Assessment of Rooftop Rain-water Harvesting Practice and Potential of West Arsi Zone of Oromia Region, Ethiopia

Bersisa Desaleny Gondol

A Thesis Submitted to

The Department of Water Resource Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Water Resources Engineering (Specialization in Water Supply and Environmental Engineering)

Office of Graduate Studies
Adama Science and Technology University

June, 2023

Adama, Ethiopia

Assessment of Rooftop Rain-water Harvesting Practice and Potential of West Arsi Zone of Oromia Region, Ethiopia

Bersisa Desaleny Gondol

Advisor: Andinet Kebede (PhD)

A Thesis Submitted to
The Department of Water Resource Engineering
School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Water Resources Engineering (Specialization in Water Supply and Environmental Engineering)

Office of Graduate Studies
Adama Science and Technology University

June, 2023

Adama, Ethiopia

Declaration

I hereby declare that this Master Thesis entitled “Assessment of Rooftop Rain-water Harvesting Practice and Potential of West Arsi Zone of Oromia Region, Ethiopia” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis are duly acknowledged through citations.

<u>Bersisa Desaleny Gondol</u> ____________________ ________________

Name of the student Signature Date

Recommendation

I, the major advisor of this thesis, hereby certify that I have closely advised/supervised the student; while developing this thesis work and read the draft thesis entitled "Assessment of Rooftop Rain-water Harvesting Practice and Potential of West Arsi Zone of Oromia Region, Ethiopia" prepared under my guidance by Bersisa Desaleny Gondol. Therefore, I recommend the submission of the thesis to the department for further review and evaluation.

Andinet Kebede (PhD)	________________________	________________
Major Advisor/Supervisor	Signature	Date

Approval Page for Thesis

I hereby certify that the recommendation and suggestion given by the review committee are appropriately incorporated into the final thesis entitled "Assessment of Rooftop Rain-water Harvesting Practice and Potential of West Arsi Zone of Oromia Region, Ethiopia" by Bersisa Desaleny Gondol.

Andinet Kebede (PhD)	__________	________________
Major Advisor/Supervisor	Signature	Date

We, the undersigned, members of the Board of examiners of the thesis by Bersisa Desaleny Gondol have read and evaluated the thesis entitled "Assessment of Rooftop Rain-water Harvesting Practice and Potential of West Arsi Zone of Oromia Region, Ethiopia" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the Degree of Master of Science in Water supply and Environmental Engineering.

____________________________	____________	___________
Chairperson	Signature	Date
____________________________	____________	___________
Reviewer 1	Signature	Date
____________________________	____________	___________
Reviewer 2	Signature	Date

Final approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

_________________________	____________________	____________
Department Head	Signature	Date
_________________________	____________________	____________
School Dean	Signature	Date
_________________________	____________________	____________
Office of Postgraduate Studies, Dean	Signature	Date

ACKNOWLEDGEMENT

It is very difficult to thank everyone who assisted me in writing this research work. However, the researcher would like to express his gratitude to the advisor, Dr. Andinet Kebede, for his genuine and vital guidance, inputs, and critical review of the thesis work and contributions in the amendment of the whole research work in to a sound full and workable manner which makes simple the image of the study with manageable difficulties.

Abstract

Water availability issue and potable water supply is crucial for increasing population and decreasing fresh water source worldwide, in Ethiopia and In West Arsi. Water supply coverage is not fully achieved to date was 68.1% in West Arsi and alternative source should be utilized in addition to existing one. Water-related issues are critical for sustainable development, and many organizations work towards improving water accessibility, quality, and management in various regions.The study was conducted to assess rooftop rainwater harvesting practice and potential for an alternative water source ofWest Arsi Zone of Oromia Region, Ethiopia. This study focuses on evaluate status of rooftop rain-water harvesting system, harvesting potential and identify rooftop compatibility for rooftop rain-water harvesting system in solving the water availability issue. Qualitative and quantitative research approach was performed using both primary and secondary source of data. Data were collected through survey of rooftop rainwater harvesting system and conducting questioners and interviews, and using roof plan for roof area estimation and metrological data was used to determine available harvesting potential, physical observation for compatibility of rooftop for harvesting and analysis. The collected data were analyzed by using statistical tools; SPSS and MS excel tools. The result shows all constructed rooftop rain-water harvesting system was not under service and some are not with full system components as per available potential. Poor design, construction method, material and luck of skilled manpower were constraints to proper functioning of constructed rooftop rain-water harvesting system. Precise operation and maintenance and management are very important and about 89% of roof type was compatible for the system. Proper design, construction methods, skilled manpower and material and, study supported with policy is very important for efficient use of this resource. If available potential is fully used 27% of water demand will be supported by the system.

Keywords: *Rain-water harvesting, rooftop compatibility and alternative water source*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

Abbreviations

BOQ	Bill of Quantity
CAD	Computer Aided Design
CIS	Corrugated Iron Sheet
ENMA	Ethiopian National Meteorology Agency
HC	Health Centers
NGO	Non Governmental Organization
O&M	Operation and Maintenance
OCA	Oromia Construction Authority
PVC	Polyvinyl Chloride
RWH	Roof-water Harvesting
RWHS	Roof Water Harvesting System
WAZ	West Arsi Zone
WAZHO	West Arsi Zone Health Office

CHAPTER ONE

1. Introduction

1.1. Background of the Study

Water is a fundamental resource required by every living organism, however large proportion of the earth‘s people do not have access to an adequate and constant supply of water (UN, 2014; Getachew, 2017). Water is limited resource and effective utilization of water resource will be very important. Rainwater harvesting (RWH)has been distinguished and practiced in many areas as an economically practical solution for reducing water shortage (Getachew, 2017; Ndiritu, 2011). To overcome the problem of water shortage, it is believed that rainwater harvesting is one of the best options.

There are numerous variables that compromise amount and quality of water supply sources. Rain is harvested in numerous ways and could be a crucial supplementary source of water. These are connected basically to the thought of ground catchments, and or roof water collecting (Simiso, 2017).

Rainwater harvesting is a collection of water supply strategies whereby rain is collected and utilized for use. The term has been connected to precipitation to be collected and stored instead of runoff, to the development of water supplies. It is the collection of run-off from rooftops and other impermeable or saturated surfaces. So that it can be utilized for domestic use, livestock or micro-irrigation. Thus, roof water harvesting was a subset of water harvesting, is indeed an alternative water supply system (Thomas & Martinson, 2007).

The fundamental roof water harvesting system is rain falls onto rooftops and that runs off. The run-off is channeled into a tank or bump; water can be drawn from that store at whatever point it is required, hours, days or indeed months after the final precipitation. The fundamental components of a roof water collection framework, as appeared in Figure 1, to create them less demanding to oversee or to progress the quality of the water collected from roof could be a satisfactory water source (Thomas & Martinson, 2007).

Water collected from roof is utilized for much purpose like drinking, cooking, garden watering, and toilet flashing, for ground recharging and other uses (Awawdeh, 2011).

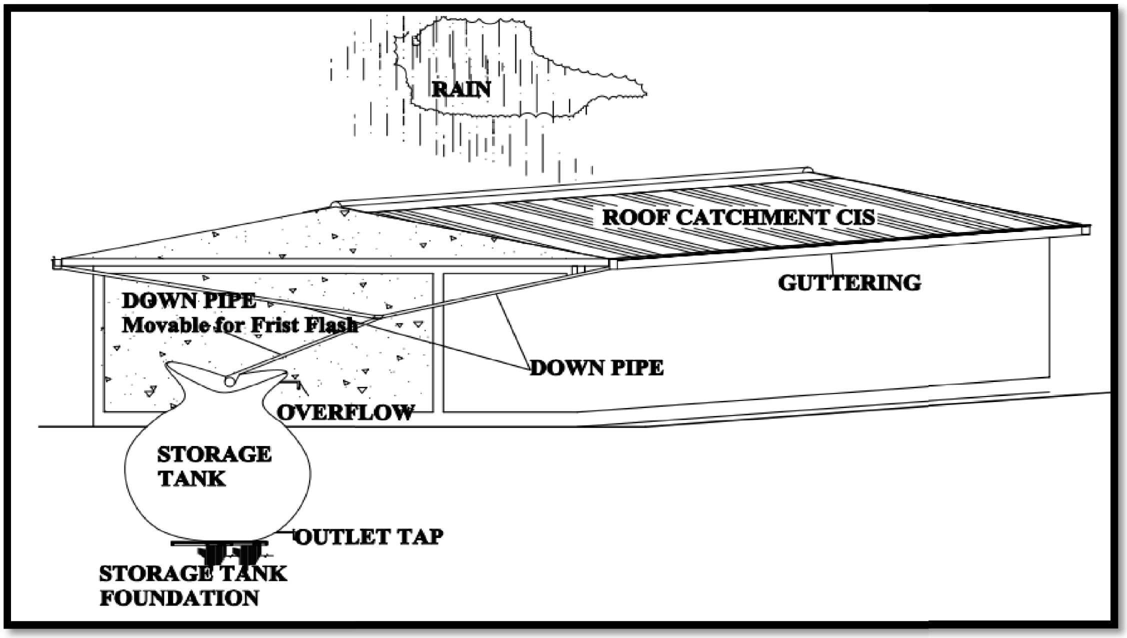


Figure 1: Simple RWH system diagram (Thomas & Martinson, 2007)

Roof water Harvest is immediate collection of rainwater from the surfaces which it has fallen directly and it excludes the runoff water from land watersheds into streams, rivers, lakes, etc (Hailamariam, 2017).

Rainwater harvesting associations have emerged in most southern and eastern African countries to spearhead rainwater harvesting activities in their respective countries. Ethiopian Rainwater Harvesting Association (ERHA) was founded on 17 December 1999 in Addis Ababa by concerned Ethiopians as an expression of their genuine interest to take part in the efforts to tackle the ever worsening threats of water scarcity (Meselech, 2019).

Ethiopia is rich in water resource having a potential of 110 billion m^3 surface water including Rainwater harvesting (Daniel, 2007). Annual rainfall in Ethiopia is 2700 mms in the south western highlands. The southern highlands of the country have a bimodal rainfall pattern (Meselech, 2019). RWH is a cross-cutting issue; it has complex interfaces with the environment, economy, gender, health and policy and in Ethiopia, there has been very few research on the issue and have not been informed by adequate research-generated data.

In West Arsi Zone (WAZ) according to water and energy office report, potable water supply coverage is still 68.1% and to increase this value roof water harvesting system (RWHS) should be used as supplementary source of water in addition of existing source. No result shows of existing water supply source from RWHS in West Arsi Zone. No policy or initiatives supports RWHS construction. But there were RWHS construction in HC and school by none governmental organization (NGO)'s. No recorded scientific research regarding RWHS in West Arsi Zone (WAZ) in increasing water supply coverage. So the status of existing RWHS, available harvesting potential, current harvesting and, harvesting system management including operation and maintenance are very important to support water supply. Study on available harvesting potential and roof top compatibility for RWHS is crucial issue for policy makers to develop initiative and policy.

To address the challenge of water scarcity safe and adequate quantity of water is crucial for human life. Water supply coverage and provision of alternative source is an alarming problem. Rainwater harvesting could be an alternative water source to support water demand in areas where there is abundant rainfall. Rooftop rain-water harvesting potential and storage requirements are important to determine its adequacy to satisfy people's water demand (Kanno et al., 2021).

The advantage of a water harvesting framework is its maintenance costs (Awawdeh, 2011). Construction of roof water harvesting in west Arsi is not full project, due to the condition that people or institutions have roof cover with good type (i.e. metal sheet roof cover) that is good opportunity for harvesting. In truth, getting water from more than one source is advantageous for sustainability of resource and resource re generation (Thomas & Martinson, 2007).

Rainwater harvesting systems is identified as an alternative water technology relevant to facilities, is commercially available, and might offer an opportunity to offset freshwater use (Energy, 2023). Making RWH systems an integral part of building conception and design as well as enshrining compulsory RWH in national building codes, in areas of adequate rainfall, RWH can supply up to 100% of domestic water needs of bungalow dwellers. (Nnaji, 2019)

Studies show RWH to be commonly used as an alternative water supply source both in developed and developing countries including Ethiopia. Despite RWH being widely practiced, some concerns and barriers exist (Dagnachew, 2018). Declination of water source is a start of need for a global and aggressive adoption of rainwater harvesting system as sustainable means of water supply and flood control.

1.2. Statement of the Problem

In Ethiopia, promotion and application of rainwater harvesting techniques as alternative interventions to address water scarcity were started through government initiated soil and water conservation programs. However, the interventions have been extended to advancement with a very limited coverage. The low level of community participation and declining attention were some of the major reasons for the limited coverage (Ngigi, 2003). The estimated potential of rooftop RWH from large public institutions in Addis Ababa to supplement the water supply at the city level is accumulated annual contribution amounts to only 0.71% of the actual supply. Even in the rainy season the harvest potential can contribute less than 2.5% of the actual municipal water supply (Dagnachew, 2018).

The water table for Siraro woreda is very deep with an average depth of 200 meters and use of underground water as source of alternative is not economical (IPMS, 2005). In West Arsi zone health centers RWH system; one or combination of component like storage tank, down pipe, gutter, fittings and connection pipe failure are observed. Investigating cause of failure of existing RWH structure system will help the concerned body to sustain RWH program and government increasing water coverage policy. Harvesting trend should be adapted to local condition after investigation of existing system. Roof water harvesting is constructed as alternative water supply source in health centers and school in west Arsi zone. In private or others institution RWH is more traditional or not constructed until now.

The constructed RWH many health centers were not under service. But still new RWH program is planned to construct. Therefore before construction of new RWH, investigating cause of failure of existing RWH structure system is required for sustainable RWHS and to meet the target of proposed RWH program. So the researcher needs to investigate failure of existing RWH system. Evaluation of what operation and maintainers management system will be used by the user, to ensure that water has its highest value and available in the dry season, by storing to transfer water from the wet season to the dry season. In other hand water harvesting trends; especially roof harvesting in the study area for household is still tradition, while harvesting potential and compatible roof type to harvest rain were not studied. Investigation of status of existing RWHS, available harvesting potential, current harvesting condition and harvesting system management including operation and maintenance are very important to support water supply in study area.

In other case people allow water flow from their home during rainy season and travel a long distance to fetch water during dry season from river or other source rather than harvesting during wet season. Similarly no active harvesting system program and initiatives; which are supported by research for the study area and the study focus on available potential, existing status and roof compatibility for the area.

Research based study of RWHS for the study area and use of the system for an alternative water source is yet not performed. Study of potential, compatibility of roof and existing status is required. Rain water harvesting is becoming an important option for underserved households and communities. Many areas in west Arsi Zone offer a good potential for the introduction of rainwater harvesting, however as many people do not appreciate the potential of rainwater harvesting for domestic and drinking water purpose this technology is undervalued.

1.3. Objective of the Study

1.3.1. General objective

The general objective of the study is to assess rooftop rainwater harvesting potential for an alternative water source in West Arsi Zone of Oromia Region.

1.3.2. Specific objectives

To address the general objective, the following specific objects were used as operational steps.

- Examining the status of the existing rooftop rainwater harvesting system
- To identify harvesting potential in the study area
- To identify rooftop compatibility for the systems

1.4. Research Questions

In line with the specific objectives, the study tried to answer the following research questions.

- What is the status of the existing rooftop rainwater harvesting system?
- What is harvesting potential in the study area?
- What is rooftop compatibility for the systems?

1.5. Significance of the Study

In Ethiopia, during rainy season people allow water to leave their home and find it over a long distance during dry season. If good harvesting system and mechanism is not provided by such study, existing system of rooftop rain-water harvesting no more support the water supply. Investigation of cause of existing RWH system failure, operation and maintenance and sustainability of RWH program is very important to both individual water need and government water coverage agenda. Thus, the output of the study helps the public and water and energy office in applying harvesting system or during developing policy related to water harvesting and all concerned body to minimize similar problem and provide friendly system and mechanism and identify how much harvesting potential is available in the study area and how much was used, and also why the potential is not used.

The harvesting trend at household level is not safe and it is only for short time of wet season and does not store for long service duration. So adoption of more advanced harvesting system is essential to support all individuals' water demand. If such water supply issue is fulfilling health care related to water problem will be minimized and environment will be safe if such harvested water will be used for environmental protection or for ground water recharge.

Rooftop rain-water harvesting development could be achieved through effective planning, implementation and evaluation of rainwater and physical and socioeconomic aspects of RWH could bring about policy framework. Assessing RWH practices in different settings, and identifying the challenges and opportunities of the existing RWH practices, the research can provide insights for policy makers and RWH practitioners to review, and improve their current approaches to support water supply demands. Since water supply status is still 68.1% searching for alternative source like RWHS is important for WAZ. The study clearly shows how much available RWH potential in the zone.

1.6. Delimitation and Limitations of the Study

The limitation of the study was:

- Luck of updated population data and recorded data related to how RWHS support existing water supply system.
- Not willingness of respondent for data collection and responding none realistic data.
- Material and resource scarcity for facilitating the study.

CHAPTER TWO

2. Literature Review

2.1. General

The practice of rainwater harvesting can be traced back at least 4000 years BC with systems employing cisterns fed with rainwater attached to single households in ancient civilizations such as Jordan, Rome, Greece and Asia. In more modern times, they have primarily been used in the rural domain where the construction of centralized infrastructure was not feasible. In the new age of sustainability, rainwater harvesting has got something of a renaissance; systems have again penetrated into cities where the bulk of the world's population resides. In excess of 100 million people worldwide are estimated to be using a rainwater harvesting system of some. Rain water harvesting systems can be separated into a number of subcategories based on how they are configured. They might communal, whereby a number of residences are connected to a tank that is fed from a large roof area, or installed on an individual basis to stand-alone households. Many systems only supply outdoor uses such as garden irrigation and pools, while the popular trend recently has been to internally plumb systems to supply a range of in home end users to maximize savings via substitution from centralized sources (Fayyaz & Sarah, 2019).

Roof water harvesting is the collection of rainwater from roof catchments and storing it in surface or subsurface reservoirs. Rainfall is pure and clean when it is released from the clouds but it is polluted upon reaching the atmosphere and the intercepting surface. The quality of the rainwater harvested from the rooftop technologies was polluted with fecal matter, hence not fit for domestic use without treatment. However, it was also accepted that with the exception of turbidity and color, the physical water quality of the rainwater harvested from the rooftop technologies was acceptable for domestic use (Simiso, 2017).

Rooftop rainwater harvesting captures, diverts, and stores rainwater from rooftops for later use. Typical uses of rainwater include landscape irrigation, wash applications, ornamental pond and fountain filling, cooling tower, and toilet and urinal flushing. With additional filtration and disinfection, harvested rainwater can also be treated to potable standards to supplement municipal potable water supplies to facilities (Energy, 2023).

