Article

Exploring factors that affect adoption of storage-based rainwater harvesting technologies: The case of Silte Zone, Southern Ethiopia

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Abstract
Intra-seasonal rainfall variability in terms of amount and distribution coupled with increasing temperature aggravates recurring drought incidences in the Central Rift Valley drylands of Ethiopia. Water harvesting and storage techniques can mitigate the adverse effects of droughts. The objective of this study was to assess the perceived causes of agro-meteorological droughts and the potential effects of storage-based rainwater harvesting technologies. In the study, secondary and primary data collected via a survey of 120 farming households from three Kebeles of the Dalocha district. Descriptive statistics such as percentage, mean, and standard deviation were used to describe sampled respondents in terms of some desirable variables. Binary logit model was used to analyze the factors that affect storage-based rainwater harvesting technology adoption. Hence, 34% of the last 32 years were severe droughts for livestock. Only 32% of the last 32 years were neither moderate nor severe droughts for livestock. Severe (34% of the years) and moderate (31% of the years) droughts for maize farming were the results of both late onset of the rainfall season and long dry spells. Only 6% of the years (2 out of 32 years) were severe drought for both livestock and maize farming implying that mixed crop and livestock farming reduces farmers' vulnerability to drought as the drought years for one farming may be good years for another. Logistic regression analyses revealed that Sex of household head, land holding size, extension service, and access to training, Total Tropical Livestock Unit (TTLU), farmers' perception and Non-farm income had significantly affected the SBRWH technology adoption decision of households in the study area. Out of both the traditional and recently introduced SBRWH technologies, the Boretta were found to be the most accepted technologies as they can store 1000-30,000 m^3 of water and the water can be used for 4-5 months of dry season. Although there were significant differences between adopters and non-adopters of SBRWH technologies in the perceptions about the benefits of, the majority of respondents perceived that these technologies can help to mitigate the adverse effects of droughts. The finding of this study indicated that, if storage-based rainwater harvesting technologies were properly implemented in large scale structures like Boretta, have the potential of improving water availability for dry spell and drought proofing.

Keywords adoption; rain water harvesting; smallholder farmers; technology.

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1 Introduction

Ethiopia, a developing country in Sub-Saharan Africa, is the continent's second most populated country; with a projected population increase from 40 million in 1984 to 94.351 million in 2017 (Adugna et al., 2018). It covers a total area of 1.13 million square kilometres, with 65 percent of it suitable for agriculture. Agriculture is the country's most important economic sector, accounting for approximately 46% of GDP, 83.9 percent of total exports, and employing over 85% of the working population (World Bank, 2018).

Agriculture in Ethiopia is heavily reliant on rainfall, and both productivity and production are heavily influenced by climatic and hydrological variability, which manifests itself as inter-annual and inter-seasonal rainfall variability, declining rainfall amounts, and in-season dry spells, which combined with rising temperatures, exacerbates recurring drought incidences (Fitsume et al., 2014). Droughts and floods are becoming more regular, with major catastrophes occurring every 3 to 5 years, compared to two or three decades ago (Fitsume et al., 2014). The great majority of rural poor people rely on rain-fed agriculture to survive, putting them exposed to highly variable and unpredictable rainfall. Even in years with "average" rainfall, ten to fifteen days without rain during a critical stage of crop development might spell disaster for hundreds, if not millions, of poor farmers (Awulachew et al., 2006). Water harvesting systems have played a vital role in enhancing the efficient use of rainfall and increasing the sustainability and reliability of rainfed agriculture, among other coping mechanisms (Biazin et al., 2012; Lupi and Mamo, 2018). In order to enhance the availability of precious water for both rain-fed and irrigated agriculture in dry land areas, the Ethiopian government has been active in the development of various water harvesting facilities (Alem et al., 2015). Rainwater harvesting has a long history in Ethiopia, dating back to the Axumite Kingdom about 560 BC (Habtamu, 1999). Even today, in Ethiopia, there are various traditional rainwater gathering devices that have been employed by communities in locations where water is scarce (Meselech, 2014). The Konso people in the south of the country have a long and well-established tradition of creating level terraces to catch rainwater in order to effectively grow sorghum in a tough region with low, unpredictable, and variable rainfall (Hailemichael, 2011).

