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# Household level rainwater harvesting in the drylands of northern Ethiopia: its role for food and nutrition security

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Today more than 800 million people around the world suffer from chronic hunger and about 2 billion from under-nutrition.

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## Contents




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## Summary

To overcome the challenges caused by climate change, and to improve food security, the Ethiopian government, together with local communities, have made large efforts by constructing rainwater harvesting techniques (RWHTs) such as household ponds, cisterns, check dams and roof water harvesting at community and household level. This study performed a literature review to synthesize research on how these efforts have had positive effects on food security in communities and household in the Tigray region in northern Ethiopia.

The result of the review indicates that the present RWHTs in the region contribute to increased crop productivity, crop diversity, livestock productivity, livestock feed, and reduced distance and time to water points. Despite the advantages RWHTs provide, their expansion to a larger region are constrained by many factors; initial investment costs, material availability and quality, risk of disease such as malaria, water loss to evaporation, limited technical design capacity and irrigation calendar skills.

This study concludes that if implemented successfully, and in accordance with local climate and geographic conditions, rainwater harvesting can serve as a powerful tool to increase reliable access to water so as to respond to the impacts of climate change and increase food and nutrition security for poor households.

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## 1. Introduction

As in many sub-Saharan African countries, most rural households in Ethiopia, especially in the Tigray regional State (northern Ethiopia), depend on rain-fed agriculture for their livelihoods (Adane, Atnafe et al. 2015, Teka, Van Rompaey et al. 2015). The agricultural productivity  in the region is constrained by various factors, for example climate change (Tesfaye and Walker 2004, Deressa and Hassan 2009) and land degradation (Teka, Van Rompaey et al. 2015).

Climate change is already happening, with multi-faceted effects on human society and the environment (Gomoro 2014). Decreasing rainfall with increasing variability, and associated trends of water scarcity, has been reported for Africa during the last 30 years (Batisani and Yarnal 2010). In the drylands of Africa, which includes northern Ethiopia, precipitation patters are erratic; the intensity of rain varies from one place to another and rainfall occurs within a limited period in a year (Asayehegn 2012). In addition, high population growth rates in drought prone areas and weak institutions coupled with low adaptive capacity have been identified as major challenges for the region (Satterthwaite, Huq et al. 2007). Many developing countries experienced repeated drought and famine that affected numerous people and their livestock (Baro and Deubel 2006). In Ethiopia, drought already occurs once every three or four years which result in increased soil loss, deforestation and pest incidence, leading to accelerated food insecurity (Fentaw 2011). The study by Tesfaye and Walker (2004), analysing rainfall data from 1950s until today, indicate that droughts have occurred in most parts of the country almost every second year (Tesfaye and Walker 2004) and the occurrence of droughts between 1965 and 2008 affected about 54 million people (EM-DAT 2010). These extreme events result in  economic losses and negative impacts on ecosystems and human health due to the warmer climates, nutrient

depletion, dissolved organic carbon, pathogens, and pesticides and salt (Mulatu, Eshete et al. 2016).
In response to the negative impacts of climate change, the Government of Ethiopia and non-governmental organizations have implemented various rain water harvesting technologies (RWHTs), defined as technologies used to collect water from surfaces on which rain falls, and subsequently storing this water with the particular aim of meeting the demand for water by humans and/ or human activities (Ilstedt, Malmer et al. 2009). RWHTs include household ponds, roof water harvestings and tanks (Nasir and Fekadu 2016). Some of RWHTs, for example ponds, locally called 'Rahya', is an old practice in some parts of the Tigray region, which is the regional focus of this study. These technologies were officially introduced to the region after the disastrous drought in 2002/2003 (Teklehaymanot 2017) to help irrigate crops, water livestock and serve as an insurance against the failure of the rains in subsequent years (Desta 2005).

Local studies, e.g. Yaebyo et al. (2015) and Teklehaymanot (2017), have studied the role of RWHTs for improving food security and climate change adaption. Their findings indicated that RWHTs improved the socio-economic standard in the society where they were introduced, as well as ecosystem services. A household survey in Guemse (Teklehaymanot 2017) indicated that 93% of households perceived that rain water harvesting can be a solution to combat the effects of climate change. However, studies were scattered over a large, and diverse, area and not organized so that they can provide satisfactory input to planners and policy makers on effective up-scaling of these technologies to other areas with similar bio-physical and socio-economic conditions.
This study aimed to explore the role of implemented RWHTs for increased food security and climate change adaptation and identify challenges and opportunities of successful implementation and up-scaling of usage in Eastern Tigray. This report is developed to review and organize information to be easily accessible for experts, planners, policy makers and researchers in their future research and development activities.

