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# Evaluation of the operational effectiveness and feasibility of small-scale water supply systems in the hinterlands in Ethiopia: Case of Afar Regional State

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**Abstract:** Access to clean and sufficient drinking water is difficult in much of Ethiopia's Afar Region. It is observed that many schemes in the region are non-functional. The study was conducted to overcome the observed problem in seven selected districts of the region. The study regarded hand-dug wells and roof water collection systems, which are the two most common features in the research areas. Eight hand-dug wells and sixteen roof water harvestings are purposively included in the study. All the water points are constructed by Kelem Ethiopia which is a non-governmental organisation and the foremost local organisation for the communities. As per the research survey, the average functional status of the hand-dug well schemes is 65.75% and the roof water harvesting schemes is 22.94%. The research was based on the qualitative data collected on site. The hand-dug well sites were evaluated using 10 parameters, and the roof water harvesting schemes were analysed using 12 parameters. The main non-functional aspects of the scheme are lack of community ownership, drying up of water sources, lack of maintenance and rehabilitation, poor coordination of beneficiaries and school roofs blowing off. Most schemes still require minor to major maintenance and rehabilitation. According to the research, the solutions for water supply are identified in relation to the desired objective.

**Keywords:** hand-dug wells, roof water harvesting, rural communities, water management, water supply

## INTRODUCTION

Water is essential for the sustainable livelihood of a community [Mtahabwa 2018]. It is a shared and limited resource. People need water to drink, cook, wash, clean, and bathe [Loh, Coghlan 2003]. Access to adequate and clean water greatly contributes to improving human health and productivity [Beyene 2012; Desalegn 2005].

According to the World Health Organization (WHO) report of 2017, three out of ten people worldwide, or 2.1 billion, lack access to safe, readily available water at home [WHO, UNICEF 2017]. "Of the 2.1 billion people who did not have safely managed water, 844 mln did not have even a basic drinking water service. This includes 263 mln people who have to spend over 30 minutes per trip collecting water from sources outside the home and 159 mln who still drink untreated water from surface water sources, such as streams or lakes" [WHO, UNICEF 2017].

Accessing adequate and fresh water for a rural community depends on various factors. These are the availability of nearby water sources, shortage of community participation in site and technology selection, implementation, operation and maintenance of the schemes [Aper, Agbehi 2011], shortage of finances at the community level for operation and maintenance of schemes, use of complicated technology without proper capacity-building [Beyene 2012], non-functionality, improper usage of water schemes, deep water table, and poor quality water [Aper, Agbehi 2011]. All of the mentioned factors harm to access potable water supply. However, rural water schemes are very prone to mechanical and technical damages [Das *et al.* 2013]. These damages prime the scheme to be non-functional for long periods.

An adequate water supply system is the key factor for national development [Zhang *et al.* 2014]. The level of sufficient and clean water access depends on the functionality of water sources. Schemes' functionality, also, depends on insufficient water facilities and poor physical structures [Beyene 2012]. Service, fetching time and community awareness are the other parameters [Liu *et al.* 2018].

Small-scale water supply schemes are the most essential water sources for large rural communities in developing countries [Tadesse *et al.* 2013]. These small schemes have lacked adequate financing, unlike large schemes. This causes the construction of schemes for short-term solutions and then the schemes cannot deliver their full supply. It is difficult to achieve the water supply goals of developing countries without adequate financial arrangements, especially for the maintenance, rehabilitation, and protection of schemes [Zhang *et al.* 2014].

The use of safe drinking water contributes to health, productivity, and social development [Desalegn 2005]. Yet, many people in developing countries continue to rely on unimproved water resources [Das *et al.* 2013]. Ethiopia is the water tower of Eastern Africa both in ground and surface water potential [Tadesse *et al.* 2013]. However, the country's rural water supply coverage is very limited and low. Its rural water supply condition is dispersing and inadequate. This happens because of the country's economy, source identification problem, and population settlement [Kibret, Tulu 2014]. The country's current water access improves from time to time by different means. Foreign-based loan programs play a great role. The country's rural water supply schemes bottleneck is the sustainability and functionality of the schemes.

Around 50% of the country's rural water schemes are non-functional [Calow *et al.* 2013], and it is worse in the Afar Region of the country. The region's major drinking water sources are streams, wells, river sands, roof water harvestings (both surface and roof), and water tank trucks. The communities away from the tributaries are in a crisis of daily water consumption during the dry season. But, most of these societies have small-scale water supply systems near their village. However, most of the schemes are non-functional. The root causes are a lack of proper design, study, run, maintenance, and treatment. Source drying and non-separated water use of animals and humans are also the other malfunctioning causes [Kibret, Tulu 2014].