There is adequate social acceptance of rainwater harvesting as a source of water in areas, where there is no adequate or sustainable fresh-water source within reasonable distance. However a vast majority of the potential beneficiaries do not understand the full benefits of rainwater harvesting (Hapugoda, 1995) .

Rooftop water collecting frameworks are valuable and used for expanding the water collection systems in both urban and rural regions, and harvesting system are very important for utilize in dry and semi-arid zones where conventional water sources are not on time accessible (Holding, 2020).

A studies show RWH to be commonly used as an alternative water supply source both in developed and developing countries such as the United States of America, United Kingdom, Australia, Germany, Ethiopia, South Africa, Sudan, Nigeria, Brazil, Saudi Arabia, and Iran (Dagnachew, 2018).

The mean annual rainfall in southern Ethiopia was 1464 mm. The wettest months occur between March and October and the driest months occur from November to February. Precipitation is characterized by a bi-modal pattern with maximum peaks during April and May t("small rainy" season) and during September and October in the "main rainy" season (ENMA, 2018; Kanno et al., 2021).

The water coming to a roof in a year can be assessed as the yearly precipitation times the roofs area, but within the tropics as it were approximately 85% of this water runs off the roof. The remaining 15% is ordinarily lost to dissipation and sprinkling. Regularly, available roof range is not sufficient to capture sufficient water to meet all the water needs of individuals within the building. In this case, either the roof area or storage must be increased to be sustainable alternative sources of water to meet required demands (Thomas & Martinson, 2007).

The design and installation of RWH system includes Catchment, Conveyance, Rainwater Storage, Tank Sizing, Quality and treatment. Rainwater Harvesting formula to calculate the monthly rainwater available for harvest: Rainfall Collected (m^3) = Catchment/Roof Area (m^2) × Rainfall (mm) × Collection Factor

Where: Catchment area (roof size) is the size of the roof where rainfall will be collected Monthly rainfall is total amount of rainfall (in mm) for the month Collection factor is a factor applied to the total monthly harvesting potential to account for losses in the system.

Rainwater Harvesting recommends using between 75% and 90%, depending on how efficiently the rainwater harvesting system collects rainfall harvesting potential (Energy, 2023).

2.2. Description of Roof-water Harvesting

Rooftop water harvesting (RWH) is to the collection and capacity of water from rooftops. The level of advancement required is easy and construction can be done at a family level, making it effectively valuable to numerous individuals. RWH can support water supply as a sole source and minimizing computation on other sources. Roof is made fabric that does not percolate the rain or contaminate the run-off. In this way, tiles, metal sheets and most plastics are more practical and have of high risk, whereas grass and palm leaf rooftops are not rational to quality of water to be collected. The bigger the roof range, the greater the runoff stream we are able collect (Thomas & Martinson, 2007).Roof Water Harvesting system is found to be in fact attainable based on system of water collection, storage and distribution, on a precipitation design with family units having a rooftop built from in fact fitting materials (Oloke, 2013).

A RWH framework with a huge water store will perform better than one with a little store. A little store will regularly flood within immediately due to excessive runoff inters the store at wet season. But little store is cheaper than a bigger one and gives cheaper water. The designer of a framework can select the combination of taken a cost and execution that best suits the user's needs and stores accessible. A large increment in store estimate to induce a moderately little increment in execution. Water stores are given different names, such as 'tank', 'jar', 'drum' and 'cistern', depending upon their estimate, shape or area. They can be over ground, underground or 'partly underneath ground' (Thomas & Martinson, 2007).

2.3. Goal and Advantages of Roof Water Harvesting

The rooftop water collection might a strategy from which water is captured from the roof catchments and supplied by embracing replica procedures to meet the family needs or community demand through storage in tanks; collected water can be put away within the sub-surface or ground water reservoir for recharge ground water support in improving ground water level future utilize . The primary reason of rooftop water collecting is to collect water and form water accessible for future utilize and in dry season, sloping, urban and coastal regions capturing and putting away water for utilize is especially crucial (Ramiz, 2020).

Points of interest of utilizing rooftop water harvesting is provides self-sufficiency to water supply, reduces the operating and purchase cost of pumping groundwater. It provides high quality water that is slight and good in minerals, improves the quality of groundwater through weakening when energized to the ground. It reduces soil disintegration in urban and country areas. Construction is cost-effective and straight forward technique, RWH structures simple to build operation and maintain. In saline or coastal regions such water gives great quality water, and when fresh water researched to the ground, it reduces saltiness conjointly makes a difference in keeping up the adjust between the fresh saline water interface, In islands, due to the constrained degree of freshwater aquifers, water gathering is the foremost favored source of water for household utilize (Purohit, 2015).

2.4. Type and Approach of Roof-water Harvesting

The surface that gets precipitation directly is the catchment of water collecting and is the zone, which really contributes water to the collecting framework. Water collected from the rooftop can to be carried through gutter to downpipe and to require water channels or channels to the harvesting storage. Water channels can to be safe and free of pollutants to get preferred quality water the harvesting potential of desired capacity (Padmanabhan, 2021). To capture sufficient water from available harvesting potential to meet all the water needs of individuals within the building, either the roof area or storage must be increased to be sustainable alternative sources of water to meet required demands (Thomas & Martinson, 2007).

Rooftop collecting water can be classified into two categories such as; Arrive Based and Roof Based. Collecting water runoff from roof surfaces which ordinarily gives a much cleaner source of water that can be easily utilized for drinking is called roof-based gathering whereas collecting rainwater runoff from arrive surfaces is called land-based collecting (Winfoundation, 2021).

Water from slanting rooftops might be caught through gutter and downpipe. At porches, the mouth of each run down should have wire mesh to restrict coasting fabric. The primary flush might a gadget utilized to flush off the water gotten within the to begin with shower. The primary shower of downpours has to be diverted and flushed off to avoid sullying rechargeable water by the likely contaminants of the air and the catchment roof (Padmanabhan, 2021).

2.5. Rooftop Rain-water Harvesting Framework

The introduced RWH water gathering frameworks were as non potable and portable water. Advanced frameworks were generally put into utilize at whatever point it sprinkled. The advanced frameworks included strengthened concrete tanks, layered press tanks, and plastic tanks; in any case, the versatile frameworks comprised pots, metallic drums/plastic drums, jerrycans, and clay pots (Asaba & Barasa, 2020).

Types of roof water harvesting: (i) storage: One way of collecting water is to store it in a storage tank on or above the ground, after shifting it from rooftop. Depending on water utilization and precipitation accessibility, a huge amount of a year's water needs can be met by this harvested rainwater. (ii) Recharge: Often, space to create storage a tank for water is lacking, and in such cases it can be utilized to revive the groundwater. In most cases, a working bore well itself can be revived with water after sifting. In a few other cases, a defunct bore well (working prior but not utilitarian), can be utilized for ground recharge. In case there is no current bore well, a ground recharge bore well can be made, after examining the aquifer or groundwater characteristics of the location. (iii) Combination: RWHS is frequently executed as a combination of storage and ground recharge. The water, after shifting, is driven to an existing storage tank on surface and flood from the tank, not exceptional in rainstorm, is driven to energize the bore well (Winfoundation, 2021).

Different RWH innovations are prepared to accommodate harvesting system frameworks locally, nationally and internationally giving a more manageable RWH system for water supply to household, organizations, and institution to meet the water shortage (Oloke, 2013).

RWH Water Collecting Framework: common place rooftop water collection framework comprises of taking after components; Roof catchment, gutter, down pipe and to begin with flush pipe, Channel unit, storage tank, Collection pit and energize well (Chowdhury, 2016).

Components of a rooftop water collecting framework; three fundamental components of a rooftop water collecting framework. Collection (Catchment) environment: Inside the case of a rooftop water collecting system, the roof of a house or of another building serves as the water collection environment. The capability and the quality of the water collected depends on the effective roof extend, roof environment and the materials that the roof is built of. Movement System: As a rule what interfacing the catchment conditions to a water capacity zone. Transport frameworks ordinarily contain of gutter or channels that drain the water that is collected from the rooftop into cisterns or other storage tank. Storage tanks: These holders are routinely inside the shape of a capacity tank or cistern, but they can as well be mortar holders, made from concrete, or they can without a doubt contain of clear vessels that are put at the edge of rooftops. The capacity holders can be solidified into a building's joined into a building's development, but too can be built on location independently away from the building. Capacity tanks that utilize gutter can be set over or underneath ground. Whatever sort of water capacity holder is utilized, the water storage capacity required must be taken into thought, with components such as the saving water, length of the dry seasons, the sum of precipitation, and the utilization of water required per individual (Buble, 2015).

2.6. Rooftop Rainwater Harvesting Practice

Rainwater harvesting could be an optional water source to fulfill or support the emergency water demand in areas where there is abundant rainfall. Rain water harvesting; the network of storage reservoirs, swimming pools artificial streams and baffling fountains of the 5th Century rock fort relied totally on rainwater harvesting. Agriculture also relied mainly on irrigation through cleverly designed, surface storage tanks. In recent years many of rain water collection skills have become obsolete. People now often rely on reticulated, central systems for drinking water supply and irrigation. So, presently Ethiopia cannot claim a well planned rainwater harvesting program. Local Investigations reveal however that - rainwater harvesting for domestic consumption is currently in practice a potential consumers are looking for appropriate technology to harvest and store rain water. A section of potential consumers are not sure about rainwater harvesting. (Project, 1995)
Rainwater harvesting has been used throughout history as a water conservation measure, particularly in regions where other water resources are scarce or difficult to access. In recent years, researchers and policy makers have shown renewed interest in water use

strategies due to rising water demand, increased interest in conservation (both water and energy), and an increased regulatory emphasis on reducing storm water runoff volumes and associated pollutant loads. In the last decade, as interest in the practice has grown, numerous state, municipal, and regional agencies have adopted or amended codes and guidelines to encourage responsible and effective rainwater harvesting practices. In addition, researchers from universities and nongovernment organizations, as well as industry consultants, have published papers and articles addressing a broad range of topics related to the installation, maintenance, costs, and performance of harvest and use systems. (Solloway, 2013)

2.7. Rooftop Rain-water Harvesting Suitability

Measures to Ensuring Sustainability of RWH system, capacity building, monitoring and evaluation and knowledge sharing and water demand management is very important as (Dzikus, 2007). In our country such supportive program and awareness creation of roof water harvesting, specifically the study area Roof water harvesting assessment is not well done to use available resource regeneration and to increase supply coverage using such system of alternative water supply mechanism.

Non-reactive roofs such as aluminum roofing sheets were found to be more suitable for RHW than asbestos, galvanized roofing sheets and concrete roofs. RWH can be made more sustainable and cost-effective by using mass balance and optimization methods for providing adequate storage for harvested water. Simple point-of-use treatment methods such Water Guard and Purifier of Water can be used to render harvested water potable (Nnaji, 2019).

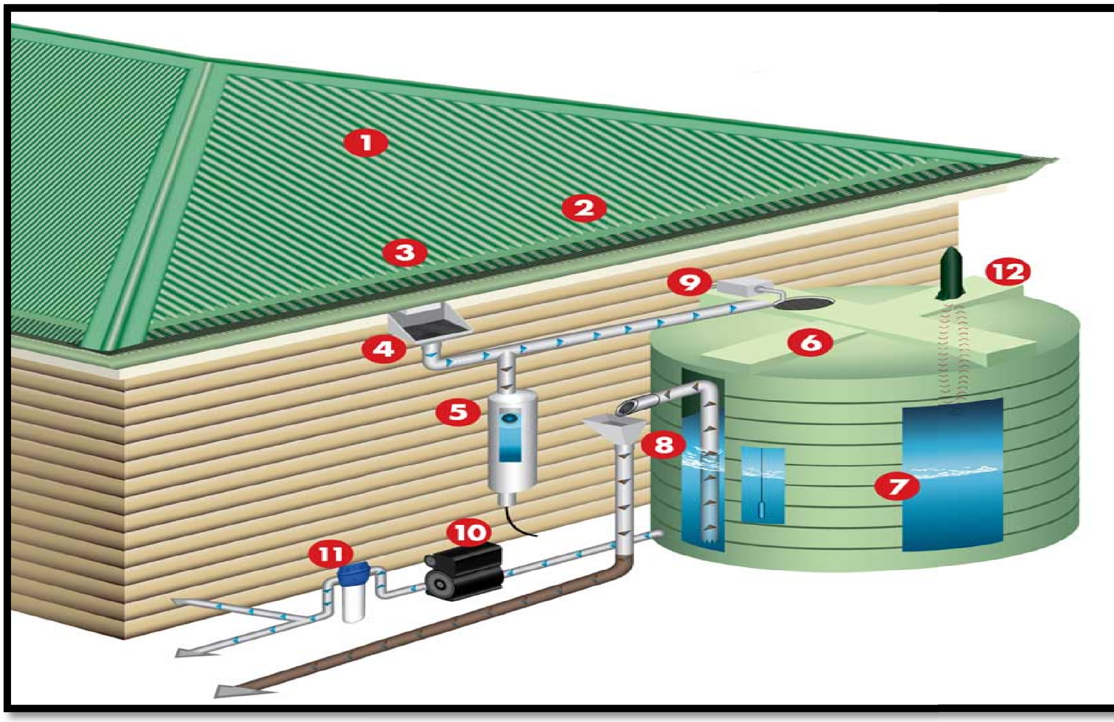
The study concludes that the rainwater collected off G.I. Sheet, Clay Tile and Asbestos made catchment is suitable for drinking and other domestic purposes. However, the first flush of water after the dry season should be discarded. To avoid any environmental problems, tank should be made mosquito proof (Hapugoda, 1995).

2.8. Roof-water Harvesting System Components

The course of action for driving water from the roof to the water store is more often than not called guttering or gutters and downpipe. The gutter is open channels carrying water sideways beneath the edge of the roof to a point fair over the water store; the downpipe are tubes driving water down from the gutter to the entrance of the water store. There are numerous ways of accomplishing the exchange of water from roof to store. Other components in a RWH framework incorporate screens and channels, flood courses of action, level ages and pumps; to lift water out of underground tanks (Thomas & Martinson, 2007).

All components of a rooftop water collecting framework ought to be made of chemically inert and nontoxic materials to keep the water quality from being defiantly influenced by chemicals. Non-toxic paint can be utilized in case the roof or other materials must be painted but no lead, chromium, or zinc-based paints. To decrease the opportunity for bacterial development, avoid any overhanging vegetation inside the water catchment area keep all surfaces clean, counting all channels and roof surfaces. If the rainwater is to be utilized for direct drinking use, it can be filtered and chlorinated or sanitized by another strategy such as boiling. Storage tanks and other open components got to have a tight and secure successful cover which will moreover keep the water from green growth from developing and mosquitoes from breeding in them (Buble, 2015).

Main components of rooftop water collection framework are; Roof, Pipes, First rain separator, Filter framework and Storage. The roof of any building is a critical catchment region, which might be a surface on which precipitation falls and it can be coordinated to capacity or for shallow aquifer energize. Water can be brought down from the roof to storage through downpipe from gutter. The primary rain water can make defilement in storage tank. So the primary rain separator evacuates this water. Gutter cartridge accessible from few producers to be mounted a couple of feet over ground on the pipeline bringing water from the roof chambers as a rule developed underground with input from the roof water pipe and yield to the capacity of mineral well for filter framework. A storage tank can be outlined based on space accessibility, needs and utilization (Winfoundation, 2021). Detailed rooftop rain-water harvesting system list are indicated on Figure 2.



Legend

1. Roof Surface.
2. Gutter Protection Screening
3. Gutter.
4. Rain Head
5. First-Flush Diverter
6. Tank Screen
7. Rainwater Tanks
8. Insect Proof Flap Valve
9. Auto-Fill System
10. Pump System
11. Irrigation Filter
12. Water Level Indicator

Figure 2: Rooftop rain-water Harvesting system (Innovative water solution, 2020)

The advent of modern appliances requires that the water supply to the house be pressurized. Switch systems that allow end-uses to be supplied by either the tank or central mains supply are commonplace, so that when a tank is empty essential supply is maintained (Ward, 2019).

2.9. Roof water Harvesting System Failure

The plan of the roof RWH frameworks failed to require into consideration family measure, water demand, Rooftop zone, roof harvesting capacity and volume of storage tank, and the current conventional RWH framework seem not meet the normal water request of family units. Percent potential unwavering quality investigation of roof RWH frameworks is not appeared achievable due to system component failure and storage capacity of the design (Getachew, 2016).

Despite RWH being widely practiced, some concerns and barriers exist. One of the concerns of RWH is the challenge associated with climate change which could reduce the volume of rainwater. A study conducted by in Australia shows that water saving through RWH can be gained in the range of 2–14% of total water consumption and that the reliability of RWH to meet the water demand of a given locality is reduced from 3 to 16% due to the effect of climate change. Still, RWH represents a climate change adaptation measure. Another barrier is revealed in a study conducted in South Africa by, reporting key challenges in South Africa associated with RWH to include the lack of a clear legal framework for the adoption of RWH, making it illegal by strict application of the law, the lack of finances to publicize RWH and build necessary infrastructure, and the nonexistence of a nationwide RWH coordinating body to facilitate RWH through approving required tenure beyond private plots. Quality of rooftop RWH represents another challenge. The biggest challenge to widespread RWH, especially in the developing world, might fall at the center of finance, followed by the volume of water depending on erratic rainfall, calling for large water storages, the inability to link with the other urban water components, poor public perception and quality, and a lack of commitment from the politicians (Dagnachew, 2018).

2.10. Rooftop Compatibility for Rooftop Rainwater Harvesting

Study concludes that the rainwater collected off; G.I. Sheet, Clay Tile & Asbestos made roof is suitable for drinking and other domestic purposes. However, the first flush of water after the dry season should be discarded. To avoid any environmental problems, tank should be made mosquito proof. (Project, 1995)

CHAPTER THREE

3. Materials and Methods

3.1. Description of the Study Area

West Arsi Zone is located at southern part of Oromia and Ethiopia. It is Surrounded by North; East Shoa and East Arsi zone, by West; Bale and West Guji zone of Oromia, by South; Sidama region and by West; Southern Nations, Nationalities and Peoples (SNNP) of region of Ethiopia. West Arsi (Afan Oromo: Arsii Lixaa/Dhihaa) a zone in Oromia of Ethiopia organized as a zone in 2006. The administrative center of this zone is Shashamane, which is located at nearly 250 km from Addis Ababa, the capital city of Ethiopia. The zone is at geographical location of6˚17'22.51''N to 7˚42'42.20''N and 38˚3'36.75''E to 39˚46'21.40''E (Figure 3).

