Evaluation of the sustainability of existing rainwater harvesting ponds: A case study of Lay Gayint District, South Gondar zone, Ethiopia

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ABSTRACT

In most of the water-scarce areas, rainwater harvesting (RWH) ponds are essential for meeting the stress of water for various purposes. Besides the performance and sustainability of those rainwater harvesting ponds were not evaluated. This study aimed to evaluate the sustainability of existing rainwater harvesting ponds in Lay Gayint District, Ethiopia. The specific objectives of this study were; (1) to assess the perception of farmers on the potential of RWH ponds, and (2) to identify factors influencing the sustainability of RWH ponds. The demographic characteristics of farm households; farmers' perception about RWH ponds; and the socio-economic conditions of households were collected using household surveys and focused group discussions. The collected data was analyzed through quantitative and qualitative data analysis methods. The results of this study revealed that almost all farmers did not have good perceptions of ponds and had not gained enough awareness of the advantages of ponds. The utilization of the ponds was surrounded by constraints like poor quality and short lifetime of the constructed ponds; low involvement of farmers within the construction of ponds; and wrong-site selection. The incidence of local disputes among the farmers was the most important impact that un-utilized ponds have exerted on the community. About 78 % of the ponds were found in a failed state and 75 % of the ponds have no fences. The construction of RWH ponds in rural districts was based on a quota system which resulted in low sustainability. About 72.2 % of the respondents have not participated in the construction of RWH ponds, on the other hand, 81.5 % didn't get any training about RWH. The majority of the respondents replied that they have no money for constructing and maintaining their ponds. Due to the different factors most of the RWH ponds didn't store and serve for the designed service period which failed to satisfy the water demand. The government shall give attention to the sustainability of ponds by facilitating the involvement of Non-Governmental Organizations (NGOs) in capacity building, technical and financial support.

1. Introduction

Rainwater harvesting (RWH) is an ancient technology practiced in many parts of the planet like North America, the Middle East, North Africa, China, and India. In Israel, complete rainwater harvesting systems are found within the Negev Desert, which was about 4000 years old (Girma, 2009; Oweis, 2004). RWH ponds are the widely used technologies following a shortage of water. These are techniques where rainwater is intercepted and used 'close' to where it first reaches the earth's surface either from roofs or ground surface (Thomas and Martinson, 2007).

The small-scale collection of rainwater from the roofs into traditional jars and pots has been practiced in Africa and Asia for thousands of years (Ruth, 2014). Rainwater is harvested in rural and urban areas, from natural or artificial surfaces, like roofs, roads, pavements, ground catchments, or slopes (Laura, 2014). In Ethiopia, rainwater harvesting pond packages provide water for humans, livestock, and residential garden horticultural crops (Desta, 2006; Alem, 1999; Amha, 2006).

The present water scarcity leads to a new paradigm in water resources management, and therefore the application of sustainable water supply solutions is essential (Uribe et al., 2015). However, rainwater harvesting ponds are not sustained by the influence of local biophysical and socio-economic parameters influencing water harvesting and water use processes (Mizyed, 2008). According to Erickson (2012), the socio-economic factors influencing the sustainability of rainwater harvesting ponds were categorized in household variables (gender, education, and age) and economic variables (wealth...
status, access to credit, social status, and household members’ perception).

The government of Ethiopia promotes rainwater harvesting ponds to fight food security problems. Some critics have minimized its role within the context of acute land scarcity, absolute poverty, vulnerability to malaria, and abundance of rivers within the country (Daniel, 2006; Nega, 2004; Emishaw, 2009). The Agriculture and Rural Development Office (ARDO) of Lay Gayint District was engaged in the implementation of rainwater harvesting ponds since 2013. Accordingly, many ponds were dug in the nine rural kebeles of the District by governmental and non-governmental organizations. The constructed ponds have no better quality and most of them do not seem to be productive and sustainable (ARDO, 2018).