In the region, there are lots of governmental and non-governmental organisations that are involved in the water supply development sectors. Their main intentions are access to instant water supply for the community. However, the sustainability and functionality of schemes are the two main parameters that should not be tolerated at all.

Limited studies have been conducted in this place for the scheme's sustainability. Assessing the performance of the prevailing schemes in the selected districts is very vital. Finding the non-functional water supply schemes, weighing and steering their significant root causes, recommending and providing scientific solutions is the summarised work of the study.

The main objectives of this research are to: a) review and assess the current hand-dug well (HDW) and roof water harvesting (RWH) water schemes' performance in the study area; b) identify the root causes of non-functionality of schemes; c) recommend scientific solutions for future consideration and rehabilitation.

## WATER SCHEMES DESCRIPTION

Ethiopia is a developing country located in Eastern Africa. The country is divided into nine regions and two federal city administrations. Afar is one of the territories of the country and is located in the eastern and north-eastern parts of the country (Fig. 1). The region has a population of more than 2 mln people.

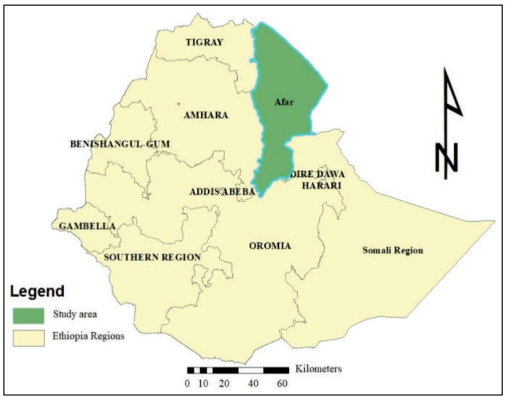


**Fig 1.** Study area location; source: own elaboration

The research is conducted in seven selected districts of the region, which are: Gulina, Awura, Dewe, Hadeleala, Semurobi, Gewane and Buremudayitu.

A total of 24 water schemes have been studied. Two-thirds of the schemes are roof water harvestings and the remaining are hand-dug wells. The elevation of the study sites extends from an altitude of almost 560 to 1,600 m.

The study area experiences a typically tropical arid and hot climate with a rainfall range of 300–1000 mm. Temperature varies from mean minima of 10–15°C to mean maxima of 28–38°C in October and May respectively. The average relative humidity is the lowest in February, 30%, and the highest – in August, 70%. The mean daily sunshine reported on an annual basis is 9 hrs. The schemes type and their district distributions are explained in Table 1.

**Table 1.** Water schemes and their district's location

| District name | Type of scheme | Number of schemes | Name of scheme |
|---|---|---|---|
| Gulina | 50 $m^3$ RWH | 2 | Bekeru and Belgi |
| | 40 $m^3$ RWH | 1 | Waenfage |
| | 30 $m^3$ RWH | 1 | Warsaye |
| Awura | 50 $m^3$ RWH | 1 | Kille |
| | 40 $m^3$ RWH | 1 | Sisiblu |
| | 30 $m^3$ RWH | 1 | Hayukele |
| | HDW | 1 | Amolderwa |
| Dewe | 50 $m^3$ RWH | 2 | Digbitu and Harahada |
| | 40 $m^3$ RWH | 2 | Anadaea and Gedangubi |
| | 30 $m^3$ RWH | 1 | Asbegoharidaba |
| Hadeleala | 40 $m^3$ RWH | 1 | Abiehada |
| | HDW | 2 | Halio and Rawa |
| Semurobi | 30 $m^3$ RWH | 2 | Dakis and Mogoali |
| Gewane | HDW | 3 | Bereforew, Oumerfage, and Asbuli |
| Buremudayitu | HDW | 2 | Kodea and Adlalit |
| | 50 $m^3$ RWH | 1 | Dababuraburi |

Explanations: RWH = roof water harvesting, HDW = hand-dug well.
Source: own elaboration.

### HAND-DUG WELLS

Hand-dug wells are holes in the ground dug by shovel or backhoe [Abbott 2013]. Historically, a dug well was excavated below the groundwater table until incoming water exceeded the digger's bailing rate. According to this water scheme, the well should have a depth of not more than 20 m and a diameter of less than 5 m.