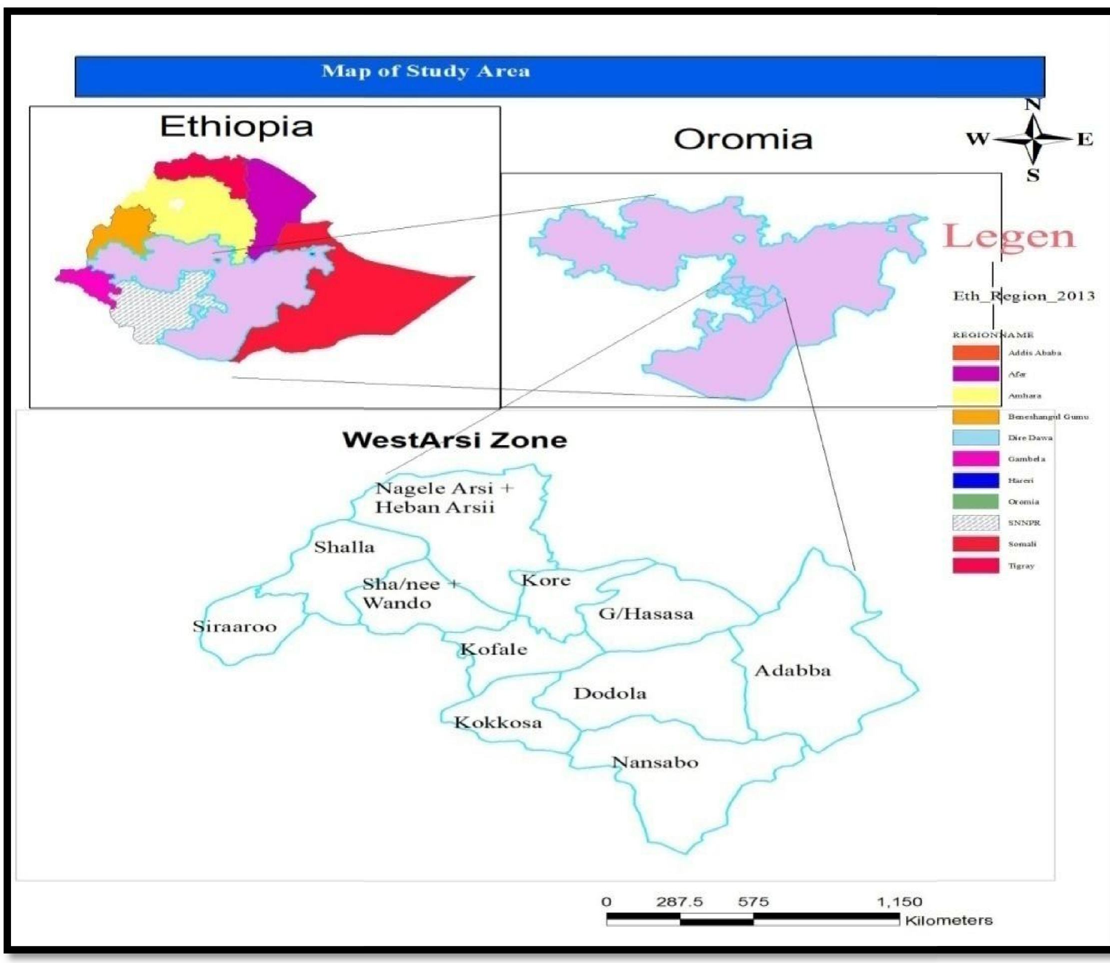


Figure 3: Map of West Arsi Zone (Source: Eth_adm_ 2013)

3.2. Rooftop Rain-water Harvesting System in the Zone

There are rooftop rainwater harvesting at households accommodation units and institutions like in health centers, school. Health centers and school water harvesting trend is more advanced system with some components, but household harvesting system is very traditional having different water yielding capacity.

3.3. Research Approach

The study was utilized through subjective investigate approach to capture in-depth and more extensive data of existing RWH structure framework contentment and operation and maintenance issues and harvesting potential available and how it was harvested. Both qualitative and quantitative data were collected from the study sites. The study involved of estimate typical roof areas within West Arsi Zone, calculate the rainwater harvesting potential and future recommended RWH system.

3.4. Research Design

The study was employed with descriptive and explanatory research design. Based on this research design, the existing trend of RWH and status of harvesting was described and challenges and prospects were explored to gain background information. Descriptive method would be planned to describe and provide magnitude and extent of the RWH construction and implementation trends as well as interrelated problems to bring upfront what is harvesting trend on the real ground and in what extent harvesting potentials is used. The explanatory design would be widely employed using ex post facto method; to identify the causes and reasons for occurrence of situations by observing an existing condition or state of affairs and searching back in time for reasonable causal factors through analysis and critical evaluation of information and data in relation with existing facts to provide better understanding and clarity of the situation in sufficient manner

3.5. Study Population

There are 13 woreda and 3 town administration and in West Arsi zone. To be specific; Adaba, Dodola, Gadab Hasasa, Nansabo, Kokosa, Kofale, Kore, Shashamane, Wando, Shala, Siraro, Nagele Arsi and Heban Arsi woreda administration and Nagele Arsi, Dodola and Shashamane town administration. Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSAE), this zone includes a population of 1,964,038 of whom 973,743 are men and 990,295 ladies. 272,084 or 13.85% of populace are urban tenants. Populations of 387,143 household units were numbered in this zone, which comes about in normal of 5.01 people to a family, and **369,533** accommodation units (CSA, 2007).This study was conducted in Siraro, Shasahamane and Gadab Hasasa woreda by researcher judgments and consultation with water office experts, Loke and Sanbate Sinkile kebele from Siraro woreda, Wakentera and Waltai kebele from Gadab Hasasa woreda and Watara Turufe and Malka Oda kebele Shashamane were selected depending on climate category; one from rift valley, one out rift valley and one from intermediate point. Thus sampling point was from two climate condition extreme point and at intermediate climate condition of study area.

3.6. Source and Type of Data

General plan for collecting the data include administration procedures, interview or observation procedures. Include an explicit statement covering the field controls to be employed and provide a general outline of the time schedule you expect to follow.

Both primary and secondary sources were used to collect data which helps to triangulate, correspond, supplement and assort it. Interview, field observation, Roof plan survey, digital camera and desk review are enabled the investigation of the pattern and general conditions under study through qualitative and quantitative approach and the followings would be sources of data for the study.

Examinations of Physical observation, design documents available and specification in relation to facts on the ground to identify actual performance and challenges that exist during construction, operation and maintenance of existing trend. Documents related to plan and design, implementation related with RWH, were assessed in similar manner. Officials at various authorities such as Engineers, managers, process owners, experts, planning and monitoring bodies were sources of data and information to exploit their intuitions, efforts they employed, major challenges and options in the context of the Zone. Interviewing and discussion with individuals and local elders/historians was also used as sources of data and information.

A structured survey questionnaire, with closed- and open-ended questions translated into Afan Oromo language, was used to gather primary data at household level and there was no problem of language barrier. Both Users and Non-Users of RWH were involved in the survey. The pre-tested questionnaire includes data on household and demographic profile, rooftop characteristics, rain water harvesting trend, household's participation in various phases of RWH, health aspects of RWH, people perception and awareness about RWH. The focus group discussion composed of 1 elders and 1 community leaders in each sample village, 1 engineer 1 officials from health office or education office and water and energy office at woreda level and at zonal level. Wide ranging issues of RWH were raised to capture the insights, thoughts, attitudes, beliefs, perceptions and practices concerning several aspects of RWH. The in-depth discussions were led by the principal researcher. Secondary data of Meteorological data were obtained from reviewed source. After calculating all the parameters that are part of the RWH per capita equation harvesting potential and harvesting compatibility was identified.

3.7. Sampling Design and Procedure

3.7.1. Sampling Techniques

Based on the nature of the field of specializations the necessary sampling techniques and size should be identified and employed in consultation with advisor.

The research techniques were selected on the basis of the clustered probability sampling and purposive (judgmental) non probability sampling techniques for both study site and respondent selection. The primary attention in purposive sampling is the researcher's judgments as to who can provide the better evidence to achieve the objectives of the study (Kumar, 2011).

All samples are collected by researcher by judgments cluster type sampling of the study population to institutional, commercial and private harvesting trend. Sampling is to describe or explain what is happening within a smaller group and provide insights into behavior of the wider research population. The sample size determination was following the concept of saturation for data collection process. The concept of saturation is the most important factor to think about when charming over sample size decisions in qualitative research (Mason, 2010). Saturation point is achieved at which the data collection process no longer offers any new or relevant data for existing system evaluation and assessment of operation and maintenance. In other case conceptual categories in of existing, trend, its drawback and available potential can be considered enough upon saturated when gathering fresh data no longer sparks new theoretical insights, nor reveals new properties of core theoretical categories. Existing harvesting is population to be to draw a fair or representative sample and generalize the results back to the population. Sampling error was considered when determining the size of the sample to address possible biases in groups of respondents & non-respondents.

Direct observation were conducted to asses' status of existing harvesting system, for cause of poor condition of existing roof water, secondary data from Meteorology agency, and standards to asses potential of RWH in solving the water availability issue and major constraints for proper functioning of RWH system by researcher visual inspection and interview, questionnaire to target population up to saturation of ideas from respondents. Problem identification and solution recommendation were collected from respondent. Clustered type non random sampling technique is applied to the study. Rainfall data from reviewed secondary meteorological data were obtained to estimate harvesting potential and storage capacity assessment. Questionnaire and interview is data collection instrument to explore cause of failure and operation and maintenance (O & M) trends and design review from zonal Health and Education office.

3.7.2. Sampling Area and Sampling Point

Concerning the technique, the study mainly focuses on; health center, school, and private house were selected purposefully from central part and the others from two extreme location of the zone to examine existing RWH system.

Physical, technical and sustainability assessment of current trend of RWH system, available potentials, system component functionality and possible operation and maintenance available, cause of component failure, current harvesting practice and feasible method, evaluating existing trend of water supply sustainability assessment, operation and maintenance sustainability assessment and designing systems assessment for safe harvesting system structure construction and reduce water supply sustainability problem. Assessment of existing water supply and demands, how RWH support the demands and what capacity should support water demand.

3.7.3. Sample Size Determination

The sample size determination was follow the concept of saturation for data collection process no longer offers new data from the different respondent or informant. Most scholars argue that the concept of saturation is the most important factor to think about when mulling over sample size decisions in qualitative research (Mason, 2010). Saturation is defined by many as the point at which the data collection process no longer offers any new or relevant data. Another way to state this is that conceptual categories in a research can be considered saturated "when gathering fresh data no longer sparks new theoretical insights, nor reveals new properties of your core theoretical categories" (Charmaz, 2006). For low response survey; sample size guidelines suggested a range between 20 and 30 interviews to be adequate (Creswell, 1998). Therefore, the study used at least a sample of 25 individuals up to saturation of primary data collection process.

The researcher determines the sample size by using (Israel, 1992) formula

$S = N/(1+Ne^2)$ where S = the desired sample size, N = study population

e = 5% the error term at 95% of confidence level confidence interval or error term; no sample was perfect; the researcher decided the permute error that was 5% error permute.

N= 369,533 Accommodation units in the zone;

$S= 369{,}533/ (1+369{,}533*0.05^2) = 399.57 \cong \underline{400}$ (The desired sample size at Zone level)

400 people from west Arsi zone were sampled to collect data and information.

3.8. Data Analysis

The data generated were analyzed using descriptions of data analytical methods, techniques, tools and statistical tests. Software used in statistical analysis are SPSS, and MS excel.

The qualitative data was obtained through questioners, face to face interview; key informant interview and focus group discussion were analyzed by interpreting and describing. Observations on site issues and all secondary data sources was analyzed by using description; whereas to comparison of the proposed existing trend, design and constructed RWH system is analyzed by graphical method and curve fitting analysis tools. Data had analyzed and presented mainly in descriptive and qualitative approach. Tables, Design, graphs and charts were used for presentation of data. Photo graphs and figures would incorporate to the research work to support and ascertain the actual situation on the real ground. Relevant computer software like; excels, word, CAD and SPSS with sufficient verbal description were part of presentation techniques.

Rainfall analysis is a crucial step in designing effective rooftop rainwater harvesting systems. This analysis helps determine the potential amount of rainwater that can be harvested from rooftops in a given area. Here's a step-by-step how to conduct a rainfall analysis for rooftop rainwater harvesting:

a) Collect Rainfall Data:

Obtaining historical rainfall data for the specific location where the rooftop rainwater harvesting system will be implemented. This data was gathered from local meteorological departments or online databases. This data cover several years to account for variations in rainfall patterns.

b) Data Preparation:

Data Preparation is organizing collected rainfall data by month, season, and year. Calculate the average monthly rainfall and total annual rainfall for the location.

c) Rainwater Harvesting Potential:

Rainwater harvesting potential is determining catchment area of the rooftop that will be used for rainwater harvesting. This is the area from which rainwater will be collected. It is measuring dimensions of the rooftop and calculates its total area in square meters.

d) Rainwater Collection Efficiency:

The efficiency of rainwater collection depends on factors such as the rooftop material, slope, and gutter system. Researcher can determine an appropriate collection efficiency value based on these factors. Collection efficiency is usually expressed as a percentage.

e) Calculation of Harvestable Rainwater:

Multiply the average monthly or annual rainfall by the catchment area and the collection efficiency to calculate the amount of rainwater that can be harvested. This will provide an estimate of the potential volume of harvested rainwater.

f) Demand Analysis:

Evaluate the intended uses of harvested rainwater, such as irrigation, flushing toilets, or even drinking after proper treatment. Estimate the water demand for these purposes. This will help you determine if the harvested rainwater can adequately meet the demand.

g) Storage Capacity:

Based on the demand analysis, calculate the required storage capacity of the rainwater harvesting system. This capacity should be large enough to store surplus rainwater during periods of low demand or low rainfall.

h) System Design and Components:

With the calculated storage capacity, design the rainwater harvesting system components, including storage tanks, filters, first-flush diverters, and distribution systems. Ensure that the system is designed to handle the estimated volume of harvested rainwater.

i) Sensitivity Analysis:

Consider conducting sensitivity analysis by varying certain parameters, such as collection efficiency, catchment area, or demand. This will help you understand the system's performance under different conditions and make adjustments accordingly.

j) Implementation and Monitoring:

Implement the designed rainwater harvesting system and monitor its performance over time. Compare the actual harvested rainwater volumes with the estimated values from analysis. Make any necessary adjustments based on real-world data.

The research is exploratory and descriptive and the method of data analysis and presentation of findings follows standard approaches of describing qualitative and quantitative data. Statistical software called SPSS was used to compute and descriptive statistics.

Step by step consideration to evaluating rainfall data for rooftop rainwater harvesting analysis to analysis rainfall data for rainwater harvesting.

i. Determine the Roof Area: Measure the area of the rooftop where rainwater will be collected. This will help in calculating the potential volume of water that can be harvested.

ii. Collect Rainfall Data: Obtain historical rainfall data of the location. You can typically get this data from meteorological departments, online databases, or weather stations. Look for data that includes monthly or yearly precipitation levels.

ii. Analyze Rainfall Patterns: Study the rainfall patterns in your area. Identify the average monthly and annual rainfall amounts. This data helps estimate the potential volume of water you can collect.

iii. Calculate Water Harvesting Potential: Multiply the roof area by the average rainfall to estimate the potential volume of rainwater that can be harvested. For instance, if the average annual rainfall is 40 mm and your roof area is 1000 m^2, you can potentially harvest 40,000 cubic meter of water per year.

iv. Consider Efficiency: Not all rainfall can be harvested due to losses from evaporation, runoff, or inefficiencies in the collection system. Factor in the efficiency of your rainwater harvesting system, usually expressed as a percentage, to get a more realistic estimate of the amount of water actually collect.

v. Assess Storage Needs: Determine the storage capacity required based on the calculated harvestable water. Consider the purposes for which you'll use the harvested water and calculate the storage capacity accordingly. This may involve using barrels, tanks, or underground cisterns.

vi. Evaluate Demand: Assess your water needs and compare them with the calculated harvested water. This will help ensure that the harvested water meets requirements. If there's a shortfall, you might need to supplement with other water sources or adjust your usage.

vii. Design the System: Based on the calculated data, design your rainwater harvesting system. Consider elements like gutters, downspouts, filters, and diversion systems to ensure efficient collection and storage.

viii. Implement and Monitor: Install the rainwater harvesting system according to the designed plan. Regularly monitor the system's performance and make adjustments as needed to optimize its efficiency.

ix. Maintenance: Keep the system well-maintained. Clean gutters, check for leaks, and ensure that the storage tanks or containers are properly sealed and free from contaminants.

Considering local conditions, the quality of the roof surface, and the design and maintenance of the harvesting system can affect the accuracy of calculations.

3.9. Materials used for the Study

Software (SPSS and Microsoft Excel) for analysis, data collection tools and materials like paper, camera, computer and measuring instrument was used. Data collection for primary data is questioner, interviews, focus group discussion and physical observation was used. Population per census truck, home per census truck, stratified sampling, identification of roof type, roof area per accommodation unit, average size household, average annual rainfall, water demand per capital, water supply per capital, runoff coefficient are instrument to conduct the study.

3.10. Ethical Consideration

All works and literature review work were cited and plagiarism was eliminated in the work. The morals of the investigation or intervention as regards the minimal abuse, disregard, and safety, social and psychological well-being of the person and community and institutional ethical consideration were considered. The principles of consent, beneficence and justice are handled in the study.

CHAPTER FOUR

4. Results and Discussions

4.1. Results

Assessing the rooftop rainwater harvesting potential for an alternative water source in the West Arsi Zone of the Oromia Region, Ethiopia involves a comprehensive evaluation of various factors that influence rainwater collection, storage, and utilization. Here's a general framework for conducting such an assessment:

Rainfall Analysis: Gather historical rainfall data of seven years 2017 to 2023 bega was used to account for variations in rainfall patterns to understand the seasonal and annual rainfall patterns. This information is crucial to estimate the potential amount of rainwater that can be harvested from rooftops.

Roof Area Estimation: Determine the total rooftop area available for rainwater collection. This includes residential, commercial, and institutional buildings. Different types of buildings might have varying roof materials and slopes, which affect rainwater collection efficiency.

Rainwater Harvesting System Design: Design rainwater harvesting systems based on the roof area and anticipated rainfall. Consider factors such as gutter systems, downspouts, first flush diverters, filtration mechanisms, and storage tanks. The design should accommodate the local climate and water demand.