In the study area, most of the rainwater harvesting ponds failed due to various constraints. The existing failed ponds on the farmers’ plot have become additional constrictions to the local community (ARDO, 2018). Therefore, investigating the factors affecting the sustainability of ponds and the perception of farmers’ on RWH ponds in Lay Gayint District could be a vital issue. This study was conducted to evaluate the sustainability of RWH ponds with the subsequent specific objectives: (1) to assess the perception of farmers on the potential of RWH ponds, and (2) to identify factors influencing the sustainability of RWH ponds. This study may help policymakers in planning the strategies for encouraging households to sustain water harvesting and storage technologies.

2. Methodology

2.1. Study area description

Lay Gaint District is found within the South Gondar Administrative Zone of the Amhara National Regional State. It lies within 11° 04’ to 12° 10’ N latitude, and 38° 12’ to 38° 37’ E longitude (Figure 1), and covers an overall area of 1,522.43 square kilometers composed of 26 rural kebeles. Lay Gaint is the fifth largest District and accounts for 11% of the overall area of the South Gondar Administrative zone. The District town, Nefas Mewcha is found 741 km far from the capital of Ethiopia and 175 km far from the regional town, Bahir Dar (EDHS, 2012). According to Lay Gayint District Agricultural Development Office/LGDARO/(2011), the minimum and maximum temperatures in the District are 5 °C and 24 °C respectively. It has two rainy seasons that are Belg (little rain) and...
Kirmet (heavy rain) with erratic distribution varying from 600 mm to 1200 mm (LGDADO, 2018).

2.2. Study approach

2.2.1. Research design

To gather adequate information that meets the stated objectives of the research, both qualitative and quantitative methods were employed during this study. This research has no ethical issue that does not need ethical approval. The collected data were coded, entered, and checked for consistency before keying into the SPSS (Statistical Package for the Social Sciences) software for further processing.

2.2.2. Sampling techniques and procedures

Among the South Gondar Administrative Zone, within the Lay Gayint District the adoption and implementation of RWH ponds are common as compared to other districts (ARDO, 2018). Most of the RWH ponds constructed within the District don’t seem to be giving service to the community (South Gondar ARDO, 2018). Due to this, the Lay Gayint District was selected purposively to identify the factors that affect the sustainability of ponds. This District comprises 25 rural kebeles that have on-farm RWH ponds and one urban with no RWH pond. A simple random sampling method was used to select farm household heads who participated in this survey.

From the 25 rural kebeles, Titra (Dega-highland), Barthiba (Woinadega-mid highland), and Amba Mariam (Kolla-lowland) were selected to represent the study area supported the agroecology conditions. From three kebeles, 108 households (28 were pond users and 80 non-users) were systematically selected for the interview and focused group discussion (Table 1).

2.2.3. Methods of data collection

The sources of data for this research were both primary and secondary data sources.

2.2.3.1. Primary data sources. Household survey: Structured closed-ended and open-ended questions were used to gather primary household data at the village level. Accordingly, the demographic characteristics of farm households; farmers' perception about RWH ponds; and the socio-economic impacts affecting the sustainability of ponds were collected.

Key informant interviews: Unstructured interviews were done with ARDO experts, development agents, and purposively selected pond user and non-user household heads.

Focus group discussion: The focus group was composed of six peasant association leaders selected from the sampled kebeles. The in-depth discussion was led by the researcher to possess perceptions over the RWH ponds.

2.2.3.2. Secondary data sources. In this study, published and unpublished materials including reports, journals, articles, books were used.

2.2.4. Methods of data analysis

The quantitative data collected from the questionnaires were analyzed using SPSS (Statistical Package for Social Science version 20.0) and the result was presented using percentages and tables. The qualitative data collected from respondents’ opinions and suggestions were analyzed using content analysis and in-depth probing.