The study area's hand-dug wells have 10 m average well depth, 3 m water depth and 1.2 m diameter. The internal well wall is encircled by a concrete ring and sealed by a concrete slab at the top. The wellhead is constructed by a composition of masonry and concrete materials. The water pump is a mechanical hand pump that lifts water by rotodynamic mechanisms. It uses the centrifugal force of rotating devices (called impellers) to increase the kinetic and pressure energy of the water. The water spring from the nearby aquifer is filtered by sand and aggregate material capped between the well concrete wall and the subsurface ground wall. Almost 93% of the studied hand-dug wells are excavated near rivers that help to feed water to the wells. The expected project population is 150 people per scheme per day. Eight hand-dug well schemes are surveyed and studied. The design drawing of the HDW scheme is shown in Figure 2 and its construction photo is shown in Photo 1.

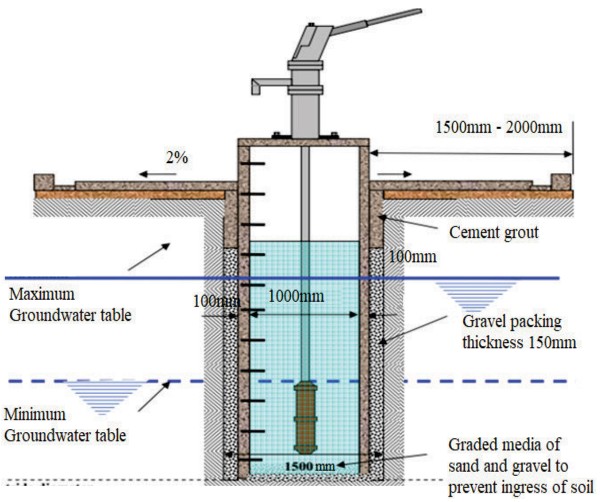


**Fig. 2.** Concrete ring hand-dug well (HDW) design; source: PWC ... [2009]

**Photo 1.** Community hand-dug well (HDW) – Kodea Village (phot.: *M.C. Shumie*)

### ROOF WATER HARVESTING

These water schemes store water during the rainy season and supply it during the dry season. The surveyed RWH tank sizes are 30, 40 and 50 $m^3$. Their physical components include a water tank, gutter, distribution point, and different pipes and accessories. Most of them are constructed jointly with the schools' roof and their primary intention is to serve as a water source for the schools' students. Due to the lack of additional water sources near the school, the population moved out from their village and lives around the school compound and uses the water together with the students.

The primary focus of the scheme is designed to serve 5 $dm^3$ per day on average for 50 students. When the schemes are filled once, the 30, 40 and 50 $m^3$ reservoirs will serve 120, 160 and 200 days respectively. But, when the population settled near the school, the water in the tank cannot serve for more than a month. The number of studied roof water harvesting schemes is 16; six of them are 50 $m^3$, five are 40 $m^3$ and the remaining five are 30 $m^3$.

The quality of the water is checked by the district water expert by using different water purifying chemicals like chlorine before it is supplied to the consumers. The quality of water is governed by both the Ethiopian and the World Health Organization's potable water quality standards. When the rain comes and pours onto the roof, the first 10 to 15 minutes of roof water does not flash into the tank for the purpose of improving the quality of water. The design drawing of the RWH scheme is shown in Figure 3 and its construction photo is shown in Figure 4.

## MATERIALS AND METHODS

The data is collected with purposive sampling techniques of 8 HDWs and 16 RWHs. All of these schemes are constructed by Kelem Ethiopia which is an exemplary local non-governmental organisation. The data gathering approach has comprised valuation and inquiry of the schemes' study, design, construction, and post-construction states. The water point location and community participation are also considered.

The expert interview and discussion have taken place on the spot. Focus group discussion was developed to talk over the issues and grasped relevant information. Schemes' visual observation took place at the field level. The necessary data like design drawings, reports, maintenance history, and spare parts purchase documents are used as secondary data.

The descriptive method of research analysis was used for analysing both the qualitative and quantitative data.

The research has been based on the qualitative data gathered on the spot. The hand-dug well schemes study emphasised on stakeholders' participation from the enhancement to the completion of the schemes [Harter 2003], schemes' community ownership, detailed water source investigation [UNICEF 2009], drying of water source, water scheme installation and workmanship, schemes maintenance and rehabilitation, the existence of guard, caretakers and fence [UNICEF 2009], community awareness, coordination among users, government and village officials.

