BC (Webb et al. 1994).

RWH is particularly important because rainfall is the sole source of water accessible locally. Despite the fact that the country has vast water resources, including 12 river basins with annual runoff volumes of 122 billion (122 x 10$^9$) m$^3$ of water and an estimated 30 billion m$^3$ of groundwater potential, the country has made very little effort to harness these resources (Awulachew et al. 2007; MoWIE 2021).

Small-scale farmers in Ethiopia, a scarcity of arable land, irrigation extension limits, irregular rainfall, and frequent dry spells all oppose a reduction in productivity, and therefore innovative RWH technology should be adopted more widely to improve water productivity for rain-fed agriculture. When contemplating the concept of RWH, the distinction between ‘rainfed’ and ‘irrigated’ agriculture becomes evident (Rijsberman & Manning 2006; Rockström et al. 2010). The potential of RWH for crop production rests in combining the utilization of rainfall events with the management of existing water to boost water productivity. Kahinda et al. (2007) discovered that supplemental irrigation of maize from RWH minimizes the probability of full crop failure and mitigates dry spells during the rainy season in Zimbabwe.

Many RWH ponds are mostly used for cattle, according to an International Water Management Institute (IWMI) assessment on Ethiopia (Awulachew et al. 2007). The mixed system of livestock and crops decreases the risks associated with
livestock rearing; in the event of a drought, cattle production takes a long time to recover, whereas crop production recovers rather rapidly. RWH ponds and cisterns are also utilized near to dwellings.

RWH ponds have been linked to detrimental health effects in Ethiopia, such as malaria outbreaks, in some areas. Their environmental viability is also questioned, because of soil salinization caused by micro dams (Awulachew et al. 2007). RWH on a wide scale, according to Rijberman & Manning (2006), might lead to water shortages in downstream communities. Furthermore, sufficient runoff is required, which is constrained by the available catchment area (Ngigi et al. 2005). This is likely to become a more critical element as the scope of RWH increases.

It is commonly known that RWH, as a production-enhancing intervention, should be part of a comprehensive strategy. Fertilizer, in particular, is a crucial component of this (Awulachew et al. 2007; Kahinda et al. 2007). In Zimbabwe, research by Maisiri et al. (2005) discovered that fertilizer application, not irrigation, determined final production. It is vital to understand the impact of water scarcity at critical growing phases if you are going to employ supplemental irrigation effectively (Kahinda et al. 2007). Choosing the proper planting date is also part of water management (Ngigi et al. 2005). The major goal of this study was to examine the various efforts made, achievements obtained, and roles played by RWH technologies in sustaining agricultural productivity throughout the preceding decade, as well as their future role in food production in Ethiopia.

1.1. Approaches to the review and literature compilation
This review paper critically rereads the issues of RWH achievements, challenges and opportunities in the Ethiopian context. This systematic review uses secondary data published in journals, research centers, annual reports, technical and consultant reports undertaken by several researchers, institutions and organizations. Though the review focused on generally available literature, items of published original research in the country were the principally used sources. All sources utilized in the work were searched and identified from different electronic databases such as Web of Science, AGRIS, Research Gate, Science Direct, Springer, different African and Ethiopian Journals, and libraries of the Ethiopian research institutes. The secondary data available at the Food and Agriculture Organization (FAO) Corporate Statistical Database (FAOSTAT) and Central Statistical Agency of Ethiopia relevant to the review were also used. Based on the review objectives and contents, all required sources were retrieved from databases mainly focusing on empirical results reported. Therefore, technically, RWH achievements, challenges and opportunities were reviewed and recommendations and future scenarios put forward.