Following droughts in Tigray, Wollo, and Hararge in 1971-1974, water collection was pushed in Ethiopia as a way to supplement rainfed agriculture. Ethiopia's Water Policy was recently created by the Ethiopian government. For example, the federal government only allotted ETB 100 million and ETB 1 billion for food security initiatives to all regions in the fiscal years 2002/2003 and 2003/2004, respectively. The regions used a large portion of this money to execute water harvesting initiatives, such as the construction of domestic ponds and cisterns (Rami, 2003).

Dalocha area, located in the scorching Great East African Rift Valley, is known for irregular rainfall, frequent droughts, agricultural failure, and a lack of permanent water sources such as streams and lakes. Dijo is the only river that crosses the district and only few villages having access to this river. People from vast area of the district had to travel for several hours to get water from the river (DWoFED, 2017). Except for a few kebele administrations along the Dijo River's flow, the rest rely entirely on rainfall for crop production. The main rainy season for growing food crops is "Meher", which lasts from June to September. The occurrence of rainfall is unreliable even during the primary producing season. Rainfall is common in the area, with late or early occurrence, uneven distribution, interruption, and insufficiency (Aziz and Tesfaye, 2012).

During the "belg" season, the few showers that fall can only support a little amount of grass for animals. As a result, the local government, in collaboration with NGOs and the community, is introducing Storage-Based Rainwater Harvesting Technology for crop production, providing water for domestic and livestock consumption, improving food security, and increasing resilience to recurring droughts through more efficient use of scarce water resources (DWoANR, 2017). Despite the technology's potential for enhancing agricultural productivity and livelihoods, farmers have been slow to adopt it (Tesfaye, 2008). Some storage-based RWH structures that have been built before and have water are not being utilised effectively. This could be due to a variety of socioeconomic, institutional, and biophysical variables (Aziz and Tesfaye, 2012). Inadequate participation by local farmers in the introduction and implementation process was another major factor in the low adoption and/or failure of the adoption process. This will allow us to show that the decision to utilize the SBRWHT is based on how smallholder farmers perceive it in the area, and to better understand their decision-making process (Angela, 2013). Hence this study focuses on objectives of the study: (1) To assess Existing Storage-based RWH structures in the study area; (2) To Examine the investigate smallholder farmers' perceptions of drought, and (3) To Estimate factors that affect Farmer’s adoption decision of rain water harvesting.

2 Study area and Methodology

2.1 Study site

The study was conducted in the Rift Valley nearly 160 km southwest of Addis Ababa, which is the capital city of Ethiopia. Geographically, it located at 8 0 02 ' 36.1" N & 38 0 10' 8" E and 7° 42' 0N & 38° 12' 0E and altitude of 1835 m above sea level. The Storage based rain water is situated in a remote area 15 km from a small village in the rural area of Siltie Dalocha district.

2.2 Data collection

Primary data was gathered through a variety of methods, including a household survey, key informant interviews, focus group discussions (FGD), personal observation of the built structures, and participation in events related to the technology.

To acquire quantitative data, the most common way was to conduct a household survey. A structured questionnaire was created and used, comprising both open-ended and closed-ended questions. The questionnaire was administered by three enumerators in each Kebeles under the supervision of the researcher. Development agents (DAs) and students stationed in the Kebeles for practical training were the enumerators. The questionnaire was translated into Siltigna and provided to the enumerators, who assisted in properly filling out the form.

FGDs and key informant interviews are excellent sources of comprehensive information that cannot be gathered from a survey. A key informant interview was done to learn more about the general state of the program's implementation, farmers' perceptions of drought and technology, and challenges with SBRWH uptake, among other things. Elderly people, model farmers, administration officials, development agents (DAs), zonal and woreda experts are among the main informants.

FGD was one of the methodologies used in the study to generate qualitative data, such as farmers' perceptions of the drought and the performance of SBRWH structures. In each kebele, two focus groups were held, one with technology users and the other with non-users, with a total of 6 to 8 people in each.