The RWH schemes have been investigated based on the following mentioned factors: the existence of a well-equipped study [Goyal 2014], adequacy of tank capacity [Komeh *et al.*

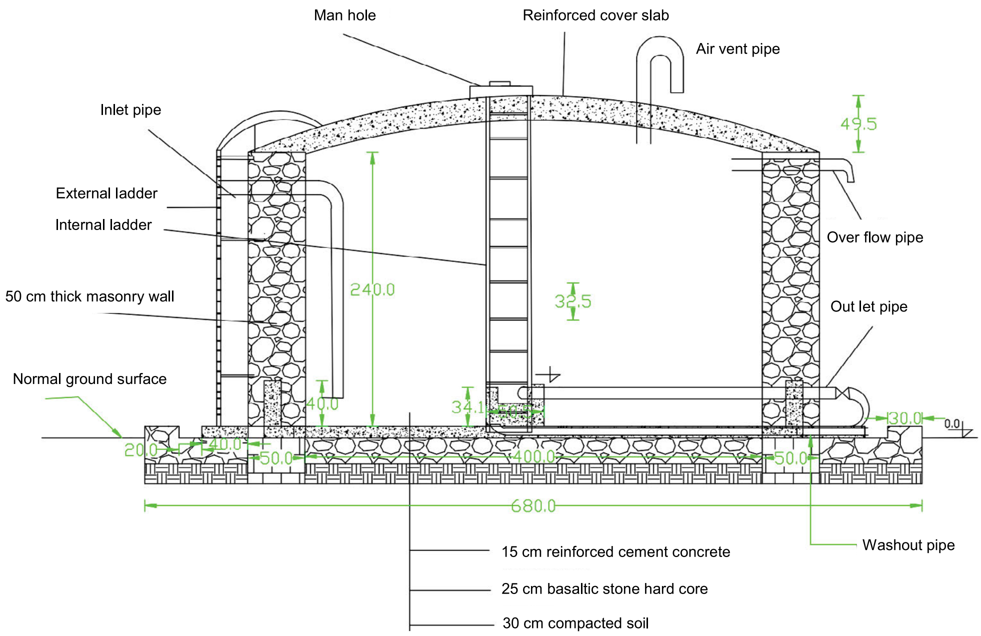


**Fig. 3.** Composite roof water harvesting (RWH) design; source: own elaboration


**Fig. 4.** Roof water harvesting (RWH) water tank and its water source – the school at Dababuraburi (phot.: *M.C. Shumie*)

2017], the quality of construction materials [Denison, Wotshela 2012], periodic maintenance and rehabilitation [JeanCharles 2007], water leakage due to improper joint between the outlet pipe and the wall of the tank [Mwamila *et al.* 2016], wall crack, malfunctioning of scheme components [TWDB 2005], school roof wind blowing, the existence of fence, caretakers and guard [Woltersdorf 2010], improper utilisation [Adugna *et al.* 2018], dependency of rainfall [Adugna *et al.* 2018], and improper construction methodology and curing [Biswas, Mandal 2014].

The research was accompanied by the HDW and RWH schemes' non-functionality parameters with their assigned weighted values collected from the distributed questionnaires. Each parameter has a varied effect. The parameters have been collected based on the snags perceived in the schemes. The parameters are thought to be the main root causes of the non-functionality of the schemes. The parameters are repeatedly reported, documented and mentioned as causes for the breakage of the schemes. In this research, the existence of these issues on the sites was also observed and checked.

The criticality and impotency weight of the parameters have been analysed and delivered based on the collected questionnaire distributed to the concerned stakeholders who rated it on such a scale: 2, 4, 6, 8, and 10. The severe cause parameters are 10, 8, 6, 4 and the minimum parameter is 2. The questionnaire was disseminated to 44 respondents. Among the respondents, four consultant engineers, two water scheme contractors, seven province water office professionals, seven province water office heads and 24 community representatives participated. The respondents' responses made average values of each parameter. The value of the weighted parameters helped to evaluate the functional status of the schemes.

The research is conducted using 10 HDW and 12 RWH evaluation parameters. The yearly functionality status of the schemes is assessed for each of the 24 schemes and crosschecked by the weight of the assigned parameters.

## RESULTS AND DISCUSSION

### RESULTS

The small-scale water supply schemes have faced numerous challenges in the provision of adequate clean water and its supply to the people [Fan *et al.* 2013]. These problems are different based on the capacity of the country in water source potential, institutional arrangement, technical capacity, finance and management [Calow *et al.* 2013]. The study has ensued different results in the case of the weighted value of schemes' non-functionality parameters, status, and causes.