## 2. Area Description

This study focused on a selected site in the drylands of northern Ethiopia, Tigray region (Figure 1). The region has a total area of 54,572 km2 (Teka, Van Rompaey et al. 2013) and is located between latitudes 12°15'- 4°50'N and longitudes 36°27' - 39°59'E. It has a diverse topography with an altitude that varies from about 500 meters above sea level in the Tekeze gorge to almost 4000 m above sea level in the Tibet Mountain (Teka, Van Rompaey et al. 2013).

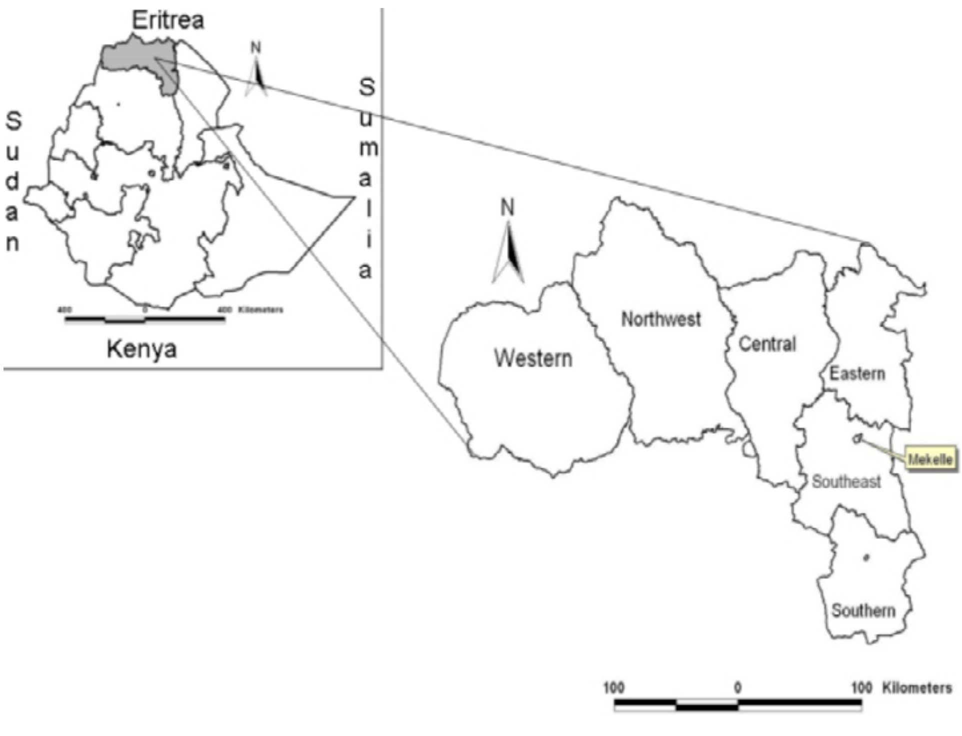


Figure 1. Location map of the study area (shaded)

Tigray is a semi-arid area characterized by sparse and highly irregular rainfall patterns and with frequent drought events (Teka, Van Rompaey et al. 2013). The main rainfall season, called 'kiremti', starts in mid-June and ends in the beginning of September. In some parts of the region, there is a second, short, rainy season called 'belg' occurring in March, April and May (Tegene 1996, Teka, Berih et al. 2014). Average annual rainfall varies from about 200 mm in the northeast lowlands to over 1000 mm in the southwest highlands (Nega 2008).

Based on the data obtained from the Central Statistical Agency (CSA 2008) of Ethiopia, Tigray had an estimated population of 4,565,000 of which 80.5 percent was rural. About 85 percent of the population in Tigray earns their living from agricultural activities, mainly rain-fed (Teka, Van Rompaey et al. 2015). Agriculture in the region consists of crop husbandry, animal husbandry and mixed farming (CSA 2008, Teka, Van Rompaey et al. 2015). Smallholder agriculture predominates with an average land holding of less than one hectare per family (Araya 2010, Teka, Van Rompaey et al. 2010, Teka and Haftu 2012, Teka, Nyssen et al. 2015, Teka 2017). The average crop yield is about 1 ton ha-1 (Teka, Van Rompaey et al. 2015). This is less than the average national annual grain yield of 1.2 ton ha-1 (Abrar, Morrissey et al. 2004).