The study also used secondary data from a variety of sources in addition to primary data. The Ethiopian Rainwater Harvesting Association (ERHA), Dalocha District Agriculture Office, Office of Finance and Economic Development, and Local Government Units principally administrative offices were the main sources of published and unpublished documents. Furthermore, the Ethiopian Meteorological Agency provided long-term meteorological data that represented the study area.

2.3 Analysis data

Depending on the objective of the study and nature of data available analysis to be made requires different approaches. Descriptive analysis and econometric models were used to estimate relationships and hypothesize the problem. Descriptive statistics were used to summarize farmers’ perceptions regarding the trend of rainfall and about storage-based rainwater harvesting practiced in the area. To summarize various properties of the sample respondents, descriptive statistics such as mean, percentage, and standard deviations were used. To examine if there are significant mean and proportion differences across groups in terms of different explanatory factors, inferential statistics such as the chi-squire test and the t-test were utilized. Statistical Package for Social Science (SPSS) version 22 software was used to compile and analyze the data. The yearly and seasonal patterns of rainfall and temperature were investigated using Microsoft Excel to handle daily rainfall and temperature data.

3 Results and Discussion

3.1 Existing storage-based RWH structures

The field study disclosed that different types of storage-based RWH systems present in the study area. Many SBRWH technologies at household level have been evolved with support of the Government, and especially household ponds can be found in almost every Kebele. The household (HH) ponds have a trapezoidal shape and water holding capacity of 60 – 180 m^3 (Fig. 1). Most of the surveyed farmers with HH ponds have begun to use the technology since the year 2003/04 during which the government started comprehensive implementation of RWH at HH level.

Fig. 1 Left: Plastic lined, and Right: Cement lined HH ponds in Dalocha district, CRV (Photo by the Author, 2019).

Fig. 2 Traditional community ponds in Dalocha district, CRV (Photo by Author, 2019).

There are also traditional community managed ponds that are present in the area. Some age old farmers cited that community ponds in the woreda are constructed during Hailessilese (at least 45 years ago) and the Derge regime (about 30 years ago) mainly as a source of drinking water for domestic and livestock (Fig. 2). The surveyed storage-based RWH systems mainly harvest runoff from either natural catchment located adjacent to the ponds or from roads, footpaths and cattle-tracks. In a similar manner Moges (2009) has found that most of community ponds were constructed in long period of time and used for domestic use, livestock drink and other purposes in Central Rift Valley of Ethiopia.

Currently the most widely practiced storage based water harvesting technique was the hillside earth dams which were constructed by hillside gully plugs and locally known as “Boretta” (Fig. 3). These structures provide a large amount of water for people, livestock and plants during the dry season. According to key informant’s interview, farmers’ demand for these structures was increasing following the recent (2015/2016) drought caused by El-Niño in the study area. Similar studies have found that hillside earthen dams indirectly benefit up to thousands of people, as the use of the stored water is never restricted to the people who built the technique (Jacob, 2011). The hillside earth dam has potential to provide a large amount of water approaches to 30,000 m^3 and for up to 1,200 people, animals, tree nurseries and vegetable gardens. A semi-circular hillside earth dam is one of the safest designs, as it has a natural spillway at each end of the dam walls which allow runoff to safely overflow (Nissen-Petersen, 2015).

Fig. 3 Currently introduced hillside gully dam (Boretta) in Dalocha district, (Photo by Author, 2019).

3.2 Farmers’ perceptions on performances of SBWH structures

One of the important performance measurements for a water storage structures knows the "residence time" of the water in the storage structure. Residence time is how long water resides in the storage structure, from the time it enters the structures to the time it gets finished upon farmer’s utilization for different purpose. About 68% of sampled respondents agree that the harvested water in small ponds may stay and be consumed for two up to three months following harvesting. But majority of the respondents 86% and 67% of them indicated that once the water is harvested in Boretta and traditional ponds it can serve from three up to four months respectively, whereas 57% of them revealed that water stored in Boretta serves four up to five months; 45% of respondents also agree that traditional community ponds stay for 4-5 months (Fig. 4). This implies that, in the study area if farmers properly implemented and used storage based rainwater harvesting in large storage capacity structures, it would reduce the impacts of droughts. This finding is in line with Ngigi et al. (2005) they conclude that the reliability of storage-based RWH technologies can be improved by increasing catchment area and storage capacity.