#### Non-functionality parameters' weight

As per the collected questionnaire from stakeholders, the water schemes' non-functionality parameter middling and fairly accurate weighted value of HDW is presented in Table 2 and the RWH is in Table 3. The numbers and names of the schemes disposed of by the parameters are also described in the tables. All schemes have been evaluated based on their measurement parameters. The schemes are assessed per all the non-functionality parameters weighted in the site. The HDW schemes are tabulated in Table 2 and the RWH schemes in Table 3 respectively.

**Table 2**. Hand-dug wells' (HDWs') non-functionality parameters and their average weighted values

| No. | HDWs' non-functionality parameters | Weighted values | No. of schemes | Name of scheme |
|---|---|---|---|---|
| 1 | lack of comprehensive water source investigation | 9.75 | 1 | 7 |
| 2 | improper pump installation and workmanship | 9.6 | 1 | 8 |
| 3 | shortage of periodic maintenance and rehabilitation | 9.55 | 3 | 2, 5, 8 |
| 4 | unbalanced supply and demand of usage of water | 8.72 | 8 | 1–8 |
| 5 | improper well excavation time | 8.51 | 2 | 2, 7 |
| 6 | water scarcity due to climate change | 8.12 | 3 | 5, 8, 7 |
| 7 | lack of coordination among stakeholders | 7.22 | 2 | 5, 7 |
| 8 | unfenced and unguarded water schemes | 6.41 | 4 | 2, 5, 7, 8 |
| 9 | nonexistence of water schemes care takers | 6.17 | 4 | 2, 5, 7, 8 |
| 10 | lack of community ownership and awareness | 5.32 | 4 | 2, 5, 7, 8 |

Explanations: (name of scheme) 1 = Adlalit, 2 = Amolderwa, 3 = Asbuli, 4 = Bereforew, 5 = Halio, 6 = Kodea, 7 = Rawa, 8 = Oumerfage.
Source: own study.

**Table 3.** Roof water harvestings' (RWHs') non-functionality parameters and their average weighted values

| No. | RWHs' non-functionality parameters | Weighted values | No. of schemes | Name of scheme |
|---|---|---|---|---|
| 1 | inadequate reservoir capacity | 9.23 | 16 | 1–16 |
| 2 | low quality of construction materials | 8.7 | 4 | 4,7, 9, 16 |
| 3 | lack of periodic maintenance and rehabilitation | 8.5 | 8 | 1, 4, 7, 8, 9, 11, 13, 16 |
| 4 | wall crack at the outlet pipe of the tank | 7.92 | 8 | 1, 4, 7, 8, 9, 11, 13, 16 |
| 5 | schemes' components malfunctioning | 7.11 | 8 | 1, 4, 7, 8, 9, 11, 13, 16 |
| 6 | school roof wind blowing | 6.5 | 4 | 4,7, 9, 16 |
| 7 | lack of existence of well-equipped study | 5 | 16 | 1–16 |
| 8 | non-existence of fence, care takers and guard | 4.78 | 16 | 1–16 |
| 9 | improper utilisation | 4.5 | 8 | 1, 4, 7, 8, 9, 11, 13, 16 |
| 10 | dependency of rainfall | 4 | 16 | 1–16 |
| 11 | improper construction methodology and curing | 3.94 | 8 | 1, 4, 7, 8, 9, 11, 13, 16 |
| 12 | water quality | 3.51 | 16 | 1–16 |

Explanations: (name of scheme) 1 = Abiehada, 2 = Anadaea, 3 = Asbegoharidaba, 4 = Bekeru, 5 = Belgi, 6 = Dababuraburi, 7 = Dakis, 8 = Digbitu, 9 = Gedangubi, 10 = Harahada, 11 = Hayukele, 12 = Kille, 13 = Mogoali, 14 = Sisiblu, 15 = Waenfage, 16 = Warsaye.
Source: own study.

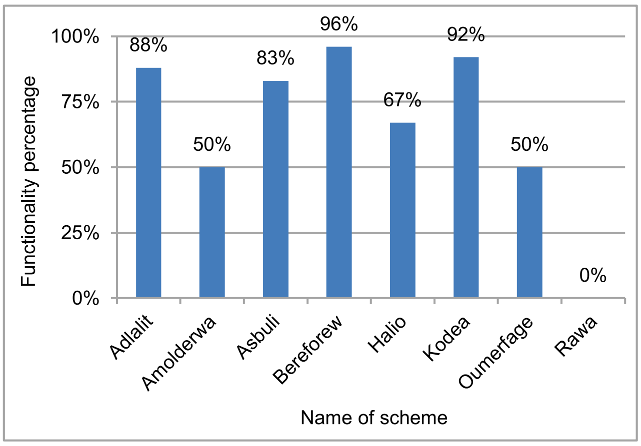


**Fig. 5.** Hand-dug wells' (HDWs') schemes functionality status in percent; source: own study

### Schemes' functionality status

Based on the perceived structures at the site, their serviceability has been assessed. The functionality of the schemes is valued as per their full and continuous provision of water throughout the year. The worthy months of the schemes in a year are the sum of the full delivery months plus half of the months with a limited capacity. Then the functionality status of HDW and RWH is shown in Figures 5 and 6 respectively. As it is indicated in the figures, the names of the schemes and their general functionality percentage are explained well. It is calculated by dividing the worthy months by the total months of the year.