The major soils of the region are identified as Cambisols, Luvisols, Rendzinas, Lithosols (Leptosols), Fluvisols, Nitosols, Arenosols, Vertisols, Xerosols, Regosols, Calcisols, Fluvisols and Andosols (Hunting-Technical-Services 1975, Nyssen, Naudts et al. 2008, Van de Wauw, Baert et al. 2008, Teka, Van Rompaey et al. 2010, Teka and Haftu 2012, Teka, Nyssen et al. 2015, Teka 2017).

Case studies from different watersheds and villages in the region (Table 1) were considered to assess the role of household level rainwater harvesting for food and nutrition security.

| Specific Site | District | Source |
|---|---|---|
| Gumse | Saesi-Tsaeda-Amba | Teklehaymanot (2017) |
| Gulle | Kilte-Awulaelo | Teka et al. (in press) |
| Abraha-Atsbeha | Kilte-Awulaelo | Gebregziabher et al. (2016) |
| Kalamino | Atsbi-Womberta | Gebreselasie (2017) |
| Arato | Enderta | Gebreselasie (2017) |
| Koraro | Hawzen | Gebreselasie (2017) |
| Sheka | Kolla-Tembien | Yaebyo et al. (2015) |
| Ahferom | Ahferom | Yihdego et al. (2012) |
| Degua Tembien | Degua Tembien | Wondumagegnehu et al. (2007) |
| Laelay Maichew | Laelay Maichew | Asaye (2012) |

Table 1. Short description of the sample sites

## 3. Implemented rainwater harvesting technologies (RWHTs) in Tigray

### 3.1. Overview

The common RWHTs implemented in the region are Tankers (Vasca), Ponds (Horeye), check dam ponds and roof water harvesting (Figure 2 – 5). These structures are implemented by the government by mobilizing the community, individual farmers and NGOs. Teklehaymanot (2017) indicated the farmers stood for 80 % of the implementation of RWHTs while the government, together with communities, stood for only 6 % and NGOs were responsible for 14 % of the implementation. Furthermore, according to Gebreselasie (Gebreselasie 2017), about 40% of the practices and technologies were implemented by family members, 19% by the community and 41% by NGOs.

The use of RWHTs include water for gardens, livestock, irrigation and domestic use, in addition to reduction in storm water runoff polluting freshwater bodies (Wondumagegnehu, Tsegay et al. 2007, Teklehaymanot 2017). In some cases, where access to potable water is limited, the harvested water is also used as drinking water. A study in Guemse (Teklehaymanot 2017) showed that 76% of these technologies are used for supplementary irrigation, 8% for human hygiene and 16% for livestock drinking.

## 3.2. Description of RWHTs

### 3.2.1. Household ponds

Figure 2 shows the common types of household ponds constructed in the Tigray region. These RWHTs were introduced to the region after the drought hit in 2002 and constructed on a massive scale with the purpose of providing supplementary irrigation for the main season crops, home gardening, human sanitation and drinking water for livestock (Wondumagegnehu, Tsegay et al. 2007). There is no official data on the number of ponds constructed till 2017 is not available in the region, however, the goal was to construct half a million household ponds in five years (BoANR 2004). There is an indication that this goal is not achieved as the result of poor technical skill on the design and implementation of these structures, but a large number of ponds have been constructed in the region.

Figure 2. Household pond 'horeyo', black polyethylene membrane lined (left) and cement plastered/rip rap (source: Mulu Haftu)

The majority of ponds have a design size of 12 m x 12 m x 2.5 m with a potential supplementary irrigation of 2000 m² of land after the cease of the rainfall (Wondumagegnehu, Tsegay et al. 2007). If not constructed correctly, or if they are badly managed, the potential water loss due to seepage and evaporation is high.

### 3.2.2. Tankers

Figure 3 shows the common type of tankers used in Tigray to collect and store rainwater. It involves improving runoff capacity of the land surface through various techniques including collection of runoff with drain pipes. This technique provides more opportunity for collecting water from a larger surface area so as to meet water demands during dry periods. Similar to the case in household ponds, there is a possibility of high rates of water loss due to seepage and evaporation. There is no official information on the number of tankers built in the region.