Rainwater Collection Efficiency: Calculate the efficiency of rainwater collection based on the design, roof material, slope, and maintenance practices. Not all rainfall can be collected due to losses from runoff, evaporation, and spillage.

Water Demand Assessment: Analyze the local water demand for various uses, such as irrigation, domestic use, livestock, and other purposes. This will help determine whether the harvested rainwater can meet these demands.

Storage Capacity: Assess the suitable storage capacity required to meet the water demand during dry spells. Consider factors like household consumption, storage losses, and the length of the dry season.

Water Quality and Treatment: Test the quality of harvested rainwater for contaminants. Implement appropriate treatment methods, such as filtration and disinfection, to ensure the harvested water meets acceptable quality standards.

Economic Viability: Evaluate the cost-effectiveness of implementing rainwater harvesting systems compared to other water sources. Consider installation costs, maintenance expenses, and potential savings from reduced reliance on other water sources.

Social and Environmental Considerations: Analyze the social acceptance and environmental impacts of rainwater harvesting. Consider factors like community involvement, cultural practices, and potential effects on local ecosystems.

Policy and Regulatory Framework: Review local regulations and policies related to rainwater harvesting. Ensure that the project complies with existing guidelines and, if necessary, advocate for supportive policies.

Community Awareness and Capacity Building: Raise awareness among the local community about the benefits and importance of rainwater harvesting. Provide training on system maintenance, water conservation, and sustainable water use practices.

Implementation and Monitoring: Implement the rainwater harvesting systems and monitor their performance over time. Regularly assess the collected data to make necessary adjustments and improvements.

4.1.1. Questionnaire Frequency Output

The gender of respondent is 53.3% male, 46% female and 0.7% missing or respondent does not tell their gender. And the age group; 7.5% are 20-30 years old, 91.8% are 31-40 years old, 0.7% are 41-50 years old and no other age group respondents. The marital status of respondents is; 26.3% are Single, 65.5% are married and 8.3% are divorced. The education level of respondents is; 0.7% Certificate, 83.8% BA/BSc. Degree and 15.5% MA/ MSc. And respondents are; 5.2% contractor, 15.3% client, 77% regulatory body and 2.5% are others category in West Arsi Zone. The respondent experience of water supply construction industry was; 50.8% below 5 years, 31.8% 5-10 years, 15% 11-15 years and 2.5% are not responding to the question. 62.5% of respondents are performing rooftop rain water harvesting, 35% not perform rooftop rain water harvesting and 2.5% are not responding to the question. The RWH system require; 0.8% very close supervision, 6.3% very close supervision, 76.3% related supervision, 0.8% very related supervision, 14.3% No supervision and 1.8 missing.

For all questionnaires occurrences level coding are described below;

(1) = Very Low Frequent, (2) = Low Frequent,

(3) = Moderate Frequent, (5) = Very High Frequent,

(4) = High Frequent, M = Missing

1. Causes of poor roof water harvesting within rooftop rain water harvesting system construction; the causes of poor roof water harvesting within rooftop rain water harvesting system construction; percentage of respondent opinion in the table below for the frequency occurrences corresponding to each of them.

The SPSS analyzed data was summarized on table 1. Bold values indicate highest rating result obtained from output data. The values in the table contain average value of occurrences frequency for 400 sample respondents.

Table 1: Frequency table of causes of poor RWH system

		Respondent opinion in %					
No	Causes Factors	1	2	3	4	5	M
2.1	Inadequate feasibility study and preliminary design	0	28.3	16	**40.5**	15.2	0
2.2	Change of plans or scope and design	0	22	**47**	18.2	12.8	0
2.3	Financial problems	11.3	2.5	**53.8**	16.8	3	12.8
2.4	Inadequate project objectives	7.5	18	**38.3**	24.3	4.5	7.5
2.5	Replacement of materials or procedures	9.8	**51.5**	20.3	16.8	1.8	0
2.6	Impediment in prompt decision making process	23	25.5	**25.8**	25	0	0.8
2.7	Technology change	13.3	**39.8**	20.8	13.5	0	12.8
2.8	Inadequate working drawing details	11.8	**35**	36	15.8	0.8	0.8
2.9	Lack of required data and inappropriate information	2.5	**30.5**	18.3	25.5	22.5	0.8
2.10	Socio-cultural factors	9.3	24.5	**59.5**	2.3	4.5	0
2.11	Inappropriate construction methods	11	21.3	26.5	**35.3**	15.3	0
2.12	Inadequate experience & Poor government policy	1.8	21.3	26.5	**35.3**	15.3	0
2.13	Poor quality materials and workmanship	11	2.3	**44.8**	2.5	39.5	0

Result of respondent shows; replacement of materials or procedures, technology change, inadequate working drawing details and lack of required data and inappropriate information, have low frequent or low impact on poor RWHS in West Arsi zone. Change of plans or scope and design, financial problems, inadequate project objectives, impediment in prompt decision making process, socio-cultural factors and poor quality materials and workmanship has moderate frequent or impact on RWHS. The result shows; the main cause of poor performance of RWHS in West Arsi is related to inadequate feasibility study and preliminary design, inappropriate construction methods and inadequate experience & poor government policy has high frequent or impact on poor performing of existing RWHS.

2. Impacts of poor harvesting system construction in supporting water supply; the level of impacts on performance of harvesting system: percentage of respondent opinion in the table below for the frequency occurrences corresponding to each was summarized on table 2.

Table 2: Frequency table of impact of poor RWH system

		Respondent opinion in %					
No	Impact Factors	1	2	3	4	5	M
3.1	Gutter failure	6.3	**37**	33.3	2.5	21	0
3.2	Storage failure	5.5	**30**	27.3	22.8	14.5	0
3.3	Pipe failure	5.5	**35.5**	21	4.8	33.3	0
3.4	Connection failure	17.3	5	29	8	**40.8**	**0**
3.5	Operation & maintenance failure	0	**29**	22.5	24.4	24	0
3.6	Design problem	0	22	18.3	**45.5**	14.3	0
3.7	Policy problem	3.3	19.8	15.3	28.3	**33.5**	**0**
3.8	Treatment and water use problem	9	**53**	1.8	20.8	13.8	1.8

The result shows impact factors like gutter failure, storage failure, operation & maintenance failure, treatment and water use problem has low frequency or low impact on poor performing of existing RWHS. And design problem has high frequency or impact on harvesting system, while; connection failure and policy problem has very high frequency or very high impact on RWHS in the study area.

3. Mitigation measures to improve the existing harvesting system to support water supply coverage. The following table indicates the direction how to manage the poor harvesting potential and system water supply construction projects in order to increase the performance of the projects by the parties involved in water supply projects in

West Arsi Zone. Percentage of respondent opinion in the table below for the frequency occurrences corresponding to each of them was summarized on table 3.

Respondent indicate that preparation of working drawing before construction of the system is basic mitigation measure for RWHS in West Arsi Zone to overcome the problem of existing harvesting system. Including all system components like; catmint, collection system, conveyance, storage and other related accessory including safe collection and treatment. All part inclusive and preliminary study and detail study with proper design is very important for proper construction of the system to overcome water shortage during driest season, especially when main water supply system does not work. Summary of mitigation method collected from all respondents are presented on table 3 below in summery of percentage occurrence of respondent opinions.

Table 3: Frequency table of mitigation measure of poor RWH system

		Respondent opinion in %					
No	Mitigation measures	1	2	3	4	5	M
4.1	Preparing proper feasibility study and preliminary design	9	20.5	**34.3**	16.8	19.5	0
4.2	Set scope of plans and prepare details design	0.8	21	**43.5**	33	1.8	0
4.3	Fixing source of budget and solving financial problems	0	19	**40.3**	28	12.8	0
4.4	Adopting adequate project objectives	7.5	9.8	36.8	**43.8**	2.3	0
4.5	Quality control on materials or procedures	10	20.5	24.5	**38**	7	0
4.6	Fast and effective decision making process	0	29.5	17.3	**42.8**	10.5	0
4.7	Adopting new technology	3.3	**42.8**	15	22.3	16.8	0
4.8	Prepare adequate working drawing details	12.8	22.8	24.5	10.3	**28**	1.8
4.9	Collect required data and appropriate information	7.5	14	**41**	23	14.5	0
4.10	Resolving Socio-cultural factors	8.3	**42.5**	36.5	12.8	0	0
4.11	Adopt appropriate construction methods	9	1.8	**45.5**	41.5	0	2.3
4.12	Provide adequate training & develop good government policy	0.8	23	**47.3**	16.8	12.3	0
4.13	Quality controls on materials and using trained workmanship	0.8	20.3	**49.3**	22.5	7.3	0

Adopting new technology and resolving Socio-cultural factors has low importance in mitigation of poor performing of RWHS. Preparing proper feasibility study, preliminary design, setting scope of plans, prepare details design, fixing source of budget and solving financial problems, collecting required data and appropriate information, Adopt appropriate construction methods, provide adequate training & develop good government policy, quality controls on materials and using trained workmanship has moderate importance in mitigation of poor performance of existing RWHS in West Arsi Zone. Adopting adequate project objectives, quality control on materials or procedures, fast and effective decision making process are more important issue in mitigation of existing RWHS in study area. The result indicated preparation of adequate working drawing and details is best mitigation with very high frequency.

4.1.2. Rainfall and Temperature Data

Rainfall data were prepared and disseminated by the Ethiopia National Meteorological Agency (ENMA) to providing climatologically information to different services of the community involved in various socio- economic activities. The information contained was used to assist the study by providing details of the climatic conditions of the nation in a given period. The data was based on data collected from a much larger number of meteorological stations. Moreover, the agency disseminates monthly, seasonal and annual climatologically data in which all necessary climatologically information and significant climatic anomalies are highlighted.

In this study the annual climate summary of the country for the year 2017 to 2023 was presented. For convenience the climate summary of the year is done on seasonal basis. From meteorological point of view, there are three rain related seasons in Ethiopia; Belg, Kiremt and Bega. Belg is a short rainy period from February to May over much of the Belg growing areas, where as over the southwestern parts of Ethiopia denotes the start of the long rainy season. Southern and southeastern parts of the country are expected to get their long rainy season during this time starting in March and peaking in April. The climate of the season is mostly hot and moist. Kiremt is the period from June to September. It is the main rainy season in which the major food crops of the country are produced. The magnitude of rainfall is higher as compared to the other seasons for many parts of the country. Normally, the southern and the southeastern lowlands of the country receive little or no rain during this season, except for little amount of rainfall that occurs towards the end of the season. Bega is the period from October to January. It is a harvesting season for various parts of Ethiopia. Bega is normally a dry season characterized by cool nights and early mornings over the highlands of northern, northeastern, central and eastern Ethiopia and by hot days over various parts of the country. It is also a short rainy season for places over southern, southeastern and southwestern parts of the country. Depending on the influences from mid latitude rain-bearing systems, some places over central, northern and northeastern Ethiopia also receive occasional showers.

The rainfall performance of the year 2017 was normal to above normal over most parts of the country. However, much area of and southern Oromia and pocket area of SNNPR had experienced below normal rainfall during year 2017. On the other hand western of the country are much wetter than 2016 annual rainfall and also central northern and eastern part the country much direr. The annual total rainfall amount of the year 2017 exceeded 1000mm over most part of specially the highland of Amhara, Benishangul-Gumuz, Western part of Oromia and most part of SNNPR, western Tigray and Gambella. In association with this, the annual total rainfall amount exceeded 2500 mm over Ambuye, Elias (Debre Elias), Enjabara, Gimi jabet Mariam and Tikil Dengay was 2649.0 mm, 2828.8 mm, 2619.6mm, 2726.3 mm and 2771.7mm respectively. On the other hand, the annual total rainfall amount was below 500mm over most portions of Afar and Somali. Higher values of extreme maximum temperature values were recorded, mostly during the hot season (Belg) 2017. In particular, the extreme maximum temperature values had exceeded 42.5^{o}C over Metema, Alamabal, Yetnora and Tefaribar. On the other hand, nights and early mornings were cold over the highlands of northeast, central and southern Ethiopia during the dry season (Bega). In association with this, minimum temperature values below the freezing point (-5^{o}C) were recorded over Segura, Agere Genet, Fursi Molale, Debre Berhan, Adigrate, and Guguftu

The rainfall performance of the year 2018 was normal to above normal over most parts of the country. However, some pocket area of Amhara, Oromia and Somali had experienced below normal rainfall during year 2018. On the other hand most parts of the country are much wetter than 2017 annual rainfall and also central, northern and eastern and also Afar region part the country much direr. Higher values of extreme maximum temperature values were recorded, mostly during the hot season (Belg) 2018. The annual total rainfall amount of the year 2018 exceeded 1000mm over most part of specially the highland of Amhara, Benishangul-Gumuz, Western part if Oromia and most part of SNNPR, western Tigray and Gambella. In association with this, the annual total rainfall amount Reported exceeded 2500 mm over Kidamaja, Gobgob, Adigrate, and Tikil Dengay was 3459.7mm, 3026.2 mm, and 2863.8mm respectively. On the other hand, the annual total rainfall amount was below 500mm over most portions of Afar and Somali. In particular, the extreme maximum temperature values had exceeded 43^{o}C over Semera, Quara, Teferi Bar and Chifra. On the other hand, nights and early mornings were cold over the highlands of northeast, central and southern Ethiopia during the dry season (Bega). In association with this, minimum temperature values below the freezing point (-5^{o}C) were recorded over Abyadi, Debre Berhan and Masha Temperature Higher values of extreme maximum temperature values were recorded, mostly during the hot season (Belg) 2018. In particular, the extreme maximum temperature values had exceeded 40^{o}C over semera, Quara, Teferi Bar, Chifra, Metema, Sanja, Gambela, Abobo, Dembidollo, Dilla, Pawe and Sherekola. On the other hand, nights and early mornings were cold over the highlands of northeast, central and southern Ethiopia during the dry season (Bega). In association with this, minimum temperature values below the freezing point (0^{o}C) were recorded over Abyadi, Debre Berhan, Masha,Maichew,Sarmider, mehal Meda, Guguftu, Dilla, Haik, Adigrat, Wegel Tena and Gashena.

The rainfall performance of the year 2019 was normal to above normal over most parts of the country. However, some pocket area of Amhara Oromia and Somali had experienced below normal rainfall during this year 2019. The rainfall performance of the year 2019 was normal to above normal over most parts of the country. However, much area of Eastern and southern Tigray and also pocket area of Oromia, Banshangul and SNNPR had experienced below normal rainfall during year 2019. The annual total rainfall amount of the year 2019 exceeded 1000mm over most part of specially the highland of Amhara, Benishangul-Gumuz, Western part if Oromia and most part of SNNPR, western Tigray and Gambella. In association with this, the annual total rainfall amount Reported exceeded 2500 mm over Agaro, Bako, Debeso, Yadota, Elias (Debre Elias), Enjabara, Gimijabet Mariam, Kessa, Maligawa, Shishinda and Yadota was 2817.1mm, 2979.5mm, 3005.5, 2628.6, 2828.8mm, 2619.6mm, 2726.3mm, 2531.2mm, 3036.8mm, 3118.1 and 2359.5 mm respectively. On the other hand, the annual total rainfall amount was below 500mm over most portions of Afar and Somali.Higher values of extreme maximum temperature values were recorded, mostly during the hot season (Belg) 2019. In particular, the extreme maximum temperature values had exceeded 45^{o}C over Metema Yohannes, Aisha, Gewane, Dubity, Elider and Semera. On the other hand, nights and early mornings were cold over the highlands of northeast, central and southern Ethiopia during the dry season (Bega). In association with this, minimum temperature values below the freezing point (-3^{o}C) were recorded over Hegere Mariam, Debre Berhan, Gojeb and Bati.

The rainfall activity of the year 2020 was near normal over most parts of the central parts of the country. However, southeast and eastern portions of SNNPR, much of Somali and Afar region, portions of southern Oromia, pocket areas of Amhara and Oromia had experienced above normal rainfall. Rainfall The rainfall activity of the year 2020 was near normal over most parts of the central parts of the country. However, southeast and eastern portions of SNNPR, much of Somali and Afar region, portions of southern Oromia, pocket areas of Amhara and Oromia had experienced above normal rainfall. The annual total rainfall amount of the year 2020 exceeded 1250 mm over western and the highland of Amhara, Benishangul-Gumuz, Eastern Oromia and most part of SNNPR and the central and western Oromia. In association with this, the annual total rainfall amount reported over Nekemte was as high as 2243.7 mm. On the other hand, the annual total rainfall amount was below 750 mm over southern portions of Afar and southern and eastern portions of Somali. Higher values of extreme maximum temperature values were recorded mostly during the hot season (Belg 2020) and in particular, the extreme maximum temperature values had exceeded 40^{o}C over Gambela, Gewane, Aisha, Dubti, Semera and Elidar. On the other hand, nights and early mornings were cold over the highlands of northeast, central and southern Ethiopia during the dry season (Bega). In association with this, minimum temperature values below the freezing point (0^{o}C) were recorded over Debre Brehan, Wegeltena, Haromaya, Mehal Meda, Bati and Aleltu.

The rainfall activity of the year 2021 was near normal over most parts of the country. However, northern Afar, Gambella and adjoining Oromia places and pocket areas of Oromia and Amhara had experienced above normal rainfall. A rainfall deficiency was the case over parts of south Oromia & Somlai and other pockets areas of Oromia. Rainfall The rainfall activity of the year 2021 was near normal over most parts of the country. However, northern Afar, Gambella and adjoining Oromia places and other pocket areas of Oromia and Amhara had experienced above normal rainfall. A rainfall deficiency is the case over parts of south Oromia & Somlai and other pockets areas of Oromia. The year 2021 was drier than 2020 in most areas except few places. The annual total rainfall amount of the year 2021 exceeded 1500 mm over northwestern, western and southwestern parts of the country. In association with this, the annual total rainfall amount reported over Nekemte was as high as 2337.1 mm. On the other hand, the annual total rainfall amount was below 500 mm over most of Afar and the southern and southeaster portions of Somali. Higher values of extreme maximum temperature values were recorded, mostly during the hot season (Belg) and in the first and last months of (Kiremt). In particular, the extreme maximum temperature values had exceeded 42^{o}C over Aysha, Chifra, Dalifagi, Dubti, Elidar, Fugnuido, Gambella, Metema, Mille and Semera. On the other hand, nights and early mornings were cold over the highlands of Ethiopia mostly during the dry season (Bega). In association with this, minimum temperature values below the freezing point (0^{o}C) were recorded over Alemaya, Bati, Debre Berhan, Mehal Meda and Immi.