## DISCUSSION

### Hand-dug wells

As the result has shown in Figure 5, the average functionality status of the surveyed HDW water schemes is 65.75%. The figure indicates that the schemes fall more or less in a good stance as a functional scheme which is greater than 50% [Abbott 2013]. Half (50%) of the schemes are almost fully functional, 37.5% are partially functional and the remaining 12.5% are non-functional.

The study centred on 10 non-functionality parameters for HDW schemes. As per the response of the distributed questionnaire, the maximum and the minimum weighted value of the parameters are 9.75 and 5.32 respectively (Tab. 2). These values are not such a far figure from the weighted average of all of the parameters, which is 7.94. So, all parameters have a pronounced effect on the scheme's performance and provision of continuous water supply.

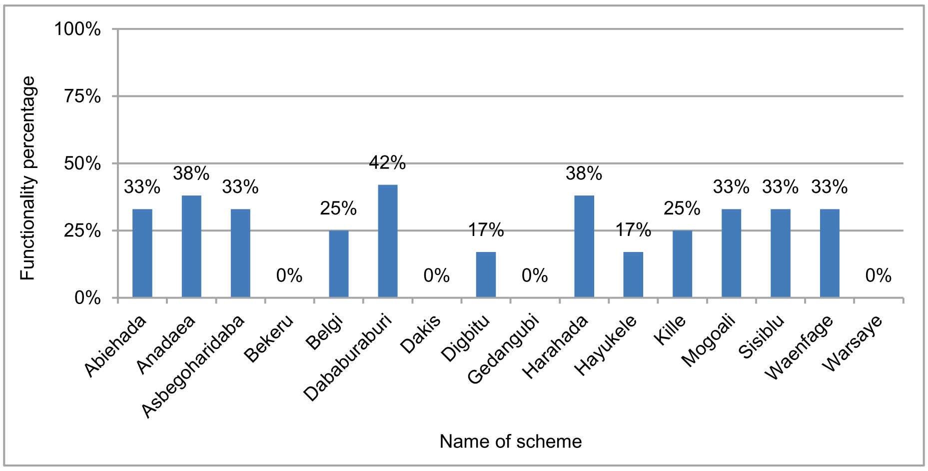


**Fig. 6.** Roof water harvestings' (RWHs') schemes functionality status in percent; source: own study

As the study has shown, the lack of comprehensive water scheme investigation and study before construction is the foremost and main non-functionality parameter of HDW schemes. According to CLAYTON *et al.* [1995], a site investigation is vital to the success of any construction project, since inadequate investigation can lead to very large construction cost overruns and unexpected output. As a result, the study indicated, that due to the lack of detailed schemes investigation, Rawa HDW is dry and non-functional. As per the researcher, practical site observation and professional comment, lots of hand-dug wells in the near environment from the study area became dried because of the construction of the schemes without critical site investigation. Therefore, a detailed HDW site study and investigation have to take place before the enhancement of excavation.

Pump installation and workmanship is the other parameter observed in the study. To increase functionality there should be well-trained pump installers and training on the operation and maintenance of the pumps for the users [KAMANGA *et al.* 2018]. The pump is the main scheme component for the extraction of deep water from the source and delivery to the users. The study has shown that due to improper installation of water pumps, some of the schemes become non-functional in some months of the year. Once the schemes malfunction, their maintenance and rehabilitation time is indeterminate and very long. Some schemes are kept for more than a year to get maintenance. Some of the issues associated with the lack of periodic maintenance are due to lack of integrated follow-up, budget constraints, lack of community ownership, useless computation among users, lack of coordination among stakeholders, lack of spare parts in nearby areas, scheme site remoteness, and shortage of skilled manpower capable to investigate and identify the malfunctioned component. So, HDW schemes have to be installed by qualified experts, it will help to elongate the scheme's service time. It also reduces the maintenance cost. For the sake of continuous water supply from the scheme, periodic maintenance and rehabilitation have to be provided on the site. The maintenance may be minor or major.

