

ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL
ENGINEERING



Rainwater Harvesting as Alternative Water Supply Source

Case Study of Siyadebirna Wayu Woreda

By
Cherotaw Teshome

A Thesis submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirement for the Degree of Master of Sciences in Civil Engineering (Water supply and Environmental Engineering)

Advisor

Dr. Ing. Mebruk Mohammed

July 2019

Addis Ababa, Ethiopia

ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF GRADUATE STUDIES

The undersigned here by certify that they have read and recommend to the institute of technology, school of graduate studies for acceptance a thesis entitled “**RAINWATER HARVESTING AS ALTERNATIVE WATER SUPPLY SOURCE: CASE STUDY OF SIYADEBIRNA WAYU WOREDA**” by **Cherotaw Teshome** in partial fulfillment of the requirements for the degree of masters of science.

APPROVED BY BOARD EXAMINERS

Mebruk Mohammed, PhD

(Advisor)

Signature

Date

Fissha Behulu, PhD

(Internal Examiner)

Signature

Date

Geremew Sahilu, PhD

(External Examiner)

Signature

Date

(Chairman)

Signature

Date

Declaration

I, the undersigned, declare that this thesis is my original work, has not been presented for a degree in any other university and that all source of material used for the thesis have been duly acknowledged.

Declared by: Name_____

Signature_____

Date_____

Abstract

The main objective of this research is identifying rainwater harvesting as alternative water supply sources in Siyadebirna wayu woreda to solve shortage of water during critical dry seasons. The research is carried out based on case-study of Ejersa kubeti kebeles (Zinjero wuha, Kubeti, Gotet dega and Kebet amba sub-kebeles), from November 2018 to May 2019. The site has about 316 individual compounds which areas 1000m^2 with an average roof area of 62m^2 and 93.6% of the study area have suitable roof distribution for rainwater harvesting system.

A descriptive quantitative study was carried out in order to achieve the objectives of the study. A daily rainfall data, catchment characteristics, roof material, family size, water consumption and water demand data were collected from primary and secondary sources. The community perspective and practice about rainwater harvesting was assessed. The collected data was analyzed using different tools including samsamwater RWH model, Google earth, GIS, MS Excel spread sheets.

The average annual rainfall of the study area is 961.12mm. The water consumption data of the specific sub-kebeles which included in the case study collected from the community through questionnaires and from local water committee. The average water consumption of the specific study area is 143 liter per compound per day. The results from minimum rainfall depth can fulfill the amount of additional water required for five months critical dry season of the study area (33m^3 from rooftop, 63m^3 from Courtyard with area 150m^2 , $15,360\text{m}^3$ from Micro/Macro). In addition to the rooftop rainwater harvesting the courtyard rainwater harvesting can applicable as combined with roof. In other ways, the possibility large amount of water collection is high. The storage tank can be under ground and covered with geomembrane for protection of water loss through infiltration. The storage tank also constructed with other materials depends on the community capacity.

The amount of water collected from this system used as intermittent. RWH can be used to bridge the dry period with the stored water when other sources are dry. Rainwater harvesting has significant advantages for the study area including health, time saving, energy saving as well as income generation.

Key words: - Rainwater harvesting, Siyadebirna wayu, Rooftop, Courtyard, intermittent, dry season

Acknowledgment

First and for most, I would like to thank my holy father, God and his mother, for his care, support and endless love during my stay in Addis Ababa University.

I am deeply indebted to my advisor Dr. Mebruk Mohammed for his excellent guidance, supervising, encouragement, unreserved support and advice throughout my research. I greatly appreciate him not only with his powerful, unlimited helpful advises in every aspect of my thesis work, but also, I would like to express my gratitude for his motivations; professional and personal ethic, that should be an icon of others.

I would tank Siyadebirna wayu woreda administration, water bureau, Ejersa kubeti kebele administration, students and teachers of Ejersa kubeti elementary school and Gotet dega elementary school for their positive acceptance. I thanks Ethiopian national metrology agency.