The rainfall activity of the year 2022 was near normal to above over most parts of the country. Gambella, the adjoining SNNPR & west Oromia areas and pocket areas of Amhara, Oromia & Afar had recorded above normal rainfall. But some places over Oromia, Somali and Benishangul Gumuz encountered a rainfall deficiency. The annual total rainfall amount of the year 2022 exceeded 1500 mm over northwestern, western and southwestern parts of the country. In association with this, the annual total rainfall amount reported over Arejo was as high as 2602.2 mm. On the other hand, the annual total rainfall amount was below 500 mm over most of Afar and the southern and southeaster portions of Somali. The annual rainfall of 2022 is lower than the one for 2021 over parts of eastern, southeast, southwest, south and western Ethiopia. Higher values of extreme maximum temperature values were recorded in February, March, April, May, June, July and September. In particular, the extreme maximum temperature values had exceeded 42^{o}C over Awash Araba, Aysha, Dubti, Elidar, Fugnuido, Gewane, Gode, Metema, Mille, Semera and Sherkole. On the other hand, nights and early mornings were cold over the highlands of Ethiopia mostly during the dry season (Bega). In association with this, minimum temperature values below the freezing point (0^{o}C) were recorded over Adelle, Alemaya, Debre Birhan, Wegel Tena, Bale Robe, Kulumsa and Mehal Meda.

The seasonal total rainfall amount of Bega 22/2023 was exceeded 300mm over Benishangul gumuz, Southwestern of SNNPRs, Southwestern Gambela and some pocket Areas of western Oromia. In particular, the seasonal total rainfall exceeds 300mm over

Abobo, Aman, Arjo, Bore, Jinka, Maji, Masha and Sawula with amount of 357.4, 487, 340.4, 435.3, 356, 325.4, 307.1, 340.7, 389.2, 483.6 and 411.6 respectively. During Bega 2022/2023, days remained hot over central and Western parts of the country particular, extreme maximum temperature values exceeded 38^{o}C Abobo, Fugnuido, Gode, Gambela, Aleiya, Metema, Elidar, Dubti and Kebridahar with values of 45, 41.8,41, 40.8, 40.2 40.2, 40, 39, and 38.8^{o}C. On the other hand, the highlands of Eastern Afar, western and central Oromia had cold nights and early mornings. Hence, the extreme minimum temperature values were as low as -4,-1.5, - 1.4, -1.2, -0.8, -0.2 and 0^{o}C over Adelle, Mehalmeda, Debre Birehan, Alemeya, Wegel Tenaand Gelemso. In general, the seasonal rainfall amount of Bega 22/2023 was normal to above normal over most parts of the country except over some pocket areas of Oromia, Amhara, and Benishangul gumuz, most of Somale region. Bega 22/2023 was wetter than Bega 2021/22 over much of the country.

Specifically the study area rainfall condition was increasing 2016 to 2019 and decrees 2019 to 2022 and increase at 2023 bega than 2022 bega. Three station Aje, Shashamane and Gofar station metrological data was used for the study from 15 stations.

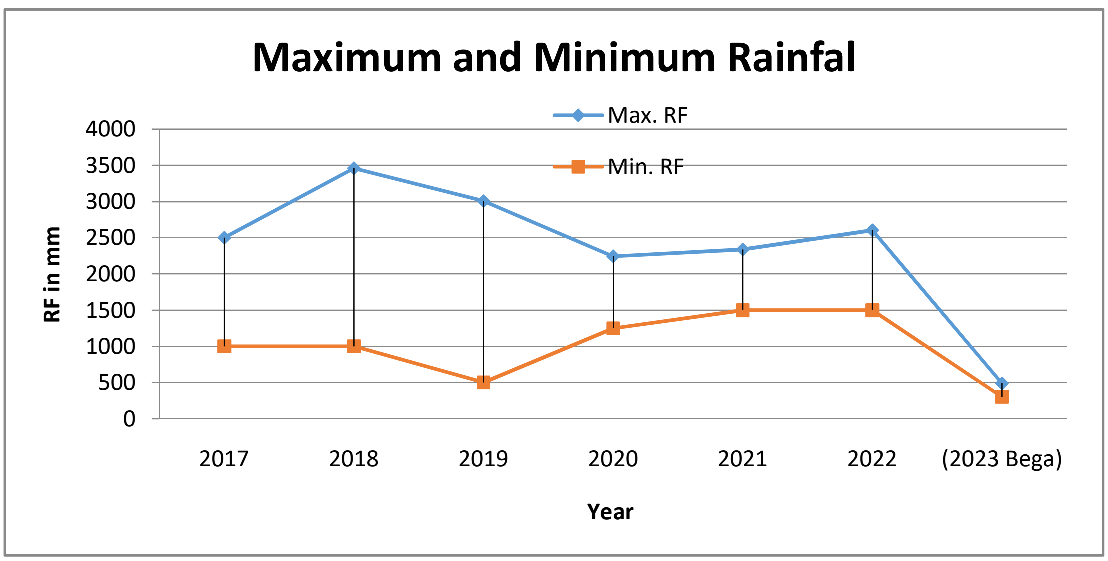


Figure 4: Annual Rainfall data of study area selected station

According to (Meselech, 2019) Annual rainfall in Ethiopia is 2700 mm in the south western highlands. From figure 4; maximum and minimum average annual rainfall intensity for the study area was 2376.49mm and 1007.14mm respectively. Average annual rainfall intensity for the study area was 1,691.82. Therefore safe harvesting potential estimation or minimum harvesting 500mm was used for the study.

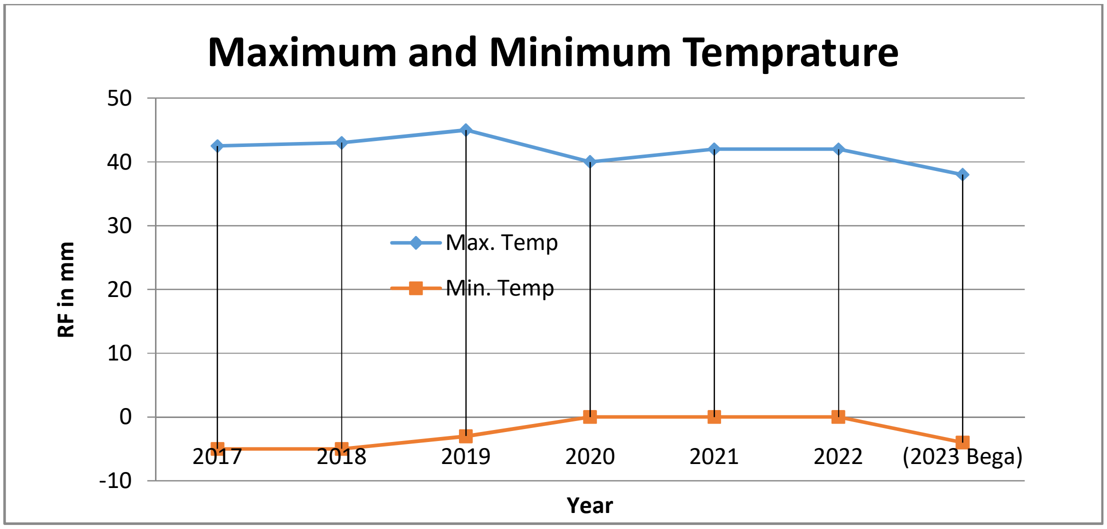


Figure 5: Annual Rainfall data of study area selected station

From figure 5; maximum and minimum average annual rainfall intensity for the study area was 41.78^0C and -2.43^0C respectively. Therefore average temperature of 19.68 ^{0}C was used for the study. This average temperature is almost similar with room temperature and collection efficiency with respect to temperature is negligible for the study area.

4.1.3. Water Supply and Demand in West Arsi Zone

As of last update data in January 2022, water supply and demand situation in the West Arsi Zone of the Oromia Region in Ethiopia; Water supply and demand can be dynamic and are influenced by various factors such as population growth, climate conditions, infrastructure development, and management practices.

To get the most accurate and up-to-date information on the water supply and demand situation in the West Arsi Zone, checking with local government authorities, water management agencies, or relevant organizations operating in the Zone. These entities often collect and maintain data on water resources, usage patterns, and ongoing initiatives related to water supply and also consider reaching out to international organizations, NGOs, or research institutions that focus on water issues in Ethiopia. They may have conducted studies or have access to data related to water resources in specific regions. Additionally, local news sources, community organizations, or academic institutions in the area may provide insights into the current water situation through reports, articles, or community initiatives related to water supply and demand.

Water-related issues are critical for sustainable development, and many organizations work towards improving water accessibility, quality, and management. According to data from West Arsi Zone Water and Energy office current water supply and demand situation in the West Arsi Zone at the end of the year 2014 EC; 73.1% at urban and 62.8% at rural area with average water supply coverage of 68.1% in the West Arsi Zone.

Typically, water supply and demand situations are influenced by various factors such as population growth, agricultural needs, industrial activities, climate conditions, and water management practices. Water scarcity can be a significant challenge in many regions, and it's crucial to have effective policies and infrastructure in place to ensure sustainable water management. Consider looking into reports from local water authorities, governmental organizations, or international agencies that may have conducted studies or assessments related to water are presented in table 4.

Domestic water demand: Domestic water demand includes use of water required for various domestic needs such as drinking, cooking, bathing, washing, and etc. Domestic water demand for a given year, y, can be calculated as: Domestic water demand = (total # population at year y) x (water consumption rate for year y)

Accordingly, domestic water demand is calculated and presented by assuming all of the total populations at every year y are beneficiary from the supply.

Non- Domestic Water Demand: The PA non- domestic water demand includes use of water for public services and unaccounted - for water

Public Water Demand including live stock: Public water demand is the total volume of water used for schools and other public services. Practically, the total volume required for public demand is about 10% of the domestic demand.

Animal Water Demand: Animal water demand varies by type of the animal.

Unaccounted - For Water or loses: Unaccounted - for water includes all water losses in the water supply system, illegal connections, improper meter, over flow & other losses. Here, about 15% of the total domestic demand is considered (15% to 25%)

Total average daily water demand: The total average daily water demand is taken as the summation of domestic, public, animal and water losses.

Maximum daily water demand: The maximum day water demand is considered to meet water consumption changes with season and weeks day. It is determined by multiplying the total average daily demand by a factor of 1.2 to 1.6 depending on local situation. For this particular site a factor of 1.2 is adopted.

Table 4: **Present and future water demand**

Description	Unit	Years					
		2019	2020	2025	2030	2035	2040
Population	Growth Rate	2.28%	2.28%	1.84%	1.47%	1.12%	0.81%
	No	1,964,038	2,008,818	2,045,780	2,075,853	2,099,103	2,116,106
Per capita demand	l/c/day	23	25	26	29	32	34
Domestic demand	m^3/d	45,172.87	50,220.45	53,190.29	60,199.75	67,171.29	71,947.59
Socio-economic factor	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Climate factor	1	1	1	1	1	1	1
Adjusted Total Domestic demand		40,655.59	5,198.41	7,871.26	54,179.77	60,454.16	64,752.83
Non Domestic Demand							
Public, Commercial and industrial Demand (10% DDD)	m^3/day		4,519.84	4,787.13	5,417.98	6,045.42	6,475.28
Animal Demand (10% of DDD)	m^3/day		**4,519.84**	**4,787.13**	**5,417.98**	**6,045.42**	**6,475.28**
Total Demands	m^3/day		54,238.09	57,445.51	65,015.73	72,544.99	77,703.40
Non Revenue Water	%		15%	17.50%	20.00%	22.50%	25.00%
	m^3/day		8,135.71	10,052.96	13,003.15	16,322.62	19,425.85
Average Day Demand including loss (8 hours)	m^3/day		62,373.80	67,498.48	78,018.87	88,867.62	97,129.25
	l/s		2,165.76	2,343.70	2,708.99	3,085.68	3,372.54
Maximum Day Factor		1.2	1.2	1.2	1.2	1.2	1.2
Maximum Day Demand(8 hours)	m^3/day		74,848.56	80,998.17	93,622.64	106,641.14	116,555.10
	l/s		2,598.91	2,812.44	3,250.79	3,702.82	4,047.05
Peak Hour Factor		2	2	2	2	2	2
Peak Hour Demand (8 hours)	m^3/day		313.92	361.72	437.83	516.85	580.46
	l/s		10.90	12.56	15.20	17.95	**20.15**

Peak hour water demand: The peak hour water demand is equivalent to 1.6 to 2.5 times (depending on local situation) the average daily water demand or 2 times the maximum daily water demand.

4.1.4. Roof Cover types and compatibility for Rain Water Harvesting

4.1.4.1. Roof Cover types

There are three roof cover type common in West Arsi Zone, Ruff (*Chita*) type; made of natural ruff grass or wheat type agricultural west as indicated on fig. 6 (a), Bamboo type as indicated on fig. 6 (b) and CIS type roof covers are widely used as indicated on fig. 6 (c).

(a) Ruff roof(Hasasa) (b) Bamboo roof(Siraro) (c) CIS roof(Shashamane)

Figure 6: Roof cover type commonly used in West Arsi

4.1.4.2. Compatibility for Harvesting Rainwater

From the three roof cover type common in West Arsi Zone, Ruff (Chita) type, Bamboo type and CIS type roof covers CIS roof cover type is most compatible for rooftop rainwater harvesting due to smooth, non deteriorated surface and easy to install harvesting system and an emerging and easily available roof cover technology. Ruff and Bamboo roof cover type are generally not compatible for RWH system due to smooth, easily deteriorated surface and not easy to install harvesting system and decreasing and easily non available roof cover technology. For ruff type a very few practice is used during rainy season, while bamboo type does not used for RWH system to support water supply system. For proper use of RWHS both ruff and bamboo roof type is not compatible. The researcher collects data from selected point to evaluate root type compatibility in study area. The rooftop compatibility and was collected at the same sampling point of focus group and interviews for validation purpose. Observed data at sampling point of study area was summarized on table 4.

Table 5 : Roof type in number observation data at different sample point/kebele

Observed Gote in WAZ	Roof type in number			
Observation point	Bamboo	Ruff	CIS	Total
Observation point 1	0	8	44	52
Observation point 2	0	6	50	56
Observation point 3	0	3	20	23
Observation point 4	0	5	57	62
Observation point 5	0	2	28	30
Observation point 6	2	4	31	37
Observation point 7	1	3	35	39
Total:	3	31	265	299
Average % of roof type	1	10.40	88.60	100

Using table 4; observed data of sample point in West Arsi Zone, out of 369,533 accommodation units 11.4% = 42,127 (ruff and bamboo roof type) accommodation units are not compatible for RWHS, while 88.6% = 327,406 (CIS roof type) are compatible for RWHS. CIS type roof are more emerging while other are diminishing as indicated on table 5 below. Due to respondent does not memorize house constructed before two years only two years emerging record was collected from study area to evaluate compatible roof cover type are in emerging status. The result shows no bamboo type roof cover were emerging and ruff type were less than 5%. The CIS type was over 95% emerging in past two years in study area.

Table 6 : Newly emerging in past two years Roof type observation data

Observed Gote in WAZ	Newly emerging in past two years			
Observattion point	Bamboo	Ruff	CIS	Total
Observations point	0	0	10.00	10.00
Observation point 1	0	0	7.00	7.00
Observation point 2	0	0	6.00	6.00
Observation point 3	0	0	9.00	9.00
Observation point 4	0	0	2.00	2.00
Observation point 5	0	1	4.00	5.00
Observation point 6	0	1	4.00	5.00
Total:	0.00	2.00	42.00	44.00
Average % of emerging roof type	0	4.54	95.46	100

Almost CIS roof type was emerging roof type as indicated on table 5. CIS roof type are very compatible for RWHS and all observed CIS roof covers were free from paints and other factors that reduce surface pollution to RWHS.

4.1.5. Available Design and Roof Area calculation

Design and BOQ for HC at West Arsi zone Health office is indicated on fig 7, a gable roof CIS roof type was more common in HC and similarly in school and private buildings.

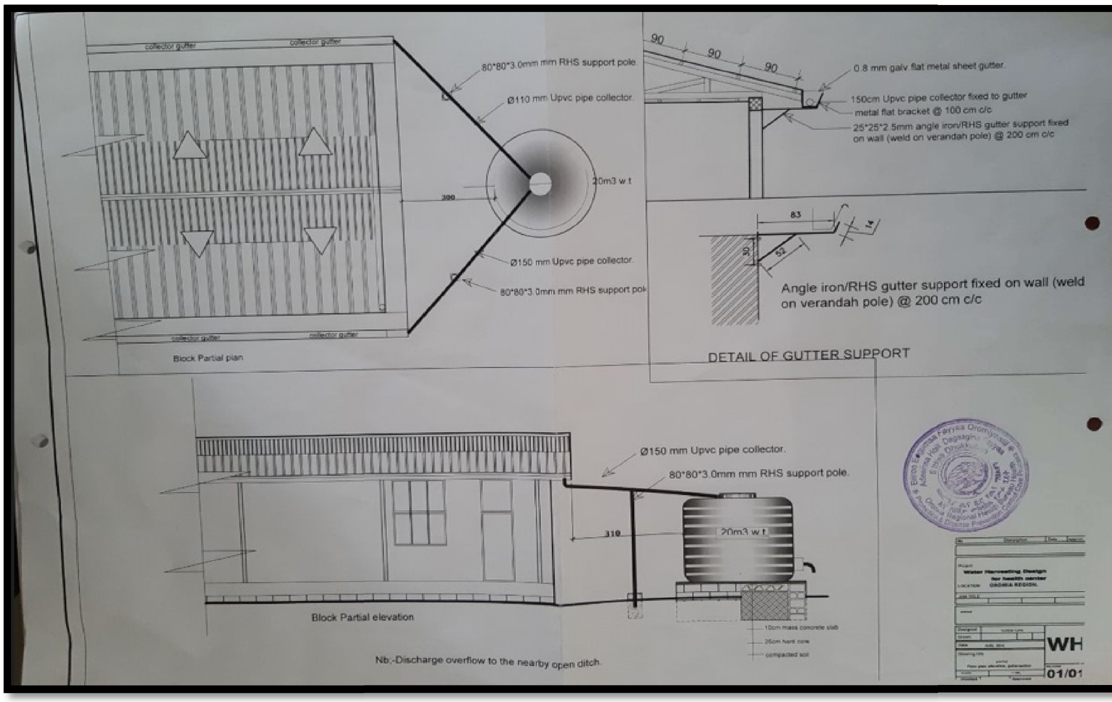
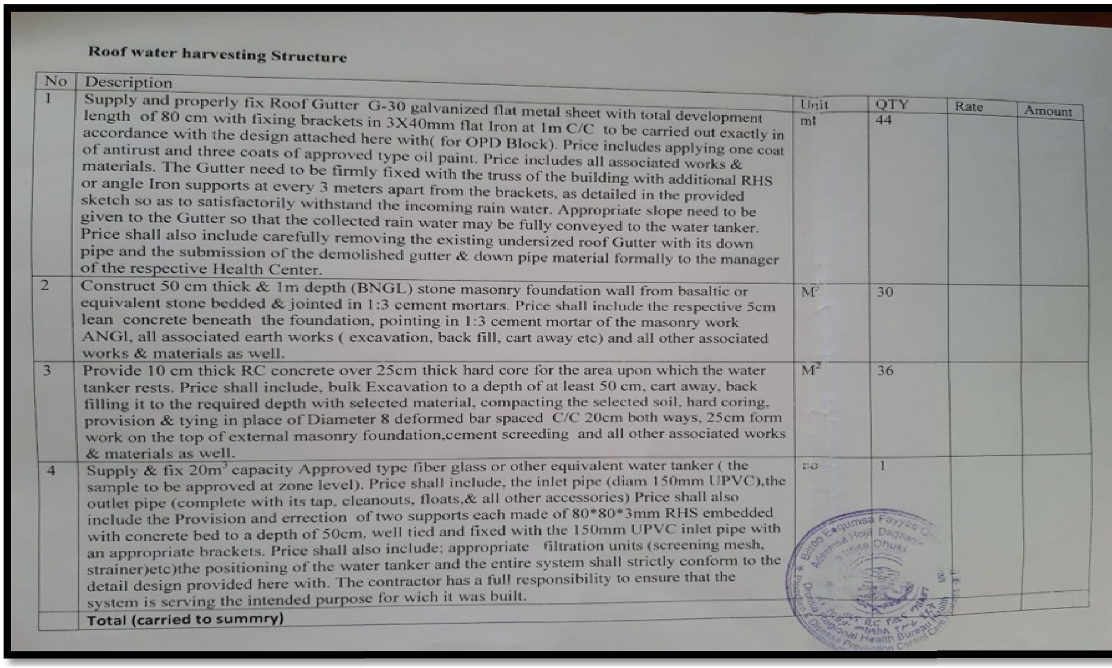


Figure 7: Typical Design for HC RWH system at West Arsi zone Health office

As indicated on fig. 8 and fig. 9, advanced component of RWH system like; first rain diverter, storage tank, valve and connection accessory and treatment system was not included in the design and BOQ.