The other important parameter is the existence of unbalanced supply and demand that leads the schemes to deteriorate and malfunction earlier. As it is known water is a finite resource. A water scheme is designed based on a demand/supply-driven approach. The study area schemes are designed to supply water for human domestic purposes only. However, it has been observed, that almost all of the studied schemes have supplied water for additional purposes like cattle and mules. They do it for their herd due to the lack of surface water in the environment. It makes up for a shortage of water in the schemes for domestic purposes. Due to unbalanced demand and supply, the performance of the scheme is lowered. So, it is preferable to suspend the usage of HDW water beyond its design purpose.

It is customary that in Ethiopia there are two major seasonal classified types: rainy and dry seasons. The dry season lasts almost for nine months and the rainy season lasts for three continuous months. There are two months of the intermittent rainy season which is the part of the dry season of the year. It means that all of the Ethiopian areas have an opportunity to get light to heavy rainfall over an average of five months. Rainfall is a big source of underground water sources. So, the water that we get by a well excavation in these rainy months and up to months after the summer is not relevant and reliable for HDW construction because it shows a false water table. Although, there are schemes found in the study areas which have limited capacity and are waterless in the dry months due to the excavation at an improper time. The water supply engineers have to consider the well excavation time as an important and critical parameter in the construction and design aspects. Inappropriate excavation time makes the scheme provide intermittent and insufficient water throughout the year. The schemes become seasonal schemes.

Climate change is the other parameter that has an indispensable impact both on the scarcity of water and flooding. The study area is one of the water-scarce areas in Ethiopia situation. The area is historically prone to flooding initiated from the upstream catchments and water scarcity due to the warm climate condition. It was susceptible to nearby climatic conditions through El-Nino and Llano [SINGH *et al.* 2016] which occurred in most Ethiopian regions in 2015. The climatic conditions had a great impact on drying shallow water sources. COCHRANE and COSTOLANSKI [2013] described the impact of climate change in Ethiopia in 2013: "The most prominent impacts of climate change are environmental, resulting in increased desertification, drought and floods, shifts in arable land and water stress". As climate change is a national and worldwide problem, water supply engineers and HDW users have to consider the situation and observe other alternatives.

Coordination among stakeholders from the enhancement to the completion of a project and in its service time is an important parameter in the functionality of water schemes. Admassu *et al.* [2003] described that the sustainability of rural drinking water supply projects is, more or less, dependent on the coordination of different stakeholders. When there is coordination, the stakeholders know and execute their responsibility in the schemes. Coordination helps to have fenced, guarded and cared water schemes. The water users use programs to fetch water and pay based on their tariffs. The caretakers make immediate minor maintenance, buy and bring spare parts, and report to the concerned heads. The lack of stakeholder coordination is endangering the functionality of the schemes. As per the result of the study shown in Table 2, Amolderwa, Halio, Rawa and Oumerfage schemes are partially functional, and less functional than Asbuli, Adlalit, and Bereforew, which are almost fully functional, due to lack of fencing, guarding and stakeholders integration and coordination. So, as a water user, designer, contractor, owner and expert of HDW schemes; the existence of fence, guard, and caretakers on the site should be taken care of. The concerned water experts have to provide training for communities (users) on how to handle, use and control the schemes and induce community ownership.

### Roof water harvestings

The average functionality status of the RWH schemes is 22.94% which is below the average functionality standard of RWH, which is 50% [Ndiritu *et al.* 2018]. As per the result of the study shown in Figure 6 most of the schemes are non-functional. The schemes are analysed based on the prioritised, distributed and collected 12 non-functionality parameters. The maximum, average and minimum weighted parameters of the respondents are 9.23, 6.14 and 3.51 respectively (Tab. 3). The weight indicates that all the parameters are significantly important and responsible for the functionality of the schemes.

The most important non-functionality parameter is the inadequacy of the reservoir capacity. The appropriate size of the reservoir helps to supply continuous water to the community [Waktola 2007]. The reservoir capacity is estimated using the maximum number of students found in the school as a design population. However, the adjoining community uses the water since they have no other nearby potable water sources as an alternative. The RWH schemes cannot provide water access for more than a month. Then, the tank stays for further months without water. In addition to this, due to the warm climate condition the tank is going to be deteriorating hence there is no balancing and cooling water pressure inside the tank. As per the reference to the reservoir, all surveyed schemes are not sufficient enough. The adequate average reservoir capacity to feed the community has to be in the 250 to 300 $m^3$ range which can serve for three months continuously. Therefore, before the initiation of any RWH scheme, a feasibility study has to take place.