2. OVERVIEW OF WATER HARVESTING
Water storage in small ponds, tanks, and cisterns has been practiced for millennia all throughout the world. Since Roman times, water held in ponds or tanks has been used for a number of reasons throughout North Africa. Tunisia and Egypt are said to still have some of these in operation (Ngigi 2003). Water-harvesting devices dating back 4,000 years or more have been uncovered in some of the world’s earliest farms, in Israel’s Negev Desert (Evenari et al. 1971). During the 1970s and 1980s, when there was a widespread drought that resulted in crop failures, there was a growing awareness regarding the potential of rainwater gathering for enhanced crop production in Africa. Several rainwater collecting projects have been built in SSA over the last three decades, each of which has cost a significant amount of money, time, and effort. Their goal was to improve plant production and rehabilitate abandoned and damaged land in order to mitigate the consequences of droughts (Dile et al. 2013; Kasso & Bekele 2016).

Water is most likely the key to lowering the risk of crop failure due to water constraint. Improved RWH could lead to higher crop yields, food security, and a better standard of living (Komariah & Senge 2013; Nyamadzawo et al. 2013). Hence, water harvesting is a promising approach that is frequently employed to address water scarcity issues in agricultural production around the world. Depending on the goal and circumstances, micro- and macro-water harvesting techniques are used in arid, semi-arid, and tropical areas. Water harvesting systems are found to have a favorable impact on agricultural productivity by providing irrigation water during important growing stages of crops, resulting in higher yields. A water collecting system also assists in groundwater recharge by reducing runoff velocity and soil erosion (Komariah & Senge 2013).

In addition to increasing agricultural output, RWH technologies have been shown to improve household food security and raise revenues (Mutekwa & Kusangaya 2006; Welderufael et al. 2008). Furthermore, in situ RWH procedures improved hydrological indicators such as infiltration and groundwater recharge, soil nutrients were enriched, biomass output rose, and soil temperatures improved, according to Li et al. (2000), Vohland & Barry (2009), and Komariah & Senge (2013). Also, rainwater collection strategies have been shown to promote floral diversity, change the ecosystem’s spatial organization,
and improve animal biodiversity by increasing the amount of biomass available for food and shelter (Rockström et al. 2010; Komariah & Senge 2013).

The use of RWH expands the irrigation area, converting more ‘blue’ water into ‘green’ water. This has a favorable influence on groundwater recharge but reduces stream flow downstream, enhancing the groundwater system’s resilience and sustainability (Glendenning & Vervoort 2011; Komariah & Senge 2013). Farmers may find water collecting appealing because it minimizes the risk of crop loss due to spatial or temporal drought, gives them more alternatives by extending the growing season, provides more ‘rainfall’ to allow them to produce a wider variety of crops, and allows them to cultivate ‘abandoned’ land (Tabor 1995; Welderufael et al. 2008; Komariah & Senge 2013).

RWH has a longstanding history in Ethiopia, with strong ties to the old Orthodox churches, and dates back to the pre-Axumit period 560 BC, according to Habtamu (1999). Rainwater was collected and stored in ponds and tanks for agriculture and water supply at that time. In Axum’s oldest palaces, the ruins of an ancient roof-water collection system can still be seen. Other evidence includes the ruins of one of Gondar’s medieval castles, built in the 15th and 16th centuries, and the rock-hewn chapels of Lalibela (almost 800 years ago), which include a pool used to hold water for religious rites. RWH systems may be found in monasteries such as Mahbre Selassie in Gondar and Debrekerbie in Shoa. The Konso people in the south of the country have a long and well-established history of creating level terraces to catch rainwater, which is then utilized to effectively grow sorghum in an exceptionally hard climate marked by low, inconsistent, and variable rainfall (Begahew 2005).

Structures like tanks are used to collect rainwater in Ogaden, in Eastern Ethiopia. People in North Omo (Gatto Valley), Eastern Hararghe, and other parts of Ethiopia have been practicing soil and water conservation for years (Habtamu 1999). With the launch of the Food for Work (FFW) program in response to the 1971–74 droughts, Ethiopian government initiatives of soil and water conservation programs began to promote and apply RWH technologies as an option to solve water scarcity. Construction of ponds, micro dams, micro basins, bunds, and terraces were among the first RWH efforts in most drought-stricken areas (Kebede 1995).