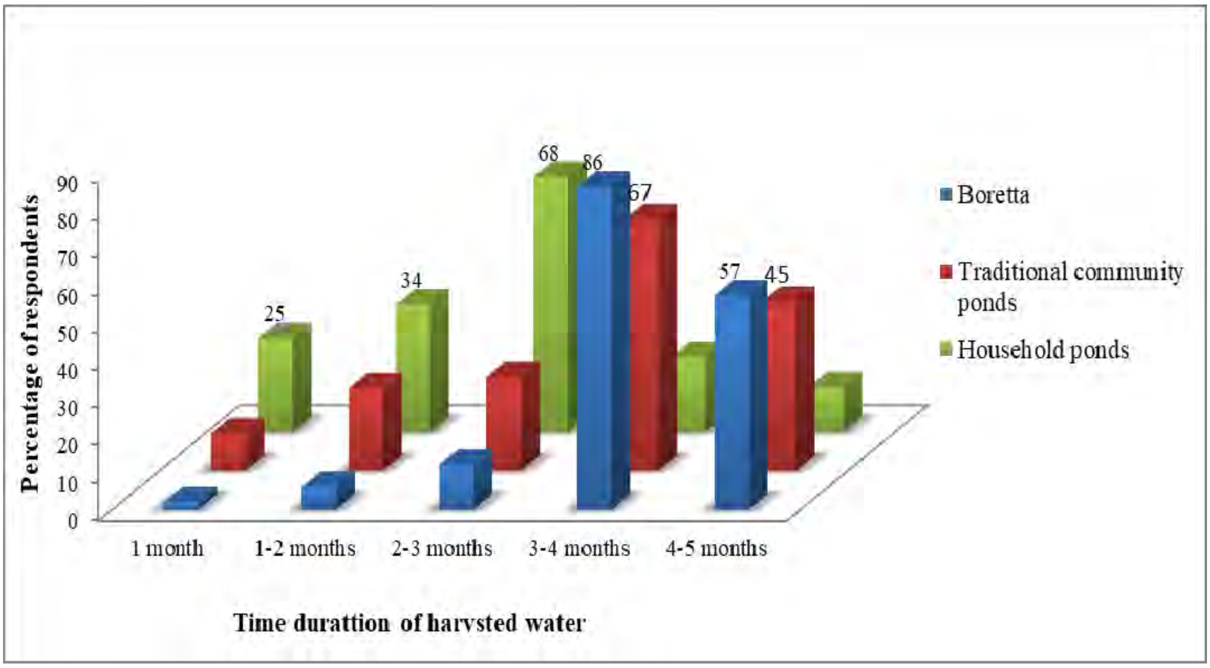

Fig. 4 Duration of harvested water in Dalocha district.

3.3 Estimating factors that influence adoption of SBRWH technology

In the previous section, we have dealt mainly with description of the sample population and test of the existence of association between the dependent and explanatory variables to identify factors affecting adoption of SBRWH technology. Identification of these factors alone is however not enough unless the relative influence of each factor is known for priority based intervention. In this section, logit econometric model was used to see the relative influence of different socio-economic, institutional, psychological and bio-physical variables on adoption and intensity of adoption of storage based rainwater harvesting technology.

Out of the total hypothesized variables, 7 of them found to significantly affect the probability and intensity of use of SBRWH technology were promoted for further analysis using the logit model. These were sex of respondents, land holding size, number of livestock owned in tropical livestock unit, farmers contacts with extension agents, farmers participation in training and farmers perception to SBRWH technology.

Before running the logit model all the hypothesized explanatory variables were checked for the existence of multi-collinearity problem (Zhang, 2022). VIF (variance inflation factor) was used for testing the association between the hypothesized continuous variables and contingency coefficient which is χ^2 (chi-square) computed for dummy variables. To avoid the problem of multi-collinearity, it is essential to exclude the variables with the high VIF value (10) for continuous variables and for categorical variables values of contingency coefficient ranges between 0 and 1, with zero indicating no association between the variables; values close to 1 indicating high degree of association.