3. Results and discussions

3.1. Demographic and socio-economic characteristics of sample households

Educational status, age, and land ownership are important factors for RWH technology adoption and utilization. About 55.56 % of the respondents were within the age range between 29 and 48. The academic level of households was found to be 48.15 % illiterate, 34.26 % read and write, and 17.59 % primary and above educations (Table 2).

About 46.25 % of non-users of RWH were found illiterate. The low level of education attained limits the farmers’ access to information and also the adoption of new water resources management techniques. This might have resulted in the reluctance to adopt and utilize new RWH technologies. In most of the RWH adoption studies, farmers with higher levels of educational attainment are more likely to adopt/practice rainwater harvesting techniques as compared to less educated farmers (Chianu and Tsujii, 2005).

About 35.71 % of RWH users and 33.75 % of non-users of RWH do not have land for cultivation (Table 2). The absence of land ownership was found to be a negative impact on the adoption of rainwater harvesting technology. Farmers who had farms were, less likely to adopt the water harvesting techniques. This however contradicts research findings by Buyinza and Wambede (2008) who reported that farmers who had large farmlands were more likely to adopt rainwater harvesting techniques.

3.2. The implementation and utilization of RWH ponds

A total number of eight operational ponds were surveyed, out of which five were constructed by individual farmers, and the remaining three were constructed by the local government (Table 3). Based on this, 50 % of the ponds were constructed in 2012/13 and 25 % of them in 2013/14. The remaining 25 % of the sample ponds were constructed in 2014/15 and 2015/16 (Table 4).

The excavated only, geomembrane lined, and cement-lined type of ponds are common in the study area. About 75 % of the ponds were only excavated type which might have problems in storing water effectively since a significant amount of water seeps from the pond (Table 5).

Awareness about RWH and utilization of ponds have a positive impact on the adoption of RWH technology. This initiates them to get involved in RWH technology adoption. Thus, about 61.1 % of the sample households have no information about rainwater harvesting before getting involved in the technology (Table 6). Only 39.3 % of the RWH users had information about RWH before getting involved in using RWH ponds.

The government assistance in RWH was also evaluated using focussed group discussions (FGDs). Form FGDs it was found that about 67.9 % of RWH pond users did not get any assistance from kebele, and district officials in promoting and financial support for maintenance (Table 7).

3.3. Perception of farmers towards RWH ponds

The participation of stakeholders during the initial stage, design and implementation of RWH ponds is that the major factor for the success of the technology adoption. The top-down approach within the adoption and adaptation of the ponds to the local situation led to considerable resistance by farmers to easily accept the intervention (Melete, 2007).

According to the woreda agriculture and rural development, and kebele development agents response, the community fully participated (as labor) during the construction of ponds through the mobilization performed by the food for work program. This was done to maximize the acceptance of the technology by the community. After 2015/16 the

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Table 1. Sample size of farm HH heads.

| Sample Kebeles | No. of households | No. of sample households |
|----------------|-------------------|-------------------------|
|                | Total             | Users | Non-users | Sum  |
| Titra          | 704               | 12    | 33        | 55  |
| Amba Mariam    | 659               | 7     | 26        | 33  |
| Barthiba       | 797               | 9     | 31        | 40  |
| Total          | 2160              | 28    | 80        | 108 |

* Kebele—the smallest administrative unit of Ethiopia.
development of ponds by the government was stopped and farmers were not interested to invest in the development of ponds. Due to this, most farmers were not benefited from the adoption of ponds and had no good perception of the development of ponds in the area.

As indicated in Table 8, about 7.4% and 13.9% of the respondents rated the success of RWH ponds as successful and moderately successful respectively, on the opposite hand, about 78.7% of the respondents stated that RWH ponds are not successful (failed) because of the technical, institutional, and environmental factors.

As presented in Table 9 above, about 63.1% of the respondents expressed that the expansion of the RWH ponds does not affect their farm plots whereas about 38.9% of the respondents believe that their plots are not narrowed by the expansion of RWH ponds.