3. RAINWATER HARVESTING IN ETHIOPIA: OPPORTUNITIES AND CHALLENGES

Farmers have always evolved and adapted to ever-changing environments by building varied and resilient farming systems in response to rapid climate changes and available opportunities (Pandey et al. 2003; Altieri & Koohafkan 2008). For supplemental irrigation on farm fields, micro-catchment and in situ RWH techniques are used more frequently than macro-catchment techniques. This may be because of the micro-catchment and in situ approaches’ lower complexity of design and lower startup costs compared to macro catchment systems. Traditional spate irrigation systems in eastern Africa are the only macro-catchment techniques that have proved popular with smallholder farmers (Tesfai & Stroosnijder 2001). Despite the prospect of improving indigenous methods through scientific skills and lessons learned from other places, recent RWH interventions have centered on the introduction of new techniques without sufficient farmer engagement, and vast attempts to implement new RWH systems have only yielded minor gains and low levels of adoption among smallholder farmers (Abera 2004; Spaan et al. 2005; Mengistu & Desta 2011).

RWH techniques alone can improve grain yields by up to 56%, while when combined with extra fertilizer, grain yields can increase by 200–600% when compared to traditional practices, according to a review of experiments across Ethiopia. Implementation of in situ and micro-catchment RWH methods can enhance the soil water content of the rooting zone by up to 50%, reducing the negative effects of dry spells. Despite the fact that integrating rainwater gathering with soil additives is usually necessary due to the existing low fertility of most dryland soils, grain production benefits vary depending on seasonal rainfall patterns. RWH techniques without the addition of nutrients had minimal effect on crop yields in the Sahara during years with evenly distributed rainfall, whereas nutrients alone led to considerably greater grain yields (Zougmoré et al. 2003). Despite the favorable effect of tied-ridges in near-normal (500–600 mm) rainfall years in Tanzania, waterlogging effects in rainy years (700–900 mm) have to be addressed with bigger applications of fertilizers that increase maize’s water uptake capacity (Jensen et al. 2003). As a result, accurate seasonal weather forecasting will aid farmers in making better immediate judgments and tactically planning for responsive farming in the next seasons.

Due to the uneven performance of RWH procedures in response to varied environmental and socioeconomic conditions, previous experiences have shown that transferring best practices from one location to another should be done with caution. As a result, it is critical to take into account current crop production factors, local knowledge, and opportunities while designing and developing rainwater gathering strategies. Implementation of zai pits with compost and manure repaired trusted
Geography, climate, economics, population, and technology all have an impact (Shendong 2009). Achieving this aim will rely severely on enhancing the efficiency of canal irrigation systems and increasing water supplies through the RWH (Mbilinyi et al. 2005). Integrated rainwater collection methods must be identified, and indigenous knowledge must be used as a decision-making tool for appropriate development (Molden et al. 2010). To systematically out-scale the impacts of micro-catchment and macro-catchment RWH techniques to a catchment size, a methodological flowchart has been developed as a decision-support tool (Ncube et al. 2009).

In situ and micro-catchment RWH methods can help to minimize long dry spells. Other agro-meteorological variables, such as short growing seasons, early rainy season termination, or protracted dry spells, could be effectively addressed through deficit or supplemental irrigation with rainwater storage ponds (Fox & Rockström 2003; Araya & Stroosnijder 2011). However, due to poor topographic conditions or a lack of runoff-inducing precipitation, macro-catchment water harvesting techniques may not be appropriate everywhere. It is also critical to look at what is accessible locally, such as rock fragments for stone mulching or bunds, manure for soil enhancement, or crop leftovers for surface mulching. Water production per unit of rainfall could be improved via genetic changes that target early growth vigor to reduce evaporation and increase drought resilience (Bindraban et al. 1999; Bennet 2005; Molden et al. 2010; Asfaw 2011).