Table 1 Estimation factors affecting adoption of SBRWH technology.

Explanatory Variables	Coeff.	S.E.	Z	P	Odds Ratio
SEXHH	2.215	1.073	4.260	0.039**	9.157
AGEHH	-0.016	0.033	.232	0.630	.984
EDUL	0.301	0.441	0.465	0.495	0.740
HHLSZ	0.212	0.218	0.943	0.331	.809
NONFAM	1.171	0.696	2.827	0.093*	3.225
OFFFAM	1.026	0.727	1.990	0.158	0.358
LNDSZ	1.509	0.607	6.194	0.013**	0.221
TLTLU	0.326	0.163	3.996	0.046**	1.386
EXTSR	3.062	1.225	6.250	0.012**	21.381
TRAINI	2.249	0.975	5.322	0.021**	9.481
MKTDS	-1.198	0.787	2.319	0.128	3.314
FAMPER	2.579	1.201	4.609	0.032**	13.180
SLOP	-0.787	0.790	0.993	0.319	0.455
Constant	-3.927	3.216	1.491	0.222	0.020

Likelihood function = 72.709; Model chi-square test = 86.066; Number of cases 120; **, * represent significance at, 5% and 10% probability levels, respectively.

3.4 Interpretation of Empirical Results

Among the explanatory variables hypothesized to influence utilization of storage-based rainwater harvesting technology, seven of them were found to be statistically significant at less than or equal to 10% probability level. These factors include sex of the household head, non-farm income source, contacts with extension agents, livestock holding, and land holding size, participation in training and farmers perception towards the technology. The effects of the model estimates were interpreted in relation to the significant explanatory variables in the model as follows:

Sex of household head: The positive and significant sign on SEX indicated that the probability of adoption of storage-based rainwater harvesting technology was higher for men than women farmers. Based on the regression result this variable was significant at 5% level with favor of male headed households indicating that being female headed might mean having low resource ownership, relatively low physical labor and poor access to information. This is in line with research finding of Adesina et al. (2000) and Aziz and Tesfaye (2013) who concluded that male farmers have a greater likelihood of adoption of alley cropping and its variants than female farmers in Cameroon and rain water harvesting technology in Ethiopia respectively.

Land size: Land is the main asset of farmers in the study area. Land holding size was positively related to the utilization of SBRWHT and significant at ($P \leq 0.05$). The odds ratio of 0.221 for availability of farm size implies that, other things being constant, the decision to use storage-based rainwater harvesting technology increases by a factor of 0.221 as farm size increases by one hectare. This finding is in-line with those of previous studies (Samia Akroush et al., 2020; Jafer, 2014). They reached to similar conclusion result also reveal a significant relationship between land tenure and adoption implying higher adoption rates on communal land as opposed to privately owned land.

Livestock holding: Tropical livestock unit, which is a proxy for measuring wealth status of household head, is found to have a positive and significant ($P \leq 0.05$) influence on adoption of storage-based rainwater harvesting technology, indicating that farmers with large number of livestock are more likely to adopt SBRWHT than others. The odds ratio for livestock holding is 1.386, implying that having one more livestock in tropical livestock unit increases the probability of adoption of SBRWHT by 1.386. This is because farmers with relatively more livestock unit make use of their income obtained from sale of livestock and their byproducts for the purchase of modern inputs for excavating storage based rainwater harvesting structures. Also farmers have seen their livestock as their major income source and as a prestige, so they worry about the risk of drought that results on death of their livestock. The study is supported by Aziz and Tesfaye (2013), Dahir (2017), Nasir and Fekadu (2017) and Abriham (2018) which confirms the same result.

Extension Contact: Farmers with more frequency of extension contacts are more likely to adopt SBRWHT than those with less frequency of extension contacts. This variable was significant at 5% (P=0.012) significance level and positively affect the adoption decision of farmers. The odds ratio for extension contact was 21.3 and it implies that increases in one more number of contact with development agents during water shortage season, increased the likelihood of adopting SBRWH technologies by 21.3 ceteris paribus. The result agrees with the finding of Abadi and Tesfaye (2006), Yismashewa (2014), James (2015) and Abriham (2018) who revealed that there was significant and positive relationship between frequency of contact with extension agent and adopting of improved technologies.