The tank and its components, distribution and collector system of an RWH scheme shall be constructed from standardised construction materials unless it is difficult to have quality and long-term service provider schemes. The study has shown that Bekeru, Dakis, Gedangubi and Warsaye schemes had been constructed from low-quality and silt-based sand, causing the tank to fail and crack. It leads to the water leak through the crack and makes the swampy area. Hence, the RWH schemes have to be constructed using standardised construction materials and checked during material delivery on site.

Lack of periodic maintenance and rehabilitation is the other important parameter checked on site. The study indicates that many components of the RWH schemes need maintenance. Half of the schemes are in need of deep maintenance of primarily severe breakage. Therefore, for reliable and continuous water supply, periodic maintenance and rehabilitation are mandatory [Kamanga *et al.* 2018].

An RWH scheme has many components: the tank itself, distribution system, and collector system, which are the main ones. The malfunctioning of a component of the scheme has harmed the functionality and provision of water to the community, 50% of the schemes are susceptible to this problem. The tank wall crack at the outlet joint is the other issue observed in the study. In the non-functional schemes, water leaks through the crack and forms swampy areas, which are responsible for breeding mosquitoes. Therefore scheme component maintenance has to be the priority.

The water is collected from the roof of the school. When the roof is blown by the wind, the scheme cannot collect water during the rainy season. Bekeru, Dakis, Gedangubi, and Warsaye schools are located in highly wind-vulnerable areas where the schemes are non-functional every year due to the roof blows. No roof – no water in RWH. Therefore, dry season maintenance of roofs has a great role in water collection in the rainy season.

The other big outcome of the study is the lack of a full and detailed investigation of water schemes. As per the researcher's observation, it is difficult to say if there were scientific studies during the implementation of all surveyed roof water harvesting schemes. The study area is one of the dry areas in Ethiopia with a rainfall shortage. RWH schemes are recommended in high rainfall potential areas [Tamaddun *et al.* 2018]. So there is a fallacy here. Therefore, it is better to say that the RWH schemes are not suitable for the study area. Hence, it is preferable to recommend and construct roof water harvesting tanks in rainfall potential areas.

The lack of fences, caretakers, and guards has contributed to the functionality of the schemes. All the RWH schemes have none of these situations. It leads to unplanned and improper utilisation of water by the consumers. The consumers fetch water for 24 hours which leads to wastage of water. As it was observed, they wash their clothes on site, fetch water for cattle, and take showers on the spot and it is just an extravagance of water. In this prospect, guarding, caring and fencing schemes has a great role in increasing schemes' performance and have an enormous contribution to the functionality of the schemes.

Rainfall is the major source of water in this world. Specifically for RWH users, if there is no rainfall – there is no water and life. Even the fluctuation of rainfall forms an unbalanced supply and demand for water. So, RWH functionality depends on the potentiality of rainfall. The problem of water quality in the study area is not a big issue because the water is cared periodically and it is clean.

## CONCLUSIONS

The functionality of the HDW scheme has to be measured based on the causes of malfunctioning parameters assessed on-site. The functionality of a small-scale water supply scheme depends on the existence of a well-organised study, design, construction, supervision and service delivery from the enhancement to the completion of the project. The parameters have played a great role in the functionality of the schemes. A particular HDW scheme has to be measured by the existence of comprehensive water source investigation, pump installation and workmanship, periodic maintenance and rehabilitation, balancing of supply and demand of usage of water, well excavation time, water scarcity due to climate change, coordination among stakeholders, fenced and guarded water schemes, water schemes caretakers, community ownership and awareness. Whereas, the RWH functionality has to be assessed by the factors like reservoir capacity, quality of construction materials, maintenance and rehabilitation, components malfunctioning, roof wind blowing, the existence of a well-equipped study, fence, caretakers and guard, proper utilisation, the dependency of rainfall, construction methodology, curing and water quality. The research has indicated that 12.5% of HDW and 25% of RWH are non-functional due to a lack of detailed feasibility study, almost 17.25% of HDW and 37.5% of RWH are partially-functional due to design and construction problems, and 17.5% of HDW and 37.5% of RWH are partially-functional due to post-construction problems. Therefore, the HDW and RWH schemes' functionality depends on all of the stages of construction and service delivery.

The sustainability of small-scale water supply is depending on the integration of all stakeholders in every corner of the scheme of the project. These stakeholders are water users, scheme owners, communities, designers, contractors, water office heads and experts. They have to share their responsibility and act accordingly.

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