Irrigation uses over 70% of the available water on the planet. Water demand for higher-valued uses such as home, industry, and hydropower is increasing. More food must be produced with less water in the agriculture sector. Many believe that achieving this aim will rely severely on enhancing the efficiency of canal irrigation systems and increasing water supplies through the RWH (Barker et al. 2000).

In Africa and Asia, it is customary for each family to construct their own water catchment system, either by digging a shallow well or by constructing a rudimentary RWH system. Both methods have advantages, but they also have disadvantages: they are unreliable decentralized water sources, they are subject to nature’s whims, water quantities collected during the dry season are insufficient, the quality of water collected could be hazardous, and structures suffer due to a lack of expertise. Furthermore, due to distance and physical constraints, most small communities and villages in Africa and Asia do not benefit from a centralized water supply system (Yongkyun et al. 2016).

People’s lack of equal access and benefit from water harvesting technologies (WHTs) due to natural and human-induced problems and constraints is mainly linked with the following attributes.

**Biophysical suitability:** Building dependable WHTs necessitates a variety of requirements and design parameters, including terrain, soil, hydrology, geology, as well as environmental, social, and cultural considerations. However, many WHTs are built without considering their viability against these needs, and as a result, existing water harvesting facilities that were intended for supplementary and full irrigation are becoming obsolete.

**Rational and equitable utilization of water resources:** The upper stream communities benefit less than the downstream communities because many of the reliable WHTs are built at the discharge site (downstream part of the watersheds), but they contribute significantly to the enhancement of water resources, resulting in a conflict of interest among the communities. As a result, the ecosystem’s functional continuity may be jeopardized, as well as upper stream communities’ motivation and excitement for protecting, conserving, and expanding their watershed, which provides water to be harvested and used downstream. This is not to say that there are no water harvesting practices on upstream parts; various in situ water harvesting techniques are used on a large scale, but because they serve as a point of retention, their economic impact on the spot is not
and cowpea. Sorghum and cowpea multi-cropping beneﬁts millet and white sorghum mono-crops and a directional output distance function for joint production of white sorghum with water harvesting as an input, to estimate a quadratic production technology. This signiﬁcantly reduces household interest in using credit and savings services to cover the costs of establishing WHTs and associated investments on their property in order to increase production and productivity and, as a result, assure household food security.

Weak organizational monitoring and evaluation: Once structures are built, funders, advocates, and government agencies do not strictly monitor their performance and functioning against their original aims, and there is a poor culture of facilities upkeep. As a result, this leads to poor performance and a shorter lifespan for WHTs in general. There is also a scarcity of trained labor at the ‘Tabia’ level sufﬁciently knowledgeable about the technologies.

Unreliability of rainfall: Rainfall is the primary design element that deﬁnes the structural component dimensions in the implementation of WHTs. However, due to the unpredictability and erratic nature of rainfall, farmers are hesitant to invest in and build promising water harvesting technologies because there are circumstances where the cost of construction may not be recouped from the beneﬁt of water harvesting, i.e., the water demanded may not be supplied in sufﬁcient quantity, lowering the value of the investment in the technologies and, in turn, lowering the value of the technologies.

The main issues that prevent the adoption and implementation of WHTs are usually related to a lack of resources, such as capital, human resources for labor, and knowledge, followed by a lack of organizational follow-up throughout building and maintenance. Problems with the physical availability and biophysical suitability of land resources, on the other hand, are reported in smaller numbers (Tafaye et al. 2021).

4. PREVIOUS RESEARCH RESULTS

To assess the economics of water harvesting, analysts have utilized a variety of methods. The most straightforward method is to compare the yields of a certain crop achieved utilizing water harvesting and standard farming approaches under the same set of experimental settings, often using the same type and quantity of fertilizer in similar soil conditions.