3.4. Factors affecting the sustainability of RWH ponds

RWH could also be a cross-cutting issue. It is a complex interface within the environment, economy, social, health, and policy (Daniel, 2006). In Ethiopia, since the adoption of RWH technology, it is surrounded by constraints that have the character of varying from place to place and from time to time. The factors that affected the sustainability of ponds were technical problems, institutional and environmental factors.

3.4.1. Technical problems

The absence of fences, roof covers, and silt traps was identified as the main technical constraints that affected the sustainability of ponds. About 75% of the ponds had not any fences and all the ponds did not have any roof covers (Table 10). The absence of roof covers in RWH ponds resulted in the loss of a significant portion of the water stored through evaporation. The presence of fences protects the edges of ponds from being eroded and entry of debris to the pond.

Sediments generated from the encompassing area were identified as a major constraint affecting the sustainability of ponds. The interviewed ARDO experts disclosed that almost all of the ponds were constructed without a silt trap. Through time the accumulated sediment might reduce the water holding capacity of the ponds. Hence the excavated only type of

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ponds was found the foremost sensitive for sedimentation than geomembrane and cement-lined types (Table 11).

In the absence of roof covers, the stored water decreases in a short period. This is because the uncovered ponds lose a significant portion of their water through sedimentation and evapotranspiration (Ahmed et al., 2015).

3.4.2. Institutional factors

At the initial stage, RWH ponds were adopted as a "quota system" to adapt the community to the technology. To satisfy the quota, the authorities were pushing the experts to dig as many ponds as possible. The ARDO experts revealed that the technology was expanded in many parts of the district without considering the environmental and social differences.

The participation of farmers in the implementation of the ponds could increase the sense of ownership and sustainability of the constructed ponds. But about 72.2% of the households have not participated in the site selection, design, construction, and maintenance of the RWH pond which might reduce the sustainability ponds (Table 12).

Onsite training about the operation and maintenance as well as water use and management aspects are highly essential to RWH users that could maximize the return obtained from the technology. Hence the absence/shortage of training for farmers was found to be a problem for promoting and sustaining the constructed ponds in the study area.

As revealed in Table 13, about 81.5% of farmers didn't get training over the operation and maintenance of ponds. Community participation enhances skill development and a sense of ownership that ends up in the effective implementation and therefore the sustainability of ponds (Mamburi, 2014; Olukotun, 2008; and Rimbera, 2012). Hence, there have been no active involvement and awareness creation to the farmers that would minimize the sustainability of rainwater harvesting ponds (Mamburi, 2014).

### Tables

| Table 6. Households’ information about RWH before getting involved in the technology. |
|---------------------------------------------------------------|
| Have information either from the government or neighbors before getting involved in RWH | RWH Users | RWH Users (%) | RWH Non-users | RWH Non-users (%) | Total | Total (%) |
|---------------------------------------------------------------|
| Yes | 11 | 39.3 | 31 | 38.8 | 42 | 38.9 |
| No | 17 | 60.7 | 49 | 61.3 | 66 | 61.1 |

| Table 7. Assistance of government in RWH ponds. |
|------------------------------------------------|
| Is there government assistance in RWH? | RWH Users | RWH Users (%) | RWH Non-users | RWH Non-users (%) | Total | Total (%) |
|------------------------------------------------|
| Yes | 9 | 32.1 | 17 | 21.3 | 26 | 24.1 |
| No | 19 | 67.9 | 63 | 78.8 | 82 | 75.9 |

| Table 8. Farmers perceptions about the success of RWH ponds. |
|-------------------------------------------------------------|
| How do you rate the success of RWH ponds in your village? | RWH Users | RWH Users (%) | RWH Non-users | RWH Non-users (%) | Total | Total (%) |
|-------------------------------------------------------------|
| Successful | 5 | 17.9 | 3 | 3.8 | 8 | 7.4 |
| Moderately successful | 4 | 14.3 | 11 | 13.8 | 15 | 13.9 |
| Failed | 19 | 67.9 | 66 | 82.5 | 85 | 78.7 |