Figure 3. Household Tanker (rectangular and hemispherical tanks) (source: Mulu Haftu)

### 3.2.3. Roof water harvesting

Figure 4 shows the household roof water harvesting methods, widely used in Tigray region. Roof-water is collected in a PVC pipe attached to the corrugated iron sheet roof and cistern/ tank on the ground. This method is practiced in a way to obtain relatively clean drinking water as well as water for domestic purposes, livestock and irrigation. Roof water harvesting involves a relatively small catchment area, the size of the individual's roof of their house. Often a tap is attached to the tank for individuals to access this water (Mbilinyi, Tumbo et al. 2005). This technology is cheaper and easier to implement and manage than tanks and ponds.

Figure 4. Household roof water harvesting (source: Mulu Haftu)

### 3.2.4. Check dam rain water harvesting

A check dam is a small, temporary or permanent, dam constructed across a drainage ditch or gully to lower the speed of concentrated flows (like an overflow weir) for a certain design range of storm events (Suganthy, Sarath et al. 2016). These structures, re-enforced with cement, are used as water harvesting structures in the region (Figure 5).

Figure 4. Household roof water harvesting (source: Mulu Haftu)

## 4. Role of the implemented rainwater harvesting technologies

### 4.1. Role of RWHTs on crop productivity and diversity and tree plantations

Crop production is the main livelihood resource in the study area and farmers have indigenous technical knowledge of how to perform agriculture in this region, collected over centuries. For the dominant crops, mays an sorghum (Triticum aestivum, Zea mays, Eragrostis tef and Sorghum bicolor), crop productivity per harvest increased by 0.4 to 1.9 ton ha-1 (Alem 2003, Yaebyo, Tesfay et al. 2015, Gebregziabher, Abera et al. 2016, Teka, Haftu et al. in press) when RWHTs were introduced. These results are consistent with the findings of Ilstedt, Malmer et al. (2009) that stated that the use of rainwater harvesting have the potential to double crop yields. However, the increase in crop productivity in the region could be significantly higher; a review study in the sub-Saharan countries (Rockström, Barron et al. 2002, Biazin, Sterk et al. 2012) confirmed that a near six fold increase in crop yields have been obtained as the result of RWHTs introduction.

The implemented RWHTs have also contributed to increased crop diversity (Figure 6). In the presence of the RWHTs, vegetable crops such as tomato (67% of HHs), onion (39% of HHs), cabbage (32% of HHs) and potato (21% of HHs) were grown in Guemse area (Teklehaymanot 2017) after the end of the rainy season. About 47% of households in Gulle watershed were also growing some kind of fruits and vegetable crops compared to none before the interventions were introduced (Teka et al. in press). In addition, some farmers were using RWHTs to irrigate planted fruits,

Figure 6. Vegetables, spices and fruit trees grown (source: REST, 2012; Rämi, 2003)

Rhamnus prinoides, Citrus sinensis,, Persea americana, Mangifera indica, Citrus limon, Coffee arabica, Leucaenia leucocephala, Sesbania sesban and Eucalyptus trees at homestead (Wondumagegnehu, Tsegay et al. 2007, Teklehaymanot 2017). After RWHT introduction, about 89% of the sampled households in Guemse reported planting of more than 2500 different tree plants(Teklehaymanot 2017). Farmers, planting crops like onion during the rainy season, and brought them to harvest using pond water for supplementary irrigation, managed to maintain large sizes and experienced large benefits from the water harvesting scheme (Wondumagegnehu, Tsegay et al. 2007).

## 4.2. Role of RWHTs on household's food security

Prior to implementation of RWHTs, about 4 - 50% of the households were able to cover their annual food demand (Teklehaymanot 2017, Teka, Haftu et al. in press). The households that could not cover their own food demand by farming had to rely on: food aid, borrowing food grain from friends or purchase additional crops, significantly reducing their income. However, after the implementation of RWHTs, about 70 - 80% of households were able to cover their annual food demand (Yihdego, Gebru et al. 2015,Teklehaymanot 2017, Teka, Haftu et al. in press), indicating a significant increase in household food security. These results are consistent with the research findings of Mutekwa and Kusangaya (2006) in Zimbabwe, that reported that successful adoption of RWHTs lead to higher agricultural productivity and household income. An increase in household's agricultural growth has a direct impact on the per-capita agricultural GDP and, as substantiated in Gallup, Radelet et al. (1998), every 1% growth in per capita agricultural GDP leads to 1.6% income growth.