Tabor (1995) conducted a millet and sorghum research study. Water harvesting enhanced yields for both millet and sorghum in this study when compared to traditional farming, although the gain in yield was dependent on whether it was a dry or rainy year.

Several studies undertook this research by comparing crop yields under four alternative scenarios: traditional techniques, water harvesting only, fertilizer usage solely, and a combination of water harvesting and fertilizer use. Under the scenarios described above, investigations were made into maize (Barron & Okwatch 2005; Smith et al. 2011) and sorghum (Fox & Rockström 2003; Smith et al. 2011) production. Water collecting alone can increase yields, but when combined with fertilizer application, yields increase even more. These increases, like those reported by Tabor (1995), are dependent on the overall amount of rain received during the growing season. Caskey et al. (2001) is the exception to this rule, ﬁnding that water harvesting alone increases yields more than fertilizer use. Finally, Zougmore et al. (2004) examined sorghum yields from two different water harvesting systems under three different scenarios: water harvesting without fertilizer use, fertilizer use without water harvesting, and water harvesting and fertilizer usage together. They came to the conclusion that combining water gathering with fertilizer application improves water efﬁciency and yield (Smith et al. 2011).

According to research conducted in Burkina Faso (Fox et al. 2005) water harvesting increases yields by at least 40% in millet and white sorghum mono-crops. The research also investigated a directional output distance function for joint production of white sorghum and cowpea with water harvesting as an input, to estimate 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. Sorghum and cowpea multi-cropping beneﬁts from water harvesting as well. These ﬁndings shed light on the financial beneﬁts of water collecting as well as its potential as a poverty-reduction technique in SSA (Smith et al. 2011).
RWH systems in macro and micro-catchments have had a mixed but generally positive effect on soil moisture regimes and crop yields (Walker et al. 2005; Mupangwa et al. 2006; Komariah & Senge 2013). Because of the higher water use efficiency, Li & Gong (2002) and Tian et al. (2003) discovered 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 corn yield by 1.9 times (Li et al. 2004; Komariah & Senge 2013).

RWH systems were demonstrated to be a reasonably low-cost solution for temporal access to a water source, according to Aftab et al. (2012). Some of the issues connected with irrigation, including water rivalry between multiple applications and users, low water use efficiency, and environmental deterioration, are mitigated by RWH. RWH is a low-cost, ecologically friendly technology that can be easily handled with little technical knowledge (Ngigi 2003; Komariah & Senge 2013). Supplemental irrigation with micro-catchment rainwater gathering during dry spells could improve the rooting zone’s soil water content by up to 30% (Biazin et al. 2012; Komariah & Senge 2013). Sorghum yields increased by 41% when harvested water from a small pond was used, and by 180% when paired with fertilizer (Fox & Rockström 2005; Komariah & Senge 2013).

In situ rainwater collecting with a sand-ditch was investigated by Abu-Zreig et al. (2011), with runoff and sediment loss reduced by 46% and 60%, respectively, while infiltration and soil moisture were enhanced. In Tunisia and the Middle East, RWH practices such as the use of jessour have lowered runoff volume and velocity, reducing soil erosion and improving soil water storage capacity and fertility (Schiettecatte et al. 2005; Komariah & Senge 2013).

Mesfin (2014) found that 48% of households in the Amhara regional state of Ethiopia were unable to meet the daily recommended caloric requirement, and that the percentage of food consumption required to bring the entire food insecure population into food poverty is 18%, with 8.7% of sample households experiencing the most food insecurity. Furthermore, the descriptive statistics reveal evidence of location as a factor, with rural households experiencing higher levels of insecurity than urban households.

4.1. Water harvesting achievements in Ethiopia

According to the Ministry of Water Resources (MoWIE 2021), around 67% of Ethiopia’s landmass is classified as dry or semi-arid, which is characterized by acute water scarcity due to unpredictable rainfall distribution, resulting in repeated drought and hunger. Apart from solely pastoral areas, more than 90 districts/woredas in the country, with a total of more than 2 million households, are drought prone and experience severe water shortages on a regular basis. More than 12 million people’s lives are in grave danger as a result of this. The expanding imbalance between food production and rapid population increase, the deterioration of natural resource bases, and the domination of cereal-based farming systems that are solely dependent on sporadic and inconsistent rainfall are all important contributors to current food insecurity (Welderufael et al. 2008).