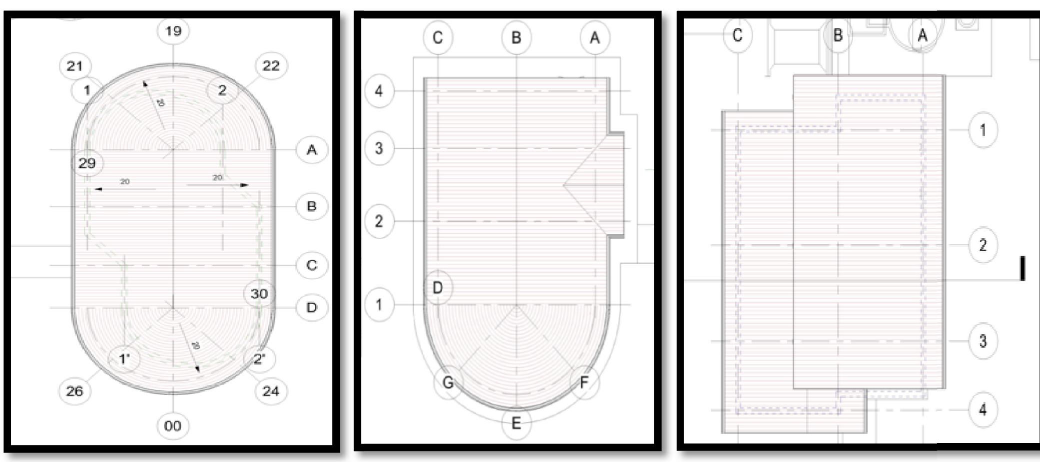


Roof water harvesting Structure

No	Description	Unit	QTY	Rate	Amount
1	Supply and properly fix Roof Gutter G-30 galvanized flat metal sheet with total development length of 80 cm with fixing brackets in 3X40mm flat Iron at 1m C/C to be carried out exactly in accordance with the design attached here with(for OPD Block). Price includes applying one coat of antirust and three coats of approved type oil paint. Price includes all associated works & materials. The Gutter need to be firmly fixed with the truss of the building with additional RHS or angle Iron supports at every 3 meters apart from the brackets, as detailed in the provided sketch so as to satisfactorily withstand the incoming rain water. Appropriate slope need to be given to the Gutter so that the collected rain water may be fully conveyed to the water tanker. Price shall also include carefully removing the existing undersized roof Gutter with its down pipe and the submission of the demolished gutter & down pipe material formally to the manager of the respective Health Center.	ml	44		
2	Construct 50 cm thick & 1m depth (BNGL) stone masonry foundation wall from basaltic or equivalent stone bedded & jointed in 1:3 cement mortars. Price shall include the respective 5cm lean concrete beneath the foundation, pointing in 1:3 cement mortar of the masonry work ANGI, all associated earth works (excavation, back fill, cart away etc) and all other associated works & materials as well.	M^3	30		
3	Provide 10 cm thick RC concrete over 25cm thick hard core for the area upon which the water tanker rests. Price shall include, bulk Excavation to a depth of at least 50 cm, cart away, back filling it to the required depth with selected material, compacting the selected soil, hard coring, provision & tying in place of Diameter 8 deformed bar spaced C/C 20cm both ways, 25cm form work on the top of external masonry foundation,cement screeding and all other associated works & materials as well.	M^2	36		
4	Supply & fix $20m^3$ capacity Approved type fiber glass or other equivalent water tanker (the sample to be approved at zone level). Price shall include, the inlet pipe (diam 150mm UPVC),the outlet pipe (complete with its tap, cleanouts, floats,& all other accessories) Price shall also include the Provision and errection of two supports each made of 80*80*3mm RHS embedded with concrete bed to a depth of 50cm, well tied and fixed with the 150mm UPVC inlet pipe with an appropriate brackets. Price shall also include; appropriate filtration units (screening mesh, strainer)etc)the positioning of the water tanker and the entire system shall strictly conform to the detail design provided here with. The contractor has a full responsibility to ensure that the system is serving the intended purpose for wich it was built.	no	1		
	Total (carried to summry)				

Figure 8: Typical BOQ for HC RWH system at West Arsi zone Health office

Typical proposed roof plan area for HC was $198m^2$, minimum annual rainfall is 500mm and assuming 85% collection efficiency; this typical HC single block can harvest $198m^2$*500mm *0.85 = **$84.15m^3$** annually. But for this RWHS only **$20m^3$** of storage tank were included in design and also constructed; that is only 23.77% of available harvesting potential were considered.



(a) Option 1 (b)) Option 2 (c)) Option 3

Figure 9: Typical Design for Model Oromia farmers (Source: OCA; May, 2022)

As indicated on fig 9, typical proposed roof plan for different topology were $85m^2$ for option 1, $73.4m^2$ for option 2 and $62.8m^2$ for option 3. So this typical model farmer's house constriction can harvest $85m^2$* 500mm*0.85 = **$36.13m^3$**, $73.4m^2$ * 100mm *0.85 =

$31.2m^3$and $62.8m^2$ * 100mm*0.85 = **$26.69m^3$** respectively annually. Using census data 5 person per households and 15L/day/person; the harvesting potential for model farmers house was 8.5/5/15 = 481.73 days < 100%, 7.34/5/15 = 98 days <100% and 6.28/5/15 = 355.86 days = 97.5% of accommodation unit yearly water demand respectively. For option 1 and 2 the potential is over accommodation unit demand and excess of personal consumption and can use for other purpose like irrigation or animal feeding. But for this initiative of housing RWHS construction is not considered.

4.1.6. Harvesting Capacity and Potentials

In HC standard typical design were used in all HC in West Arsi Zone. For such typical roof area is calculated by multiplying length and width of projected plan of roof plan. On fig 7 the roof plan is 22m long and 12m wide having roof area (A)= 22*9 = $198m^2$, assuming collection efficiency (C_{eff}) = 85%. Using roof area and minimum annual rainfall intensity I= 500mm harvesting capacity(C) of typical accommodation unit is C = A*I*C_{eff} = 264*0.5*0.85 = $84.15m^3$ of storage capacity is required. But as indicated on fig $20m^3$ of storage tank was supplied for RWHS construction while no system was included in model farmers' house construction initiatives. Observed constructed harvesting storage capacity and available potential of selected sample point is illustrated on fig. 10.

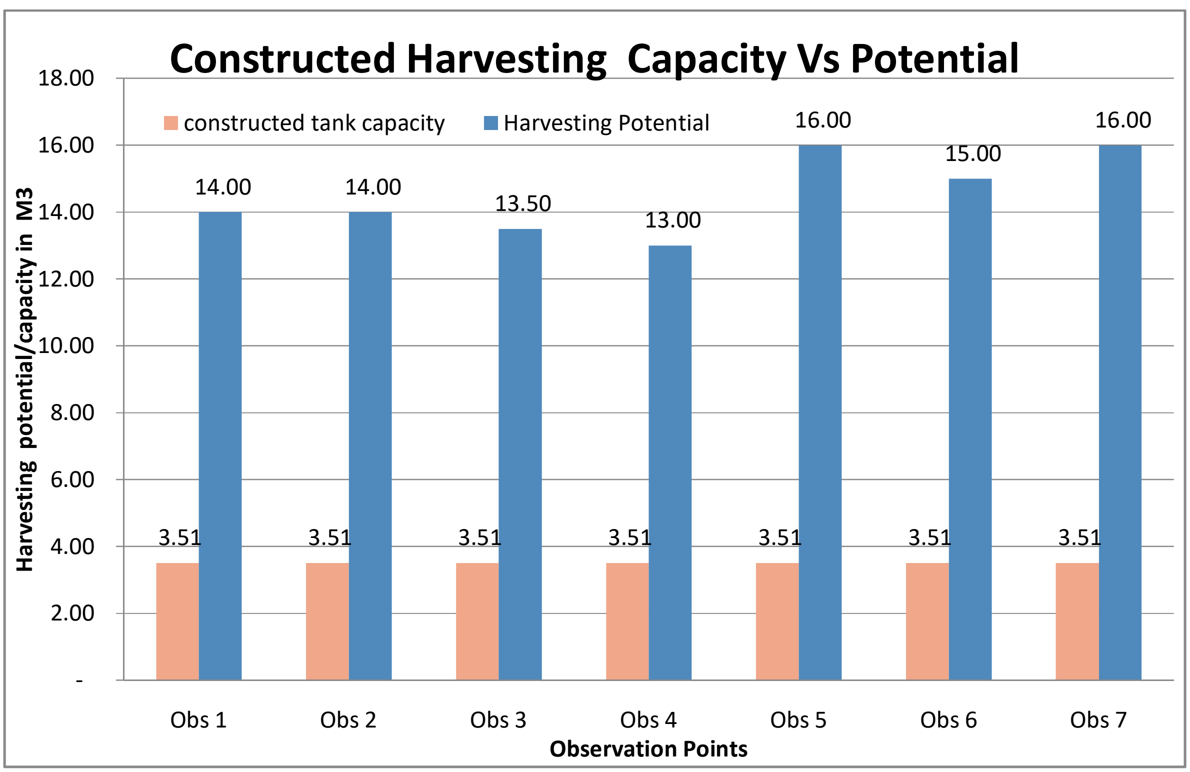


Figure 10: Average observed roof area and tank and average required tanks

In all observed points average maximum constructed tank capacity was only 24% of harvesting potential. Therefore the RWH was underutilized with almost 76% of potential was neglected.

4.1.7. Physical observation of Roof Water harvesting system

The observation of RWHS at different kebeles was illustrated with their problems on fig.11 to fig 16 below.

On figure 11 the installed gutter for RWH system were not properly fixed, no down pipe and proper storage tank, no other RWH system full components. There is toilet near the RWH system and washing dish was used as storage tank which were direct contact with floor and walkway to toilet.

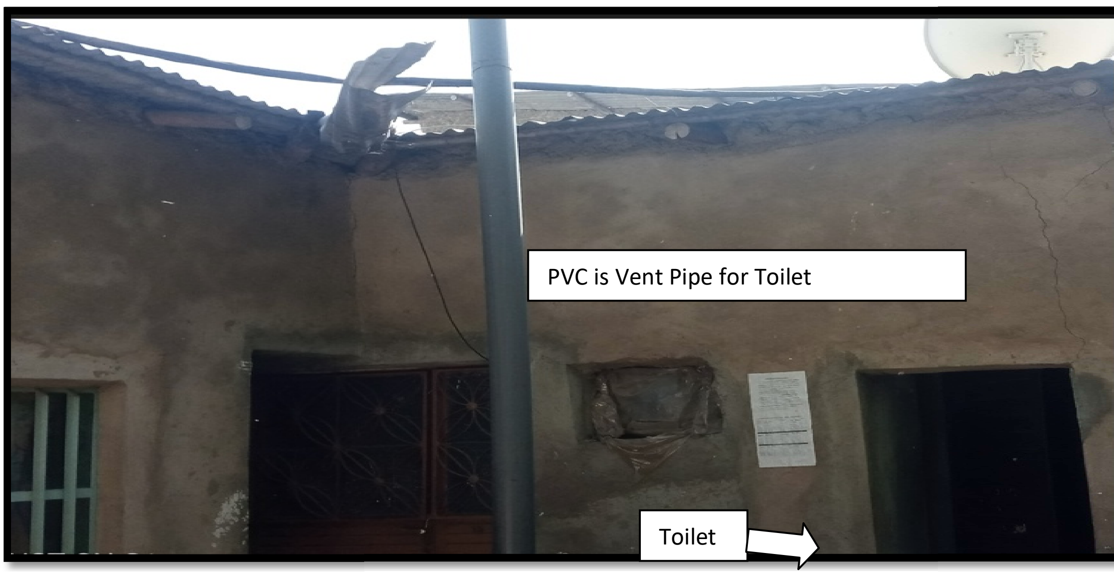


Figure 11: Private RWH system at Observation point 1; November 2022

On figure 12; RWH system installed were null function due to different problem like storage tank leakage, downpipe connection problem, gutter fixing problem and valve and other accessory connection problem.

Figure 12: Gutter dismantled and damped out at Observation point 2; September, 2022

Figure 13; Gutter installed for RWH system were dismantled and damped out away from the building as west material.

Figure 13: Gutter dismantled and damped out at Observation point 3; September, 2022

On figure 14; storage thank were broken due to improper installation, downpipe connection problem and other accessory connection problem and destroyed storage tank, Gutter and PVC connection.

Figure 14: Destroyed storage tank and Connection at Observation point 4; September 2022

On figure 15; Destroyed storage tank foundation, valves and connection due to improper construction of foundation and luck of operation and maintenance.

Figure 15: Demolished storage tank foundation, at Observation point 5; November, 2022

Figure 16: Damped storage tank at Observation point 6; December 2022

Figure 16; storage tank supplied for RWH system was damped out away from its construction site. The owner or concerned body does not manage all component and proper functioning of RWHS as asset. No regulatory or auditing to manage these resource.

Table 7 : Roof water harvesting component status

Observed RWH system in WAZ		Roof Type	RWH component stutus observation													
Num.	Observattion point		Roof surface	Gutter	Gitter protection	Rain head	1st flush	Tank screen	Rainwater tanks	Insect proof flap valve	Gitter fill	Pump system	water level Indicator	service accesory	current stutus	Tank capacity (L)
1	Wakentera town Private house	CIS	free	ok	No	free	No	No	ok	No	No	No	No	fails	no service	60
2	Wakentera Warehouse	CIS	free	fail	No	free	No	No	fails	No	No	No	No	fails	no service	2,000
3	Waltai school	CIS	free	fail	No	free	No	No	fails	No	No	No	No	fails	no service	2,000
4	Wakentera HC	CIS	free	ok	No	free	No	No	ok	No	No	No	No	fails	no service	10,000
5	Waltai town Private house	CIS	free	ok	No	free	No	No	ok	No	No	No	No	fails	no service	30
6	Waltai Warehouse	CIS	free	fail	No	free	No	No	ok	No	No	No	No	fails	no service	2,000
7	Waltai school	CIS	free	fail	No	free	No	No	ok	No	No	No	No	fails	no service	2,000
8	Waltai HC	CIS	free	ok	No	free	No	No	fails	No	No	No	No	fails	no service	10,000
9	Watara Turufe Private house	CIS	free	fail	No	free	No	No	ok	No	No	No	No	fails	no service	30
10	Watara Turufe Warehouse	CIS	free	ok	No	free	No	No	ok	No	No	No	No	fails	no service	2,000
11	Watara Turufe school	CIS	free	ok	No	free	No	No	fails	No	No	No	No	fails	no service	2,000
12	Watara Turufe HC	CIS	free	fail	No	free	No	No	ok	No	No	No	No	fails	no service	10,000
13	Malka Oda town Private house	CIS	free	fail	No	free	No	No	ok	No	No	No	No	fails	no service	60
14	Malka Oda Warehouse	CIS	free	ok	No	free	No	No	fails	No	No	No	No	fails	no service	2,000
15	Malka Oda school	CIS	free	fail	No	free	No	No	ok	No	No	No	No	fails	no service	2,000
16	Malka Oda HC	CIS	free	fail	No	free	No	No	fails	No	No	No	No	fails	no service	10,000
17	Loke; town Private house	CIS	free	ok	No	free	No	No	ok	No	No	No	No	fails	no service	60
18	Loke; Warehouse	CIS	free	ok	No	free	No	No	fails	No	No	No	No	fails	no service	2,000
19	Loke; school	CIS	free	fail	No	free	No	No	ok	No	No	No	No	fails	no service	2,000
20	Loke; HC	CIS	free	fail	No	free	No	No	ok	No	No	No	No	fails	no service	10,000
21	Sanbate; town Private house	CIS	free	ok	No	free	No	No	ok	No	No	No	No	fails	no service	40
22	Sanbate; Warehouse	CIS	free	fail	No	free	No	No	fails	No	No	No	No	fails	no service	2,000
23	Sanbate; school	CIS	free	fail	No	free	No	No	ok	No	No	No	No	fails	no service	2,000
24	Sanbate; HC	CIS	free	ok	No	free	No	No	fails	No	No	No	No	fails	no service	10,000
															Total	84280
															Avrage	3511.67

As indicated on table 6, sampled roof size and available average tank capacity is 3.51m^3 while available potential is 84.15m^3. The study area has potential to harvest 84.15m^3 and existing average storage tank is 3.51m^3; that is 4.17% of available potential. And no RWHS was under proper service in study area. Generally the status of RWHS in WAZ is not good.