Training: The model result indicates that it affects the decision of farmers to adopt SBRWHT practices positively and significantly at ($P \leq 0.05$). The odds ratio of utilization of RWHT by a farmer increases by a factor of 9.481 as member of a household is trained in the given storage-based rain water harvesting technology. The result of this study is in agreement with the findings Yismashewa (2014) and Aziz and Lutta et al. (2020) who explained The results show that access to extension services and training, level of monthly income, main source of livelihood, land tenure, membership in social groups and availability of active farm labor significantly influenced the adoption of water harvesting structures.

Farmer's perception toward SBRWHT: In this study smallholder farmers were asked whether they had positive or negative perception towards the SBRWH technology. Mangisoni et al. (2019) stated that underscore the potential gains from rainwater-harvesting technologies in improving farmer income and food security, and the need to promote the technologies as a package, because a household may implement different technologies on the same field depending on diverse social, economic, institutional and environmental factors. while Yengoh et al. (2010) stated that a smallholder famer who has a positive attitude adopts the RWH technologies at a higher rate than those smallholder farmers who have a negative attitude. In this study, this variable has a statistically-significant positive effect at 5% on adoption of SBRWHT; i.e., farmers who have positive perceptions towards SBRWHT are more likely to adopt it. The coefficient for perceptions was 2.579 (Table 1). This suggests that if famers' perception towards SBRWH technology increases by 1 unit, more people will adopt this technology by 2.579 units. The odds ratio for this variable was 13.180, this also imply that a farmer who has a positive perception is likely to adopt SBRWHT at 13 times the odds of a farmer who has a negative perception. This finding is in lined with He et al. (2007), James (2015) and Shange (2015) who report that when farmers' perception/attitude towards RWHT is positive then a household is expected to subsequently adopt this technology.

Non-farm income: Non-farm income is a critical determinant of adoption of storage-based rainwater harvesting technology. The findings suggest that in presence of credit constraints, nonfarm income, including remittances, can induce investment in modern agricultural inputs. The model result indicates that the variable correlates positively with the utilization of SBRWHT and was significant at ($P \leq 0.10$) probability level. The result of this study consistence with the finding of Diiro and Sam (2015) and disagree with the findings of Yismashewa (2014) who concluded that non-farm income has negative relationship with adoption of water harvesting technology.

4 Conclusions

The results of the study revealed that almost all of smallholder farmers have positive perception for SBRWH technologies as it reduces drought and erosion impacts. Storage-based rainwater harvesting helps to reduce vulnerability of communities arising from the shortage of water induced by temporary or permanent changes in the climate and/or the depletion of the water resources. Household ponds with plastic and cement lined and earthen ponds without any lined material, traditional community ponds, sand dams and gully plugs (Boretta) are the major storage-based RWH technologies in Dalocha District. The harvested water from Storage-based technology was greatly used for domestic use, livestock drinking, and for off-season and supplemental irrigation. Farmers also use harvested water for mud preparation when they construct houses.

The result of the binary Logit model revealed that sex of household, land holding size, livestock holding in tropical livestock unit, extension service, access to training, farmers perception towards SBRWH technology and having non-farm income were significant at ($P\leq0.10$) probability level and found have a positive related with adoption of Storage-based RWH technology in Dalocha District.

5 Recommendations

Based on the findings and conclusions of the study, the following recommendation remarks can be drawn for further consideration in the region in particular and in the country at large:

(1) SBRWH technologies are found to be important to the local communities to mitigate the adverse effects of droughts for both livestock and maize farming. Hence, future extension effort should focus on scaling these technologies to the wider non-adopter communities thus by enhancing the capacity of the farmers in the proper establishment and maintenance of the technologies.

(2) Although the Boretta structures have been found to be important for domestic, livestock and crop production, their construction costs are very high. Therefore, external supports are required in the construction of these structures in appropriate sites using the machinery systems.

(3) Extension service and training were determining factors that hinder the adoption of the technology. Therefore, there is a need to provide training and extension services to farmers, to develop and disseminate more effective and affordable types of rainwater harvesting and storage technologies

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