My lecturers are the bases of the climbing ladder are greatly acknowledged for giving me the basic all science that opens the way to struggle. My classmate friends, you are so friendly and you deserve my honest appreciation. I enjoyed pleasant time with you. Thank you so much all of you.

Finally, I offer my greatest appreciation to my beloved mother, Yeshibir Zerfe for her prayer.

Acronyms and Abbreviations

RWH.....	Rainwater Harvesting
WHO.....	World Health Organization
DRWH.....	Domestic Rainwater Harvesting
IDF	Intensity Duration Curve
IDW.....	Inverse distance weighted
CRU.....	Climatic Research Unit
MoWR.....	Ministry of water resources
UN.....	United nation
CVM.....	Contingent value method
NMSA.....	National Metrological Service Agency
GTP.....	Growth transformation plan
FGD.....	Focal group discussion

Operational definitions

In this thesis the words listed below have the following contextual meaning. Use the words as the following definitions.

Rain: - is water falling in drops condensed from vapor in the atmosphere.

Excess rainfall (Effective Rainfall): - is the part of rainfall that is neither retained on the catchment nor infiltrated in to soil. It is equal to the total amount of rainfall minus all abstractions including interception, depression storage, evaporation and infiltration.

Catchment area: - is an area where water is collected.

Run off: - the part of rain that neither infiltrate into the soil nor evaporate.

Storage /tank/pond: - water tight structured used for contain or stored rainwater.

Kebeles:- small administration parts of the woreda.

Sub kebeles (got):- smallest administration of the kebeles.

Arid: - (land or a climate) is having little or no rain.

<https://en.oxforddictionaries.com/definition/arid>

Semi-arid:- characterized by very little annual rainfall, usually from 10 to 20 inches (25 to 50 cm). <https://www.dictionary.com/browse/semiarid>

Courtyard: - the compound which one farmer lives.

Table of Contents	Page
Declaration	II
Abstract.....	III
Acknowledgment.....	IV
Acronyms and Abbreviations	V
Operational definitions	VI
List of Tables.....	X
List of Figures.....	XI
CHAPTER ONE.....	1
1.0 Introduction	1
1.1 General	1
1.2 Statement of the problems	4
1.3 Objectives of the study	5
1.3.1 General objectives	5
1.3.2 Specific objectives	5
1.4 Research questions	5
1.5 Significance of the study	5
1.6 Limitation of the study	6
1.7 Organization of the thesis	6
CHAPTER TWO.....	7
2.0 Literature review	7
2.1 Historical development of rainwater harvesting.....	7
2.2 Some of world countries practice rainwater harvesting	8
2.3 When and where rainwater harvesting is applicable?	9
2.4 Suitability and Factors that affect the rainwater harvesting	9
2.5 How the user use collected rainwater?	10
2.6 Types of water harvesting	12

2.6.1 Domestic rainwater harvesting	12
2.6.2 Commercial rainwater harvesting.....	13
2.7 Components of rainwater harvesting.....	13
2.8 Water storage tanks available on the market.....	14
2.9 Sizing storage reservoir	15
2.10 Rainwater harvesting delivery systems	16
2.11 Advantages and disadvantages of rainwater harvesting	16
2.11 Effectiveness of the technology.....	17
2.12 SamSamWater rainwater harvesting tool	19
CHAPTER THREE.....	21
3.0 Material and methodology.....	21
3.1 Description of study area	21
3.2 Sample size determination.....	23
3.3 Survey Design and Sampling Techniques	23
3.4 Data sources and methods of analysis.....	24
3.4.1 Primary Data.....	24
3.4.2 Secondary Data.....	25
3.5 Rainwater and community.....	26
3.6 Health and water	26
CHAPTER FOUR	28
4.0 Results and Discussion.....	28
4.1 Water demand analysis according to GTP II.....	28
4.2 Current water supply situation of the study area	28
4.3 The demand gap	29
4.4 Alternative water sources available in the study area	29
4.5 Rainfall analysis of the study area	30