4.1.8. Summarized Interview Results at Different kebeles

Generally six kebeles from West Arsi zone were being selected as per expert's guidance and researcher purposive judgment techniques. The following questions were raised similarly in all kebeles for group of interviewed peoples selected based on their knowledge about the subject.

a) How was the construction of the rainwater harvesting in WAZ?
b) What are the rainfall conditions and the construction of rainwater harvesting?
c) What are the problems of rainwater harvesting?
d) Construction of rainwater harvesting would be more useful if controlled in any way
e) What was the capacity of the rainwater harvesting?

In all focus point respondents reflects there is almost no rainwater harvesting work, and the existing one is cracked and not in service. If it had served, it would have helped us with up to 10% of our water needs. No more than 5% of RWHS available potential was just started, even very few was started by individuals during the rainy season. Some have been built as programs in health centers, while others have been started in schools, although very small. It has not been adequately stored and used for the non-rainy season. As WAZ water office, the rainwater harvesting work is underutilized and a forgotten resource. Therefore, study of this water resource with such research would bring great benefits. If the system was installed properly it saves the cost and times spend looking for water.

There are suitable conditions for storing rain water, because the almost all roof of houses was currently compatible for RWHS. There is very few old Ruff and Bamboo roof type, while rainfall conditions are sufficient to store enough water. Therefore, there is enough rainfall to store water and suitable rainwater harvesting rooftops are available in the study area.

Rainwater storage tank that individuals collect water from their homes have problems with inadequate storage capacity. A serious problem with individual harvesting system was it doesn't have enough rain storing capacity for available potential and components. The health centers and schools are in trouble due to factors such as broken gutters, leaking pipes, less storage, broken storage and lack of proper rainwater storage facilities. In many places water is not stored due to lack of storage even though one has gutters and down pipes; this is due to lack of attention, lack of awareness about self-sufficiency in water demand and the idea that the government should provide us a water. Therefore, both private and public RWHS are problematic.

If there were a water self-sufficiency program on the part of the government, everyone would be made to store and use rainwater. Those that are built and those that are broken can be repaired and get attention. WAZ can receive rainfall up to twice a year; this is very likely to harvest rainwater, there is a great opportunity if it is worked on.

4.2. Discussions

Causes of poor roof water harvesting within rooftop rain water harvesting system; Result of respondent shows; replacement of materials or procedures, technology change, inadequate working drawing details and lack of required data and inappropriate information have low frequent or low impact on poor RWHS in West Arsi. Change of plans or scope and design, financial problems, inadequate project objectives, impediment in prompt decision making process, socio-cultural factors and poor quality materials and workmanship has moderate frequent or impact on RWHS. The result shows; the main cause of poor performance of RWHS in West Arsi is related to inadequate feasibility study and preliminary design, inappropriate construction methods and inadequate experience & poor government policy has high frequent or impact on poor performing of existing RWHS.

Impacts of Poor harvesting system construction in supporting water supply; the result shows impact factors like gutter failure, storage failure, operation & maintenance failure, treatment and water use problem has low frequency or low impact on poor performing of existing RWHS. And design problem has high frequency or impact on harvesting system, while; connection failure and policy problem has very high frequency or very high impact on RWHS in the study area.

Mitigation Measures to Improve the Existing harvesting system to support water supply coverage adopting new technology and resolving Socio-cultural factors have low importance in mitigation of poor performing of RWHS. Preparing proper feasibility study, preliminary design, setting scope of plans, prepare details design, fixing source of budget and solving financial problems, collecting required data and appropriate information, Adopt appropriate construction methods, provide adequate training & develop good government policy, quality controls on materials and using trained workmanship has moderate importance in mitigation of poor performance of existing RWHS in west Arsi Zone. Adopting adequate project objectives, quality control on materials or procedures, fast and effective decision making process are more important issue in mitigation of existing RWHS in study area. The result indicated preparation of adequate working drawing and details is best mitigation with very high frequency.

From the three roof cover type 88.6% of accommodation units are CIS roof cover type; which is good for RWH system and 10.4% is ruff type and 1% is bamboo type are not suitable for RWHS construction to obtain water of the required quality and quantity. Therefore by projecting the roof type percentage; of household accommodation in West Arsi Zone; 95%*369,533 = 327,406 units CIS type while 10.4%*369,533 = 38,431 unit is ruff and 1%*369,533 = 3,695 unit is Bamboo type and thus; 327,406 units is compatible for RWHS construction in west Arsi Zone.

Therefore, despite the large accommodation units, sufficient rainfall harvesting capacity and sufficient rainfall, there is no deliberate initiative to harvest water for drinking water, agriculture, livestock breeding and other services. In this way, it will help to increase water conservation program and increase economic growth. The study area has potential average 10.99 m^3 roof areas and can harvest 4.67m^3 for individual accommodation units and this value can service the whole family for 62.26 days. This will increase water supply coverage by 17.1% of annual demand. If the source is fully utilized the individual water supply coverage will increase to 85.2%.

Assuming 20 person per HC and 15L/day/person; the harvesting potential for HC block; typical HC single block can harvest **84.15m^3** annually. But for this RWHS only **20m^3** of storage tank were included in design and also constructed; that is only 23.77% of available harvesting potential and 76.23% of potential were not plane for use. In real condition no potential of RWHS were under service both in school and HC. For typical model farmers house initiatives there were **36.13m^3**, **31.2m^3** and **26.69m^3** harvesting potentials respectively annually for option 1, 2 and 3. Using census data 5 person per households and 15L/day/person; the harvesting potential for model farmers house was 8.5/5/15 = 481.73 days < 100%, 7.34/5/15 = 98 days <100% and 6.28/5/15 = 355.86 days = 97.5% of accommodation unit yearly water demand respectively. For option 1 and 2 the potential is over accommodation unit demand and excess of personal consumption and can use for other purpose like irrigation or animal feeding. But for this initiative of housing RWHS construction is not considered.

Implement the designed rainwater harvesting system and monitor its performance over time is very important. Cooperation of the actual harvested rainwater volumes with the estimated values from analysis and identification of RWHS problem and make any necessary adjustments based on real-world data will increase the system acceptance as alternative water source.

Suggested Maintenance Procedures for Rainwater Harvesting Systems;

- ❖ Keep gutters and downspouts free of leaves and other debris
- ❖ Twice a year inspect and clean pre-screening, inlet filtration devices, and first flush diverters
- ❖ Four times a year inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots.

- Check mosquito screens and patch holes or gaps immediately
- Once a year inspect condition of overflow pipes, overflow filter path, and/or secondary runoff reduction practices once a year inspect tank for sediment buildup
- Every third year clear overhanging vegetation and trees over roof surface every third year, check integrity of backflow preventer (unless required more frequently by state or local regulations)
- Every third year Inspect structural integrity of tank, pump, pipe, and electrical system every third year replace damaged or defective system components every third year by owner or qualified third party inspector source

The condition of the structures on the rainwater harvesting system was not good. Failure to clean the roof before the rains to store enough and clean water, dust and leaf litter was accumulating on the roof reducing the quality and amount of water stored. Insect traps and those that prevent these wastes from entering the gutter are not being built, and even the gutters are leaking in many places, and in some places leaking and occasionally demolished. Although down pipe, joints of the gutter to each other are problematic. Down pipe connected to gutter not delivering water safely to reservoir.

Despite the availability of sufficient rainwater storage capacity and rainwater harvesting potential, there was no appropriate use this resource. The problem was that going to the river in search of the rain that has flowed from their house. The problems with constructed rainwater reservoirs include;

- Incomplete RWH essential components
- Even the existing structures are not built with quality, experienced and skilled manpower and treating these structures as assets; lack of protection, repair and maintenance
- Low understanding and attitude towards RWH and no policy applied to the issue

RWH built and subsequently built will be effective if;

- Dust and leaf litter are regularly cleaned or prevented from entering gutters before rains begin
- Construct, maintain and regularly repair all components required for RWHS including insect and other object trap, gutter and storage

- Construction and preparation of adequate and suitable reservoirs, ground water recharge of surplus water from the reservoirs, construction of reservoir terrain in a proper and risk-free manner.
- Check the storage position regularly and adjust it, if it sinks, adjust it with a proper maintenance
- Build a primary rainwater removal system

Local climatic conditions, rooftop characteristics, and water demand patterns can influence the accuracy of analysis. Regular maintenance and upkeep of the rainwater harvesting system are also important to ensure its continued efficiency. The success of the assessment depends on accurate data collection and thorough analysis. Collaborate with local stakeholders, governmental bodies, NGOs, and experts in water management to ensure a holistic and effective approach.

In general, it was necessary to build and maintain RWHS components in the right way with the necessary quality and experienced professional and competent manpower and repair if damaged. Operation and maintenance is a key element for constructed RWHS in utilizing water supply from this alternative source. Development of O&M for the system require team of expert to standardize the methods and code based procedure but as basic procedures; roof preparation and cleaning to get free water from roof catchment, Gutter preparation and cleaning including object trap to collect safe water from roof, preparation downpipe with insect trap and first flush diverter, preparation of safe and enough storage tank at appropriate location, preparation good foundation for tank, preparation of filtration and treatment methods compatible for intended use, and preparation and protection system component including valves, and connection are basic operation and maintenance procedure.

5. Conclusions and Recommendations

5.1. Conclusions

Rooftop rain water harvesting system in West Arsi Zone is not developed well as general. There is a little bit starting of RWH system in health centers and very little in schools. Even though constructed harvesting system was almost not in service. Almost in all observed RWH system there is a physical system failure; like gutter failure, down pipe failure, storage failure, connection pipe and valves failure and no operation and maintenance method employed and systematic system failure; no full system components, policy or regulation. The causes of failure are poor workmanship during construction, poor material quality and construction method and lack of maintenance program. There was emerging compatible CIS roof cover type for RWHS in the zone and decreasing rate of non compatible roof cover type of Ruff and Bamboo type. There was huge harvesting potential in the zone which will support more than half of water demand during wet season and 17.1% during dry season. The available potential can increase water supply coverage from 68.1% to 85.2% of water demand. If fully utilized RWHS will increase water supply more. Therefore RWHS can be alternative water supply source in west Arsi Zone. This resource can uses like ground water recharge and resource re generation, commercial, agricultural use and environmental protection if properly used.

The required storage capacity of the rainwater harvesting system should be large enough to store surplus rainwater during periods of low demand or low rainfall. System design and components should comply with the calculated storage capacity, design the rainwater harvesting system components, including storage tanks, filters, first-flush diverters, and distribution systems. Ensure that the system is designed to handle the estimated volume of harvested rainwater.

5.2. Recommendations

Rooftop rain water harvesting system in West Arsi Zone of Oromia region of Ethiopia was an available potential of supporting water need in the zone. Therefore every individual can harvest its water demand 50% of water demand during wet season and 10% during dry season. Thus if used the water coverage of the study area will be increased from 68.1% to over 100% during wet season and 78.1% during dry season. The government can increase water supply coverage by developing policy and RWH system initiatives by available harvesting potential and high available roof cover compatibility.

Current government house construction initiatives of model farmers house is also gable and heaped roof type. This roof type has guttered and down pipe on its construction. Only advanced component of RWH system like; first rain diverter, storage tank, valve and connection accessory and treatment system is needed to install the system. The cost of RWHS is relatively advantageous for concerned body to develop the system as alternative water source.

Recommended operation and maintenance for WAZ RWHS;

a) Just before the arrival of rainy season, the rooftop/catchment area has to be cleaned properly.
b) The roof outlet on the terrace should be covered with a mesh to prevent entry of leafs or other solid waste into the system.
c) The filter materials have to be either replaced or washed properly before the rainy season.
d) The diversion valve has to be opened for the first 5 to 10 minutes of rain to dispose of the polluted first flush.
e) All polluted water should be taken away from the storage structures.
f) The foundation of storage structures shall be checked depending on the actual site condition
g) Inspection and maintenance of RWHS component before rainy season
h) Build capacity and awareness creation on good operation and management practices
i) Develop or formulate standards/ codes/certificates for roof top rainwater harvesting systems and a scheme for annual license
j) Provide Technical assistance for good operation and management, and for water treatment.

Proper operation and maintenance of rainwater harvesting systems helps to protect water quality in several ways. Regular inspection and cleaning of catchment, gutters, filters and tanks reduce the likelihood of contamination. Water from other sources should not be mixed with that in the tank.

Monitoring and evaluation by concerned stakeholder on RWHS is recommended. Program for implementation of RWHS is very important. RWHS standard, Policy and guideline is recommended to implement the system. Assessment of constructed RWHS is important and investigation of existing system and design is very important and O & M of RWHS is also important.

Recommendations for future study: conducting sensitivity analysis by varying certain parameters, such as collection efficiency, catchment area, or demand. This will help to understand the system's performance under different conditions and make adjustments accordingly. And evaluate the intended uses of harvested rainwater, such as irrigation, flushing toilets, or even drinking after proper treatment. Estimate the water demand for these purposes. This will help you determine if the harvested rainwater can adequately meet the demand.

References

Asaba, J. & Barasa, B. (2020). Contribution of Rainfall on Rooftop Rainwater Harvesting and Saving on the Slopes of Mt. Elgon, East Africa. *The Scientific World Journal*, 6 , 7-8.

Awawdeh, M. (2011). Rainwater harvesting assessment for a small size urban. *International Journal of Water Resources and Environmental Engineering, 4* (12), 415-422.

Buble, G. (2015). *Rooftop Rainwater Harvesting*. Retrieved December 15, 2021, from greentumble.com/rooftop-rainwater-harvesting/:https://greentumble.com/rooftop-rainwater-harvesting/

Charmaz, K. (2006). *saple size policy for qualitative studies using in-depth review.* UK: Sage Publications Ltd.

Chowdhury, S. (2016). *Tips and Technique of Rooftop Rainwater Harvesting.* Ackdane Perez.

Creswell, J. (1998). *research design: Qualitative, Quantitative and Mixed method Aproach.* California : Ackdane Perez.

CSAE. (2007). C*encus.* Addis Abeba: Central Statistical Agency of Ethiopia.

Dagnachew, A. (2018). Assessing the Potential for Rooftop Rainwater Harvesting from Large Public Institutions. *International Journal of Environmental Research and Public Health*, 6.

Daniel, K. (2007). *Rainwater harvesting in Ethiopia; capuring the realisties and Exploring opportunities.* Addis Ababa: Forum for social studies.

Dzikus, A. (2007). *Policy paper.* UN -Habitat, Nairobi: Water for Cities Programme.

Energy, (2023). *Water-Efficient Technology Opportunity: Rainwater Harvesting Systems*. Retrieved 6 3, 2023, from https://www.energy.gov/femp/water-efficient-technology-opportunity-rainwater-harvesting-systems

ENMA. (2018). *Monthly rainfall data.* Addis Ababa: Ethiopia National metrology agency.

Fayyaz. A. & Sarah. W. (2019). *Alternative Water Supply Systems.* Melbourne: iwapublishing.com.

Getachew, R. (2016). Reliability analysis of roof rainwater harvesting systems in a semi-arid region of sub-Saharan Africa: case study of Mekelle, Ethiopia. *Hydrological Sciences Journal, 61* (6), 135–140.

Getachew, H. (2017). *Modeling Approach for Identification of Potential Rainwater Harvesting Sites in Arsi Zone, Eastern Ethiopia.* Addis Abeba: Addis Ababa University.

Hailamariam, M. (2017). Rooftop Rainwater Harvesting as an Alternative Approach of Sustainable Water Supply: A Case Study of Addis Ababa Ethiopia. *International Journal of Environmental Sciences*, 12.

Hapugoda, K. (1995). *CommunitY Water Supply & Sanitation Project.* Battaramullaa, Srilanka: Ministry of Housing, Construction & Public Utilities.

Holding, N. (2020). *Rooftop water collecting frameworks.* Israeli irrigation solution.

Innovative water solution . (2020). Rainwater Harvesting System. Hill country, Australia.

Israel, G. (1967). *Determining sample size.* Florida: Ifans Extension.

Kanno, G., Lagiso, Z., & Abate Z., (2021). Estimation of rain water harvesting potentioal foremmergency water demand in the era of COVID 19. The case of Dilla town, Southen, Ethiopia. *Environmental* , 15-16.

Kumar, R. (2011). *Research Methodology: step by step guide for beginner.* New Delhi: sage.

Mason, M. (2010). *sample size and saturation.* London: Book Trust.

Mekonnen, Z. (2018). analysis of observed and percived climate change and variablity in Arsi Nagelle District, Ethiopia. *Environment, Development sustainability*, 8.

Meselech, S. (2019). *Overview of the Ethiopian Rainwater Harvesting Association (ERHA).* Addis Ababa: Ethiopian Rainwater Harvesting Association (ERHA) Secretariat.

Ndiritu, J. (2011). Yield–reliability analysis for rural domestic water supply from combined rainwater harvesting and run-of-river abstraction. *Hydrological Sciences Journal, 56* (2), 56(2): 238−248.

Nnaji, C. (2019). Sustainable Water Supply in Buildings through Rooftop Rainwater Harvesting. *The Construction Industry in the Fourth Industrial Revolution* (pp. 390-400). swezerland: Springer.

Oloke, O. (2013). Assessment of Rainwater Harvesting Potential in Ibadan,. *Environmental Engineering Research, 18* (2), 91-94.

Padmanabhan, M. (2021). Methods of Rainwater Harvesting. *The contracto* , 5-6.

Prasadab, S. (2021). Feasibility of roof top rainwater harvesting potential - A case study of South Indian University. *Science Direct* .

Purohit, M. (2015). *Rooftop rainwater harvesting in Chhattisgarh.*

Ramiz, G. (2020). *Civilclick.com*. Retrieved from https://www.civilclick.com/rooftop-rainwater-harvesting/: https://www.civilclick.com/rooftop-rainwater-harvesting/

Simiso, B. (2017). An Assessment of the Quality of Rainwater Harvested Using Rooftop Rainwater Harvesting (RWH) Technologies in Swaziland. *Journal of Agricultural Science and Engineering, 3* (6), 55-64.

Thomas, T. & Martinson, D. (2007). *Roofwater Harvesting.* Delft, The Netherlands: IRC International Water and Sanitation Centre.

UN, (2014). *Water and energy.* Paris: Uite Nation.

Ward, F. (2019). *Alternative Water Supply Systems.* Melbourne: iwapublishing.com.