In numerous places around the world, RWH during excess seasons for use during crucial periods has become a viable approach. It aims to enhance the lives of rural people by bridging dry spells with supplemental irrigation of rain-fed crops in smallholder farming systems at a low cost and with few outside inputs. This could be attained by a water harvesting system that collects runoff in small storage structures. Water harvesting can lower the risk of crop failure by allowing for early planting, which allows for the most efficient use of rainfall and so protects the crop from rainfall fluctuations. In food-insecure places where land is becoming scarce, efficient rainwater collection and storage is crucial. Capturing additional runoff from rainfall, as well as efficient water storage and usage, has become a key component of Ethiopia’s drought and famine response strategy.

In the highlands, heavy and prolonged rainfall during the wet season is the primary source of degradation, notably soil erosion. Rain/runoff flushes nutrient-rich soil, seeds, and fertilizer down the drain. Large gullies serve as permanent drainage ditches, reducing soil moisture levels. Water is a serious limitation in many regions of the country during the dry season, and women, children, and cattle must travel long distances to obtain it. In this way, it is as if a blessing has been turned into a curse. Peak hydrographs during rainy seasons and no flow during dry seasons, high rainfall fluctuation that leads to large runoff variability, and erosion and sedimentation problems all risk water availability. Effective watershed treatment and diverse RWH initiatives are required to change it (Araya & Stroosnijder 2010).

Water is one of the three pillars (land, labor, and water) for development under the country’s Agriculture Development Led Industrialization (ADLI) policy and food security programs. Despite the fact that the country’s entire surface and groundwater potential is projected to be more than 120 billion m³, access remains a major issue. Only 247,500 hectares (5.8%) of the overall 4.25 million hectare irrigation potential has been realized through small-, medium-, and large-scale irrigation projects. Traditionalists make up 55% of the developed land. The Oromia area, which covers 32% of the country, has the
most irrigation potential. The financial, physical, and human capital required to successfully exploit the available potential are all insufficient. Obviously, there are a number of physical, technical and socio-economic problems (Yihun et al. 2013).

Ethiopia’s Water Policy was recently published by the Ethiopian government. Most of the major rivers have been the subject of basin-wide integrated master plan studies that look ahead 30–50 years. Another approach for increasing water productivity in the production system was presented as a key pillar in the national food security policy (IMF 2000). In each of the short-term (2002–2006), medium-term (2007–2012), and long-term (2013–2016) planning stages, the targeted aim in the water sector, primarily through home level water collection, micro and small irrigation, is 400,000 hectares (OIDA 2000).

Over 42,000 water harvesting structures have started production in the Amhara region (northwestern region of the country), out of 242,000 completed water harvesting structures. As a result, 21,194 acres of land have been irrigated, benefiting 148,244 farm households. Women lead 14% of these households. The region’s irrigated land is mostly supported by shallow wells, river diversion, and spring development Lakew (2006) and Dereje (2006).

In the Oromia area (central eastern and western parts of the country), total irrigated land with water harvesting is 65,508 ha, compared to 68,565 ha planned (95.5% achievement). A total of 343,953 households (92%) have benefited as a result of this. On top of the 31,311 hectares that already exist, 379 hectares of traditional irrigation are being established through river diversion. 75% of the 216,290 ponds planned are in food insecure districts, with the remaining 25% in non-food insecure districts. Apart from drinking and crop production, farmers have sold their stored water, or utilized it to make mud for house construction, soil blocks, and to raise seedlings in nurseries Fox et al. (2005) and Lakew (2006).