4.5.1 Rainfall pattern	30
4.5.2 Effective rainfall (Runoff)	31
4.5.3 Thiessen polygon method	32
4.5.4 Rainfall Intensity	33
4.6 Runoff coefficients	35
4.7 Potential for Rainwater	36
4.7.1 Rooftop Rainwater Harvesting	36
4.7.2 Courtyard rainwater harvesting	37
4.7.3 Micro/Macro Catchment Rainwater harvesting	38
4.8 Summary of RWH systems potentials	39
4.9 SamSamWater - Rainwater Harvesting Tool (results)	40
4.9.1 Rooftop catchment.....	40
4.9.2 Courtyard catchment	43
4.9.3 Micro/Macro catchment (natural land).....	44
4.10 Summary of SamSamWater - Rainwater Harvesting Tool (results)	46
4.11 Pond (storage) size	47
4.12 Cost estimation	48
CHAPTER FIVE.....	52
CONCLUSION and RECOMMENDATION	52
5.1 Conclusion.....	52
5.2 Recommendations	54
References	55
Annexes	59
Annex 1	59
Annex 2	60

List of Tables

Table 2.1 Advantages and disadvantages of rainwater harvesting	16
Table 3.1 Sample size selection.....	24
Table 3.2 Number of corrugated iron sheet roof and area of roof.....	25
Table 3.3 Rainfall amount in rainy seasons.....	26
Table 3.4 Ten top causes of morbidity for Deneba Health center (year 2010 E.C)	27
Table 3.5 Water consumption of kebet amba	27
Table 4.1 Monthly average rainfall of Deneba station	30
Table 4.2 Effective rainfall of the study area	31
Table 4.3 Average annual rainfall results	33
Table 4.4 IDF curve table	34
Table 4.6 Potential of rooftop RWH	36
Table 4.7 Potential of Courtyard RWH.....	37
Table 4.8 Potential of Micro/Macro RWH.....	39
Table 4.9 Summary of RWH potentials	39
Table 4.10 Location, roof type and roof size of the study area	40
Table 4.11 Construction cost of 1 m ³ underground tank with lining of sand-cement.....	51

List of Figures

Fig 2.1 Three basic components of a rainwater harvesting system.....	14
Fig 3.1 Geographical location of study area.....	21
Fig 3.2 Geographical situation of the study area.....	22
Fig 3.3 Frame work of the research.....	22
Fig 3.4 Traditional household rainwater collection system.....	26
Fig 4.1 Graph of average monthly rainfall of Deneba station.....	31
Fig 4.2 Graph of effective rainfall of the study area.....	32
Fig 4.3 Gauge station used for analysis.....	33
Fig 4.4 IDF curve of the study area vs ERA.....	35
Fig 4.5 Mass curve diagram for rooftop and courtyard.....	38
Fig 4.6 Monthly rainfalls for an average year.....	41
Fig 4.7 Water availability and water demand throughout the year for rooftop.....	42
Fig 4.8 Water level in the tank throughout the year for rooftop.....	42
Fig 4.9 Water availability and water demand throughout the year for courtyard.....	44
Fig 4.10 Water level in the tank throughout the year for courtyard.....	44
Fig 4.11 Water availability and water demand throughout the year for micro/macro.....	45
Fig 4.12 Water level in the tank throughout the year for micro/macro.....	46

CHAPTER ONE

1.0 Introduction

1.1 General

The nature contributes for us treated and pure water with the process of Hydrologic cycles. But the human and others polluted this pure water by different activities and paid a lot of capitals for treating the polluted water. Therefore, investigation for utilizing this pure water before it gets polluted and minimizes the capital which invested for water treatment. Planning best management systems for rainwater (runoff) improve the overall life of the community and minimize the environment degradation as well as the human life and their holdings loss by floods.

Large scale and modern water supply schemes in rural Ethiopia remains a challenge owing to the unique and rugged terrain, and the scattered settlement pattern of the rural people. One technique that appeals today that can be of significant importance in the development of the subsector is roof water harvesting at household level. In such areas it is difficult to think that communities can be served by a centralized water supply schemes, at least it is expensive. Other sources require long walk and time for women and children to fetch water (Alem, 1999).