Winfoundation, (2021). *Winfoundations.org/rooftop-rainwater-harvesting-rrwh*. Retrieved December 23, 2021, from Rooftop rain water harvesting (RRWH): ttps://www.winfoundations.org/rooftop-rainwater-harvesting-rrwh/

Appendixes

APPENDIX A: QUESTIONNAIRE COVER LETTER

Adama Science and Technology University, Adama, Ethiopia
P.O.Box: 1888 Adama
Telephone Number: +251-22-211-3961
E-mail Address: irccd@astu.edu.et
Website: http://www.astu.edu.et

This letter serves as a confirmation that (Mr. Bersisa Desaleny Gondol) is conducting a research as a requirement for the completion of the Degree of Master of Science in Water Resource Engineering (Specialization in Water Supply and Environmental Engineering) in the School of Civil Engineering and Architecture at Adama Science and Technology University.

The research is conducted on the "Assessment of Rooftop Rain-water Harvesting System of West Arsi Zone of Oromia Region, Ethiopia". This study, which has been approved by the Adama Science and Technology University, focuses on rooftop rain water harvesting system within the zone.

The research will be conducted within the conventional ethical standard requirements for the research as specified in the Guideline of the Adama Science and Technology University (ASTU).

Participation is voluntarily and willing participants can withdraw at any time. The responses will be kept strictly confidential .No name are required on the questionnaire.

Thank you in advance for your cooperation.

Kind Regards

Bersisa Desaleny
(Researcher)

APPENDIX B: RESEARCH QUESTIONNAIRE

RESEARCH QUESTIONNAIRE

Dear Respondents

My name is Bersisa Desaleny. I am a postgraduate student at Adama Science and Technology University; School of Civil Engineering and Architecture with a Master of Science Degree in Water Resource Engineering (Specialization in Water Supply and Environmental Engineering). I am conducting a research on "Assessment of Rooftop Rain-water Harvesting System of West Arsi Zone of Oromia Region, Ethiopia". The purpose of this study is to investigate cause of poor Rooftop Rain-water Harvesting System, and mitigation measures/improving Mechanisms/ of Poor harvesting in West Arsi Zone. DO NOT write your name on this questionnaire paper. Your participation is voluntarily. Your responses are anonymous and you can skip any questions you are not comfortable with. Thank you for your participation. Please help me trying to answer all the questions!

Section 1: General information about the respondents

1.1 bio data

1. What is your gender?

   Male ☐ Female ☐

2. Age group

   Below 20 ☐ 20-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ above 60 years ☐

3. What is your marital status?

   Single ☐ Married ☐ Divorced ☐ Widowed ☐ Others ☐

4. What is your education level?

   Certificate ☐ Diploma/Level ☐ BSc. Degree ☐ MSc. Degree ☐ PHD ☐

5. Which of the following best describes your company? For your Company description Tick only one box

   Contractor ☐ Client ☐ Others ☐

   Consultant ☐ Regulatory Body ☐

6. How long have you worked in the water supply construction industry?

   Below 5 years ☐ 5-10 years ☐ 11-15 years ☐ above 15 years ☐

7. Have you ever been perform rooftop rain water harvesting

   Yes ☐ No ☐

8. How would you rate that; how the Governmental Office of water supply of West Arsi Zone supervises RWH system?

a) Very close supervision ☐
b) Close supervision ☐
c) Related supervision ☐
d) Very related supervision ☐
e) No supervision ☐

Section 2: Causes of Poor Roof Water harvesting within rooftop rain Water harvesting system

The following are examples of causes Poor Roof Water harvesting within rooftop rain Water harvesting system Construction Projects; Please put this mark (√) in the table below for the most frequent Occurrences corresponding to each of them.

		Level of Occurrences				
No	Causes Factors	1	2	3	4	5
2.1	Inadequate feasibility study and preliminary design					
2.2	Change of plans or scope and design					
2.3	Financial problems					
2.4	Inadequate project objectives					
2.5	Replacement of materials or procedures					
2.6	Impediment in prompt decision making process					
2.7	Technology change					
2.8	Inadequate working drawing details					
2.9	Lack of required data and inappropriate information					
2.10	Socio-cultural factors					
2.11	Inappropriate construction methods					
2.12	Inadequate experience & Poor government policy					
2.13	Poor quality materials and workmanship					

Section 3: Impacts of Poor harvesting system construction in supporting water supply

From your experience measure the level of impactions on performance of harvesting system indicate how frequently these resulted in the following: Please put this mark (√) in the table below for the most frequent Occurrences corresponding to each of them.

VLF (1) = Very Low Frequent, LF (2) = Low Frequent, MF (3) = Moderate Frequent, HI (4) = High Frequent, VHF (5) = Very High Frequent

		Level of Occurrences				
No	Impact Factors	1	2	3	4	5
3.1	Gutter failure					
3.2	Storage failure					
3.3	Pipe failure					
3.4	Connection failure					
3.5	Operation & maintenance failure					
3.6	Design problem					
3.7	Policy problem					
3.8	Treatment and water use problem					

Section 4: Mitigation Measures to Improve the Existing harvesting system to support water supply coverage

The following table indicates the direction how to manage the poor harvesting potential and system water supply construction projects in order to increase the performance of the projects by the parties involved in water supply projects in West Arsi Zone.: Please put this mark (√) in the table below for the most frequent Occurrences corresponding to each of them.

		Level of Occurrences				
No	Mitigation measures	1	2	3	4	5
4.1	Preparing proper feasibility study and preliminary design					
4.2	Set scope of plans and prepare details design					
4.3	Fixing source of budget and solving financial problems					
4.4	Adopting adequate project objectives					
4.5	Quality control on materials or procedures					
4.6	Fast and effective decision making process					
4.7	Adopting new technology					
4.8	Prepare adequate working drawing details					
4.9	collect required data and appropriate information					
4.10	Resolving Socio cultural factors					
4.11	Adopt appropriate construction methods					
4.12	Provide adequate training & develop good government policy					
4.13	Quality controls on materials and using trained workmanship					

APPENDIX C: RESPONDENT OUTPUT FREQUECY DATA

Frequency Table

a. **Sex of informant**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	3	.8	.8	.8
	Male	213	53.3	53.3	54.0
	Female	184	46.0	46.0	100.0
	Total	400	100.0	100.0	

b. **Age of informant**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	20-30	30	7.5	7.5	7.5
	31-40	367	91.8	91.8	99.3
	41-50	3	.8	.8	100.0
	Total	400	100.0	100.0	

c. **Merit's status**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	single	105	26.3	26.3	26.3
	married	262	65.5	65.5	91.8
	divorced	33	8.3	8.3	100.0
	Total	400	100.0	100.0	

d. **Education level**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	certificate	3	.8	.8	.8
	BSc	335	83.8	83.8	84.5
	MSc/MA	62	15.5	15.5	100.0
	Total	400	100.0	100.0	

e. **Informant Company type**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Contractor	21	5.3	5.3	5.3
	client	61	15.3	15.3	20.5
	regulatory body	308	77.0	77.0	97.5
	others	10	2.5	2.5	100.0
	Total	400	100.0	100.0	

f. **Experience of water supply**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	below 5 years	203	50.8	52.1	52.1
	5-10 years	127	31.8	32.6	84.6
	11-5 years	60	15.0	15.4	100.0
	Total	390	97.5	100.0	
Missing	System	10	2.5		

Total		400	100.0		

g. **Perform RWH system construction work**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	10	2.5	2.5	2.5
	yes	250	62.5	62.5	65.0
	no	140	35.0	35.0	100.0
	Total	400	100.0	100.0	

h. **How RWH system are supervised**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	7	1.8	1.8	1.8
	very close supervision	3	.8	.8	2.5
	close supervision	25	6.3	6.3	8.8
	related supervision	305	76.3	76.3	85.0
	very close supervision	3	.8	.8	85.8
	no supervision	57	14.3	14.3	100.0
	Total	400	100.0	100.0	

i. **Inadequate feasibility study and preliminary design**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low frequency	113	28.3	28.3	28.3
	Moderate frequency	64	16.0	16.0	44.3
	high frequency	162	40.5	40.5	84.8
	very high frequency	61	15.3	15.3	100.0
	Total	400	100.0	100.0	

j. **Change of plans or scope and design**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low frequency	88	22.0	22.0	22.0
	Moderate frequency	188	47.0	47.0	69.0
	high frequency	73	18.3	18.3	87.3
	very high frequency	51	12.8	12.8	100.0
	Total	400	100.0	100.0	

k. **Financial problems**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	51	12.8	12.8	12.8
	very low frequency	45	11.3	11.3	24.0
	low frequency	10	2.5	2.5	26.5
	Moderate frequency	215	53.8	53.8	80.3
	high frequency	67	16.8	16.8	97.0
	very high frequency	12	3.0	3.0	100.0
	Total	400	100.0	100.0	

l. **Inadequate project objectives**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	30	7.5	7.5	7.5
	very low frequency	30	7.5	7.5	15.0
	low frequency	72	18.0	18.0	33.0
	Moderate frequency	153	38.3	38.3	71.3
	high frequency	97	24.3	24.3	95.5
	very high frequency	18	4.5	4.5	100.0
	Total	400	100.0	100.0	

m. **Replacement of materials or procedures**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	39	9.8	9.8	9.8
	low frequency	206	51.5	51.5	61.3
	Moderate frequency	81	20.3	20.3	81.5
	high frequency	67	16.8	16.8	98.3
	very high frequency	7	1.8	1.8	100.0
	Total	400	100.0	100.0	

n. **Impediment in prompt decision making process**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	3	.8	.8	.8
	very low frequency	92	23.0	23.0	23.8
	low frequency	102	25.5	25.5	49.3
	Moderate frequency	103	25.8	25.8	75.0
	high frequency	100	25.0	25.0	100.0
	Total	400	100.0	100.0	

o. **Technology change**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	51	12.8	12.8	12.8
	very low frequency	53	13.3	13.3	26.0
	low frequency	159	39.8	39.8	65.8
	Moderate frequency	83	20.8	20.8	86.5
	high frequency	54	13.5	13.5	100.0
	Total	400	100.0	100.0	

p. **Inadequate working drawing details**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	3	.8	.8	.8
	very low frequency	47	11.8	11.8	12.5
	low frequency	140	35.0	35.0	47.5
	Moderate frequency	144	36.0	36.0	83.5
	high frequency	63	15.8	15.8	99.3
	very high frequency	3	.8	.8	100.0
	Total	400	100.0	100.0	

q. **Socio-cultural factors**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	3	.8	.8	.8
	very low frequency	10	2.5	2.5	3.3
	low frequency	122	30.5	30.5	33.8
	Moderate frequency	73	18.3	18.3	52.0
	high frequency	102	25.5	25.5	77.5
	very high frequency	90	22.5	22.5	100.0
	Total	400	100.0	100.0	

r. **Lack of required data and inappropriate information**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	37	9.3	9.3	9.3
	low frequency	98	24.5	24.5	33.8
	Moderate frequency	238	59.5	59.5	93.3
	high frequency	9	2.3	2.3	95.5
	very high frequency	18	4.5	4.5	100.0
	Total	400	100.0	100.0	

s. **Inappropriate construction methods**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	44	11.0	11.0	11.0
	low frequency	85	21.3	21.3	32.3
	Moderate frequency	190	47.5	47.5	79.8
	high frequency	21	5.3	5.3	85.0
	very high frequency	60	15.0	15.0	100.0
	Total	400	100.0	100.0	

t. **Inadequate experience & Poor government policy**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	7	1.8	1.8	1.8
	low frequency	85	21.3	21.3	23.0
	Moderate frequency	106	26.5	26.5	49.5
	high frequency	141	35.3	35.3	84.8
	very high frequency	61	15.3	15.3	100.0
	Total	400	100.0	100.0	

u. **Poor quality materials and workmanship**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	44	11.0	11.0	11.0
	low frequency	9	2.3	2.3	13.3
	Moderate frequency	179	44.8	44.8	58.0
	high frequency	10	2.5	2.5	60.5
	very high frequency	158	39.5	39.5	100.0
	Total	400	100.0	100.0	

v. **Gutter failure**

		Frequency	Percent	Valid Percent	Cumulative Percent

Valid	very low frequency	25	6.3	6.3	6.3
	low frequency	148	37.0	37.0	43.3
	Moderate frequency	133	33.3	33.3	76.5
	high frequency	10	2.5	2.5	79.0
	very high frequency	84	21.0	21.0	100.0
	Total	400	100.0	100.0	

w. **Storage failure**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	22	5.5	5.5	5.5
	low frequency	120	30.0	30.0	35.5
	Moderate frequency	109	27.3	27.3	62.8
	high frequency	91	22.8	22.8	85.5
	very high frequency	58	14.5	14.5	100.0
	Total	400	100.0	100.0	

x. **Pipe failure**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	22	5.5	5.5	5.5
	low frequency	142	35.5	35.5	41.0
	Moderate frequency	84	21.0	21.0	62.0
	high frequency	19	4.8	4.8	66.8
	very high frequency	133	33.3	33.3	100.0
	Total	400	100.0	100.0	

y. **Connection failure**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	69	17.3	17.3	17.3
	low frequency	20	5.0	5.0	22.3
	Moderate frequency	116	29.0	29.0	51.3
	high frequency	32	8.0	8.0	59.3
	very high frequency	163	40.8	40.8	100.0
	Total	400	100.0	100.0	

z. **Operation & maintenance failure**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low frequency	116	29.0	29.0	29.0
	Moderate frequency	90	22.5	22.5	51.5
	high frequency	98	24.5	24.5	76.0
	very high frequency	96	24.0	24.0	100.0
	Total	400	100.0	100.0	

aa. **Design problem**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low frequency	88	22.0	22.0	22.0
	Moderate frequency	73	18.3	18.3	40.3
	high frequency	182	45.5	45.5	85.8

		Frequency	Percent	Valid Percent	Cumulative Percent
	very high frequency	57	14.3	14.3	100.0
	Total	400	100.0	100.0	

bb. **Policy problem**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	13	3.3	3.3	3.3
	low frequency	79	19.8	19.8	23.0
	Moderate frequency	61	15.3	15.3	38.3
	high frequency	113	28.3	28.3	66.5
	very high frequency	134	33.5	33.5	100.0
	Total	400	100.0	100.0	

cc. **Treatment and water use problem**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	7	1.8	1.8	1.8
	very low frequency	36	9.0	9.0	10.8
	low frequency	212	53.0	53.0	63.8
	Moderate frequency	7	1.8	1.8	65.5
	high frequency	83	20.8	20.8	86.3
	very high frequency	55	13.8	13.8	100.0
	Total	400	100.0	100.0	

dd. **Preparing proper feasibility study and preliminary design**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	36	9.0	9.0	9.0
	low frequency	82	20.5	20.5	29.5
	Moderate frequency	137	34.3	34.3	63.8
	high frequency	67	16.8	16.8	80.5
	very high frequency	78	19.5	19.5	100.0
	Total	400	100.0	100.0	

ee. **Set scope of plans and prepare details design**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	3	.8	.8	.8
	low frequency	84	21.0	21.0	21.8
	Moderate frequency	174	43.5	43.5	65.3
	high frequency	132	33.0	33.0	98.3
	very high frequency	7	1.8	1.8	100.0
	Total	400	100.0	100.0	

ff. **Fixing source of budget and solving financial problems**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low frequency	76	19.0	19.0	19.0
	Moderate frequency	161	40.3	40.3	59.3
	high frequency	112	28.0	28.0	87.3
	very high frequency	51	12.8	12.8	100.0
	Total	400	100.0	100.0	

gg. **Adopting adequate project objectives**					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	30	7.5	7.5	7.5
	low frequency	39	9.8	9.8	17.3
	Moderate frequency	147	36.8	36.8	54.0
	high frequency	175	43.8	43.8	97.8
	very high frequency	9	2.3	2.3	100.0
	Total	400	100.0	100.0	

hh. **Quality control on materials or procedures**					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	40	10.0	10.0	10.0
	low frequency	82	20.5	20.5	30.5
	Moderate frequency	98	24.5	24.5	55.0
	high frequency	152	38.0	38.0	93.0
	very high frequency	28	7.0	7.0	100.0
	Total	400	100.0	100.0	

ii. Fast and effective decision making process					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low frequency	118	29.5	29.5	29.5
	Moderate frequency	69	17.3	17.3	46.8
	high frequency	171	42.8	42.8	89.5
	very high frequency	42	10.5	10.5	100.0
	Total	400	100.0	100.0	

ii. **Adopting new technology**					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	13	3.3	3.3	3.3
	low frequency	171	42.8	42.8	46.0
	Moderate frequency	60	15.0	15.0	61.0
	high frequency	89	22.3	22.3	83.3
	very high frequency	67	16.8	16.8	100.0
	Total	400	100.0	100.0	

jj. **Prepare adequate working drawing details**					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	7	1.8	1.8	1.8
	very low frequency	51	12.8	12.8	14.5
	low frequency	91	22.8	22.8	37.3
	Moderate frequency	98	24.5	24.5	61.8
	high frequency	41	10.3	10.3	72.0
	very high frequency	112	28.0	28.0	100.0
	Total	400	100.0	100.0	

kk. **Collect required data and appropriate information**					
		Frequency	Percent	Valid Percent	Cumulative Percent

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	30	7.5	7.5	7.5
	low frequency	56	14.0	14.0	21.5
	Moderate frequency	164	41.0	41.0	62.5
	high frequency	92	23.0	23.0	85.5
	very high frequency	58	14.5	14.5	100.0
	Total	400	100.0	100.0	

ll. **Resolving Socio-cultural factors**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	33	8.3	8.3	8.3
	low frequency	170	42.5	42.5	50.8
	Moderate frequency	146	36.5	36.5	87.3
	high frequency	51	12.8	12.8	100.0
	Total	400	100.0	100.0	

mm. **Adopt appropriate construction methods**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Missing	9	2.3	2.3	2.3
	very low frequency	36	9.0	9.0	11.3
	low frequency	7	1.8	1.8	13.0
	Moderate frequency	182	45.5	45.5	58.5
	high frequency	166	41.5	41.5	100.0
	Total	400	100.0	100.0	

nn. **Provide adequate training & develop good government policy**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	3	.8	.8	.8
	low frequency	92	23.0	23.0	23.8
	Moderate frequency	189	47.3	47.3	71.0
	high frequency	67	16.8	16.8	87.8
	very high frequency	49	12.3	12.3	100.0
	Total	400	100.0	100.0	

oo. **Quality controls on materials and using trained workmanship**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very low frequency	3	.8	.8	.8
	low frequency	81	20.3	20.3	21.0
	Moderate frequency	197	49.3	49.3	70.3
	high frequency	90	22.5	22.5	92.8
	very high frequency	29	7.3	7.3	100.0
	Total	400	100.0	100.0	