So far, 732,336 programs have been implemented in the country, benefiting 93,236 homes, totaling 3.7 million people. As a result, this is thought to help with household food security. Low-cost water pumping and family drip equipment/systems have been and continue to be pushed alongside the storage facilities. Treadle pumps, watering cans, family drip systems, and tied ridges are all examples of this. However, the quantity of water required in terms of the number of schemes is far less than that actually required. Many farmers find that hand-pumping and watering with cans to the root of each plant takes too much time and effort (Table 1).

Historically, the Embankment dam from Somalia was introduced by UNHCR in the Aware refugee camps in Sudan. They were designed to gather water only for human consumption when first built. However, Hope for the Horn, a local NGO that works closely with pastoralists, has been striving to improve the technology by taking into account some of the pastoralists’ suggestions. Machine-built Embankment dams are intended to serve both animals and humans. The main dam and the silt trap were augmented with an outlet canal connected to two shallow wells, from which water is pumped to an elevated distribution cistern and then delivered to cattle troughs and human collecting sites by gravity (Yohannes 2016). The average Embankment dam costs around 1.4 million Ethiopian Birr to build, with a capacity of 60,000 m³ of water (one dollar is about 8.5 Birr). It is assumed that such a volume of water will last for three or four months, supplying up to 20,000 people and their animals. Embankment dams are part of a system that includes environmental rehabilitation, including

| No | Type of technologies | Achievements (in number) | Beneficiary Households | Estimated area of land (ha) |
|----|----------------------|-------------------------|------------------------|-------------------------|
| 1  | Shallow (hand dug) wells construction | 308,338                | 308,338                | 18,500                  |
| 2  | Shallow wells improvement | 850                    | 850                    | 51                      |
| 3  | Household trapezoidal surface ponds | 205,787                | 205,787                | 6,173.61                |
| 4  | Cisterns/tanks | 5,632                   | 5,632                  | 168.96                  |
| 5  | Cistern improvement | 877                    | 877                    | 26.31                   |
| 6  | Community ponds | 49,311                  | –                      | –                       |
| 7  | Spring development | 32,727                  | –                      | –                       |
| 8  | River diversion in ha² | 37,020                  | 148,080                | 37,020                  |
| 9  | Runoff diversion in ha | 31,386                  | 62,772                 | 31,386                  |
| Total |                       | 732,336                | 93,326                 |                         |

Table 1 | Summary of achievements of four regions (North western, central eastern, western and eastern parts of Ethiopia) in 2003/2004 physical year (adopted from Lakew 2006)
closing the command area, planting trees, and using site-specific soil and water conservation measures such as micro basins and soil bunds (Yohannes 2016).

As a result, biological and physical interventions such as a silt trap and fodder banking were beneficial. Check dams were constructed using locally available dead and living tree branches. Nurseries also produced a lot of indigenous multi-purpose trees (for fodder, fruit, and medicinal purposes), as well as a few fast-growing exotic plants. Water and environmental committees, made up of elders, women, and youth, were formed at the start of the dam construction Hussain & Hanjra (2003) and Yihun et al. (2013).

Currently, 17 Embankment dams have been built along 400 kilometers, with an average distance of 60 kilometers between them. The five districts of Gashamo (5 Embankment dams), Aware (5 Embankment dams), Harshen (3 Embankment dams), Kebrebehyah (3 Embankment dams), and Jigiga (3 Embankment dams) are covered by these dams, which function as a blue (water) and green (fodder) belt (1 Embankment dam). The blue and green belts’ spatial distribution is based on a number of factors, including the distribution of other water sources (natural, traditional, and tanks), clan and sub-clan distribution, mobility patterns, and reciprocity among clans with territorial flexibility (Yohannes 2016).