According to (Alem, 1999), reviews the roof water harvesting in Ethiopia has the advantage of being low cost, relatively simple in design (household technology), less laborious and it saves time. It provides suitable water during the rainy season, a period when the rural people are full with the plugging activities and when there is scarcity of labor. The rainwater are more appropriate in areas where there are no rivers, ground water sources around, and where rainwater is the only feasible means of providing a water supply.

Water harvesting is the activity of direct collection of rainwater, which can be stored for direct use or can be recharged into the groundwater. Water harvesting is the collection of runoff for productive and usable purposes (Dr.G.Ravikumar, 2013).

Rainwater can be used to meet part of domestic water demand including both potable and non-potable. In urban areas, at a household, rainwater can be used for flushing toilets, watering gardens and washing floor and these uses are known as non-potable. While in rural areas, it becomes the main source of water for potable uses which include drinking, bathing and cooking. In rural areas it is recommended to treat the collected rainwater prior to use particularly if it is intended to be used for drinking (Che-Ani A, 2009).

Rainwater harvesting is a technology used to collect, convey and store rain for later use from relatively clean surfaces such as a roof, land surface or rock catchment. The water is generally stored in a rainwater tank or directed to recharge groundwater. Rainwater infiltration is another aspect of rainwater harvesting playing an important role in storm water management and in the replacement of the groundwater levels. The practice of collecting rainwater from rainfall events can be classified into two broad categories: land-based and roof-based. Land-based rainwater harvesting occurs when runoff from land surfaces is collected in channel dikes, ponds, tanks and reservoirs. Roof-based rainwater harvesting refers to collecting rainwater runoff from roof surfaces which usually provides a much cleaner source of water that can be also used for drinking (Khoury-Nolde, 2007).

Rainwater harvesting systems can be installed in both new and existing buildings and harvested rainwater used for different applications that do not require drinking water quality such as toilet flushing, garden watering, irrigation, cleaning and laundry washing. Harvested rainwater is also used in many parts of the world as a drinking water source. (Environmental Agency,2010) reported that rainwater is very soft there is also less consumption of washing and cleaning powder. Utilizing of rainwater for washing purpose less amount of detergent is used and released into the environment. With rainwater harvesting, the savings in potable water could amount up to 50% of the total household consumption.

Rainwater harvesting from rooftops is a simple, cheap technology that promotes sustainable water management (Garrison, 2011). This technology can be adopted as a household project or in hospitals, schools, households. Collected water can be used for non-potable uses or for potable supply with appropriate treatment. The technology requires a little or no energy because capture systems often use low-volume, non-pressurized, gravity fed systems or low power pumps

(Klaus W, 2009), Rainwater harvesting technology would provide social development, economic wellbeing and environmental sustainability. The RWH technology facilitates women by providing water which is otherwise brought from distanced water sources. It reduces their physical hardship and mental stress as well as time required to fetch water from other water sources. The saved time can thus be used for other productive purposes such as domestic work, agriculture and livestock activities, and child care. Appropriately designed rainwater harvesting systems will have minimal maintenance costs associated with its upkeep and therefore will show the best long-term relationship between cost and financial benefit.

Further, it would reduce runoff that can cause surface water pollution and urban flooding. In drought areas or where the surface water or groundwater is saline or polluted, rooftop rainwater harvesting is the only sustainable alternative for ensuring continued access to safe drinking water. Rainwater harvesting from the roof tops would reduce the total volume of

runoff from the roofs. Installing a rainwater harvesting system would reduce the water supply costs and also provides significant savings as a storm water management tool (Sadia Rahman, 2014).

In rural areas where access to tap water is limited, rainwater harvesting is the best practice for water supply. People use rainwater for toilet flushing or watering the garden or crops because it is available for free and its use reduces their expenses for purified drinking water that they obtain from drinking water companies. Moreover, more people are becoming aware of the necessity to take care of the Earth's natural resources, including drinking water sources and energy. Due to the increased demand for purified drinking water groundwater levels decrease, with negative effects on various ecosystems as a result (Lieste et al. 2007). Therefore, the use of collected rainwater as an alternative to the use of purified drinking water fits into a policy of sustainable management and environmentally friendly behavior (Janette Worm, 2006).