| Table 9. Perception of farmers on the expansion of RWH ponds. |
|-------------------------------------------------------------|
| Do you think that expansion of RWH ponds have narrowed down your plots? | RWH Users | RWH Users (%) | RWH Non-users | RWH Non-users (%) | Total | Total (%) |
|-------------------------------------------------------------|
| Yes | 9 | 32.1 | 33 | 41.3 | 42 | 38.9 |
| No | 21 | 75.0 | 47 | 58.8 | 68 | 63.1 |

| Table 10. Fences and roof covers of ponds. |
|-------------------------------------------|
| Do ponds have fences and roof covers? | Fences of RWH ponds | Roof covers of RWH ponds |
|-------------------------------------------|
| No. | Percentage | No. | Percentage |
|-------------------------------------------|
| Yes | 2 | 25 | 0 | 0 |
| No | 6 | 75 | 8 | 100 |

| Table 11. Sedimentation of RWH ponds. |
|---------------------------------------|
| Type of pond | Volume/capacity of Pond in M³ |
|--------------|-------------------------------|
| Under construction (2013/14) | April, 2018 | April, 2019 | Change in volume b/n 2013/14 & 2019 (%) |
| Excavated only | 104 | 96.5 | 93 | 14.6 |
| Geomembrane lined | 24.5 | 23 | 22.5 | 8.2 |
| Cement lined | 14 | 13.5 | 13.2 | 5.7 |
4. Conclusions

Rainwater harvesting is a key water management tool for water-scarce areas. For meeting the demands of water for various purposes several rainwater harvesting ponds are constructed in numerous parts of the country. The evaluation of the sustainability of rainwater harvesting ponds is critical for ensuring the aim of construction and taking measures on future development and maintenance activities. During this study, the perception of farmers and constraints affecting the sustainability of rainwater harvesting ponds was evaluated. In most of the rural kebeles, the development and implementation of the rainwater harvesting ponds were a quota system rather than demand-driven and participatory construction that resulted in low sustainability. Most of the ponds didn’t serve for the designed service period and did not store water for various uses. The RWH ponds might play a key role in increasing the water supply, food security, and overall GDP. Besides, the performance of the RWH ponds needs regular checking and maintenance for reducing the probability of failure. The sustainability of the ponds within the district was surrounded by technical problems, financial, institutional, and environmental factors. Constraints just like the absence of fences and covers, sedimentation, low participation of farmers during the implementation of ponds, inappropriate location of ponds, lack of training, and environmental constraints affected the sustainability of RWH structures. These constraints resulted in the existence of more numbers of failed rainwater harvesting ponds on the plots of the farmers. For enhancing the sustainability of RWH ponds the government shall support them in financing the construction, awareness creation, increasing sense of ownership by participating the community within the site selection and construction of RWH ponds. Furthermore, pieces of training about the effective water utilization, maintenance, and management of schemes shall be delivered to the users.

3.4.4. Financial constraints

During the initial periods of rainwater harvesting technology adoption; the development of ponds was financed by the government. Most of the constructed ponds that were afforded freely for RWH demonstration were not long-lasting. Due to financial constraints, most of the RWH ponds were not maintained for a long period. As indicated in Table 14, 92.6 % of the sample farmers did not have enough money to maintain ponds. Farmers’ income level was a crucial factor that affects the sustainability of rainwater harvesting ponds (He et al., 2007).

### Declarations

**Author contribution statement**

All authors listed have significantly contributed to conceived and designed the experiments; performed the experiments; analyzed and interpreted the data; contributed reagents, materials, analysis tools or data and wrote the paper.

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**Data availability statement**

Data included in article/supplementary material/referenced in article.

**Declaration of interests statement**

The authors declare no conflict of interest.

**Additional information**

No additional information is available for this paper.

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