Only when paired with enhanced soil fertility management is a water collection system economically viable (Fox et al. 2005). The run-off agroforestry system, which combines micro-catchment with agroforestry, provides enough water to produce both woody and herbaceous plants for the provision of feed in Ethiopia (Abdelkadir & Schultz 2005; Komariah & Senge 2013). Because a micro-water harvesting system collects water across a vast region, it necessitates additional effort during construction. Because the plastic used to mulch the ridges is hazardous to the environment, biodegradable plastic film should be used instead (Wang et al. 2008; Komariah & Senge 2013). Despite the effectiveness of a number of RWH systems (Rockström et al. 2009; Glendening & Vervoort 2010; Komariah & Senge 2013), Ngigi (2003) noted that the impacts of RWH systems in Ethiopia, Kenya, Tanzania, and Uganda are still negligible.

Soil storage and watershed treatment elements of RWH are largely absent due to capacity constraints, with considerable variance between locales. Hand-watering using cans is time-consuming and labor-intensive, resulting in water waste. High seepage and evaporation losses (estimated at 24 and 6 liters/day/m², respectively), high sediment in the ponds, loss of productive land to surface ponds, cost versus benefit for cisterns having an excessive payback period, technical capacity limitation at the grass-roots level during implementation and insufficient extension follow-up on already established schemes, concern about malaria and the inadequacy of the local market in view of the targeted high value horticultural crops are all also to be mentioned (Amsalu & De Graaff 2006).

5. CONCLUSION AND FUTURE PROSPECTS

Subsistence rainfed agriculture will continue to be the primary source of food for Ethiopia’s rapidly growing population due to physical and economic water constraint. The severe agricultural water scarcity in this region is linked to rainfall unpredictability and substantial non-productive water flows rather than total yearly precipitation. In drought-prone areas, productive green transpiration accounts for less than 15% of total terrestrial precipitation. As a result, RWH techniques have the potential to significantly improve and sustain rainfed agriculture in the region. In Ethiopia, for supplemental irrigation on farm fields there are numerous RWH approaches in situ, and at micro- and macro-catchment level. The attempts to implement new RWH systems in the country, on the other hand, have only yielded minor gains and low levels of adoption among smallholder farmers. Therefore, focus should be given to indigenous techniques, or those adapted from indigenous RWH traditions, which are more extensively used and accepted by smallholder farmers than introduced technologies.

RWH through conservation tillage practices has influenced the characterization of rainfall by significantly reducing surface runoff over agricultural lands by up to 100% when compared to conventional tillage, according to an investigation of catchment hydrology in response to agricultural water use innovations (Kongo et al. 2010). RWH systems received little attention from research and development actors three decades ago. A number of regional or international organizations working in Ethiopia have recently undertaken research and development projects. In the region, efforts to include remote sensing and modeling approaches for assessing agricultural water management techniques and watershed hydrological responses have yielded promising results. The economic, environmental and social constraints to the development of acceptable RWH technologies, on the other hand, have yet to be resolved. Ethiopian farmers require technological and institutional assistance in order to develop their traditional techniques.

With sufficient backing from local research and development, but also with suitable governmental directives, the exemplary results of supplemental irrigation through RWH for enhanced agriculture in China’s dry regions might be reproduced in
Ethiopia. Farmers will be able to methodically analyze the worth of the innovations they want to investigate owing to the facilitation of farmer-driven experimentation, while academics will have a place to learn about socioeconomic and biophysical implications on farmers’ decisions to systematically apply the impacts of micro-catchment and macro-catchment RWH techniques to a catchment size.

According to an analysis of Ethiopia’s numerous indigenous soil and water conservation systems, development projects should use traditional practices in resource conservation programs. Stone bunds were first popularized in northern and southern Ethiopia once they were combined with the traditional knowledge of lynchets, locally known as ‘Daga.’ As a result, more coordinated efforts are required to establish indigenous traditions and adapt RWH approaches to the existing socioeconomic and biophysical contexts. In Ethiopia, the much-needed green revolution and climate change adaptations should combine rainwater harvesting ideas with agronomic principles.

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CONFLICT OF INTEREST

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