## 4.3. Role of RWHTs on Livestock feed, size and productivity

Feed availability through grass incorporation into the home-garden system has increased (personal observation) (Figure 7). A study in Guemse (Teklehaymanot 2017) reported an increase in livestock feed from crop residue increment by 46%, from 2.3 ton/ha in 2003 to 3.3 ton/ha in 2016 with the use of RWHTs. This results in that livestock feed availability increases throughout the year. Before implementation of RWHTs, only about 10% of the sampled households were able to feed their animal for 12 months (Teklehaymanot 2017). This implies that farmers have to look for alternative options to feed their animals during feed shortages on their own farm; borrowing feed from neighbors, friends or relatives, buying from markets or migrate with their livestock in search of feed. However, with introduction of RWHTs, about 86% of the sampled households were able to feed their livestock for the whole year. These results are in line with the findings of (Descheemaeker, Amede et al. 2010) in northern Ethiopia, and Ilstedt et al. (2009) in other African countries who reported that increased access to water led to increased animal feed.

Figure 7. Improved grass incorporated in home-garden agroforestry (source: Kassa Teka)

In most of the sampled sites, the number of livestock and the livestock size has also increased in the presence of RWHTs. RWHT user households own 13% - 80% more livestock compared to non-users (Asayehegn 2012, Yaebyo, Tesfay et al. 2015, Teklehaymanot 2017). Bee keeping is also influenced by the availability of water and forage. RWHT user households own 90% more bee colonies (Figure 8) compared to non-users (Teklehaymanot 2017).

Figure 8. Honey bee management and honey production in Tigray (source: Kassa Teka)

In addition to increased livestock type and size, livestock productivity, also improved as the result of implemented RWHTs. Milk production of a local dairy cow increased by 12–133% (Yaebyo, Tesfay et al. 2015, Teklehaymanot 2017), which is fundamentally important in the study area where milk yields are low; currently below 2000 kg cow-1y-1 (Gerber, Vellinga et al. 2011). Honey production was also reported to increase in the region from 24 – 137% (Yaebyo, Tesfay et al. 2015, Teklehaymanot 2017). The increase in forage and water availability were the major drivers for increased animal productivity. These results are consistent with the findings of Erkossa et al. (Erkossa, Haileslassie et al. 2014) who indicated rainwater harvesting as the most important means to increase agricultural and livestock productivity.

### 4.4. Role of RWHT on water availability for both human and animals

A study in Guemse (Teklehaymanot 2017) showed that RWHT introduction have played an imperative role in reducing distance to potable water points by half, from more than 60 minutes (for 72% of respondents) to less than 30 minutes (for 100% of the respondents).

The reduced time invested in transport helped farmers, and women and children in particular, to reduce water-related workload and increase time spent on their farms and increase their incomes (Malesu, Sang et al. 2006). Moreover, the reduced walking distance for livestock decreased their energy use and increased productivity (Teka et al. in press). These results are consistent with findings of Aroka (2010) , reporting that RWHTs results in more water being available closer to communities in turn resulting in less time and energy spent, both for humans and animals, on gathering water from far away Wachira (2013).

### 4.5. Role of RWHTs on HHs' socio-economic situation

As indicated in Table 7, data from household surveys reveal that rainwater harvesting resulted in increased income from crop and livestock production, contributing to increased household income. In the presence of RWHTs, the average household's income increased from 3975 birr (200 USD) to 18602 birr (930 USD) (Yaebyo, Tesfay et al. 2015, Teklehaymanot 2017). On the wealth category scale developed by USAID, categorizing household to earn 5600 Ethiopian birr per capita per year as threshold, 79% of the RWHT users and 34% of non-users were categorized to have a "high" well-being after introduction of RWHTs in a community.
The increased income has resulted in an increase in children from farming households enrolled in school. A study in

Guemse (Teklehaymanot 2017) indicated that among farmers, there was a 24% increase of children joining school in households with access to RWHTs. A study in central Tigray (Asayehegn 2012) indicated that the number of RWHT users who completed nine years of schooling is twice as high compared to non-users. Furthermore, a study in Ahferom district (Yeabyo et al., 2015) revealed that the mean of the RWHT user's education is 3 times higher than the mean of non-users.

A difference in the type of housing was also reported between RWHTs users and non-users. According to Asayehegn (2012), 66% more users than non-users own constructed/improved houses. This can be related to the increased on-farm income and increased confidence to request credit from, and the trust by, the local micro-finance. It has also been reported that RWHTs users had 11% more credit utilization compared to non-users (Asayehgn, 2012).

## 5. Hurdles for scaling up the use of RWHTs

Despite the advantages RWHTs provide, their expansion to the entire region and outside are challenged by;

- **Funding**: covering initial investments in infrastructure, personnel training, and ongoing maintenance costs may be constraining issues and require commitment and cash.
- **Material availability**: The lack of construction materials such as cement and clean graded river sand, in some parts of the region, and lack of sufficient water for construction in others, pose a constraint to implementation and add to the overall cost.
- **Potential sites for disease**: The ponds, in some areas, become potential sites for malaria vector propagation and other waterborne diseases. As ponds store run-off water, pollutants from the surrounding may flush into the ponds which may also create health issues when the water is used for drinking purpose.
- **High water loss to seepage and evaporation**: as most of the RWHTs are implemented on open areas and with poor lining materials, there is intensive evaporation and seepage which shorten the pond's/tanks life and/or its irrigation potential.
- **Limited technical design capacity and irrigation calendar skills**: limited access to skilled manpower to properly design the technology based on rainfall, runoff area and storage is a constraint to successful implementation of RWHTs. Moreover, post-harvest management skills such as the use of irrigation calendars, improving the methods of irrigation, and the use of water saving techniques is lacking in many areas.

## 6. Way Forward

Considering the key findings of this study, the following recommendations are suggested for critical consideration by researchers, planners and practitioners:

- Survey based assessments aimed at identifying the interest and capacity of the local community have to be carried out before adopting the technology to increase the chance of being successful.
- The participation of beneficiary farmers and other stakeholders is important during the planning, implementation and utilization stages of an implementation program to increase the productivity of the RWHTs.
- There is no reliable baseline data of farm performance, RWHT functioning over time, etc. This makes it difficult to plan, coordinate, budget, or manage the implementation of RWHTs. Successful implementation and up-scaling of RWHTs needs careful attention to data organization and analysis.
- RWHTs are not effective enough, because of siltation, evaporation and seepage of the structures related to designing problems, material and site selection. Thus, technical support and training to farmers and technicians is imperative. This should also be supported by improved access to credit so that farmers will have the financial means to overcome these challenges.
- The technology should be complemented with other technologies, e.g. family drip irrigation systems to effectively

utilize the harvested water and to solve labor constraints for pumping the water manually from the RWHTs and applying it directly to the crops (Gebremedhin 2015).

- Preventive measures, such as covering bodies of stored water and protecting the water from direct sunshine, could be implemented to mitigate against mosquito breeding and water loss due to evaporation.
- Fencing the water harvesting structures is essential. Most ponds are not fenced and pose a risk to children and animals.
- Integrated institutional arrangements should be promoted to co-ordinate and streamline the design, implementation and evaluation of rainwater harvesting technologies.
- Agricultural cooperatives could help share the costs of investing in RWHTs in a community. If small-scale farmers entered such groupings, it would reduce per capita cost by allowing them to pool resources and rainwater harvesting infrastructure, yielding better results as a collective than as individuals.

## 7. Conclusions

This review demonstrates that RWHTs in the Tigray region contributed to an increased food and nutrition security. This increase was demonstrated by an increase in crop productivity, crop diversity, and increased access to water points. It also resulted in an increase in livestock feed, livestock productivity and size. Despite the many advantages RWHTs provide, their expansion to the entire region and outside are constrained by many factors such as initial investment, material availability and quality, risk of disease such as malaria, water losses to evaporation, limited technical design capacity and irrigation calendar skills.

These challenges can be met by: i) complementing the technology with other water saving technologies such as family drip irrigation systems, ii) preventive measures such as covering bodies of stored water to protect the water from direct sunshine, iii) technical support and training to farmers and technicians, and iv) financing the technology through improved access to credit.

This study concludes that, if successfully implemented, and in accordance with local climate and geographic conditions, rainwater harvesting can serve as a powerful tool to increase reliable access to water so as to respond to the impacts of climate change and increase food and nutrition security for access poor households.

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