Drinking water is generally obtained from two sources: ground water (wells, boreholes, etc.) and surface water (rivers, lakes, etc.). There are considerable scopes for the collection of rainwater when it falls. The potential of rainwater harvesting (RWH) and the perseverance of mitigating water-scarcity related problems are also confirmed by the fact that many researchers are working on these issues (Mandal, 2014).

In Siyadebirna wayu surface water sources are scare and all these sources dried at the end of December. Drilling ground water wells are difficult due geographical situation of the area. Most villages of the case study area located near to the cliff. Rainwater harvesting is the appropriate alternative water supply sources for this area.

1.2 Statement of the problems

The ministry of water resources (MOWR, 2002) reported that about 67% of the country's regions are categorized as arid and semi -arid which are characterized by acute water shortage because of erratic rainfall distribution and resulting in recurrent drought and famine. Excluding the purely pastoralist areas, more than 90 woreda with a total of more than 2 million households in the country are drought prone and regularly hit by severe water shortages (Fitsume Yemenu, 2014).

The settlement of population in rural part of Ethiopia is scattered, this also has big influence on the water supply system. The centralized water supply system for these scattered villages is expensive. Therefore, the advisable and economical water supply system for scattered village is non-central. For non-centralized water supply system the first challenge is the availability of water sources around each village.

Siyadebirna Wayu Woreda communities travel longer distance and time for water access. Most villages of the Woreda located on highland over steep slope which creates difficulty in drilling wells. The lowland part usually gets some spring water. Some communities also travel the abyssal part for fetching the water from springs. The communities of this Woreda hygiene are very poor due to lack of water for non-domestic demands. Even they wash their cloths for only big holidays by traveling long distance and have the same trends for shower. The communities exposed for different hygiene related disease and water shortage problems.

The settlement of the study woreda kebeles are scattered and near to the cliff. This also has high pressure on the ground and surfaces water sources which flow into lowlands by cause of slopes. Rainwater can serve as an alternative water source for rural villages where other water sources are not available or less. Rainwater harvesting systems also serve as an alternative decentralized water source. Decentralized water sources, like rainwater, are needed to guarantee long-term ecologically sound water supplies.

In many areas RWH has now been introduced as part of an integrated water supply, where the town water supply is unreliable, or where local water sources dry up for a part of the year. But RWH can also introduce as the sole water source for communities or households. The technology is flexible and adaptable to a very wide variety of conditions. It is used in the richest and the poorest societies, as well as in the wettest and the driest regions on our planet (Janette Worm, 2006).

According to reports of UN officials, Ethiopia is among the nine countries of Africa which possesses great potential for RWH. It is estimated that the country could feed 520 million people through RWH (Wubetu, 2016). The situation of Siyadebirna Wayu woreda has abundant rainfall 900 to 1500 mm/year (Abirham Cherinet, 2017) which, if collected and used properly can sustain the water access of the society in the woreda. Thus, this research will evaluate the possible impact and utilization of the rainwater harvesting technologies in the

woreda, by taking a specific kebele as case study. The case study site will be selected so that it may represent the critical water stress situation of the Woreda. The main objective of the water harvesting approach would be in addressing the hygiene and water shortage related diseases.

1.3 Objectives of the study

1.3.1 General objectives

The general objective of this study is identifying the rainwater harvesting as decentralized alternative water supply sources in Siyadebirna Wayu Woreda.

1.3.2 Specific objectives

- ❖ Identify the scale of the water shortage related problem in the woreda.
- ❖ Classify the possible alternative sources of water for the community in the woreda.
- ❖ Identify the rainfall pattern and potential for rainwater harvesting.
- ❖ Recognize the latest technologies for the rainwater harvesting applicable in the woreda for domestic water supply.
- ❖ Assess the community attitude towards the rainwater harvesting.

1.4 Research questions

- a) What are the problems of the woreda community related with water shortages?
- b) Which type of alternative water sources available in the woreda?
- c) What is the potential of rainwater will be harvest in the woreda? What is its pattern?
- d) How to implement the latest technologies of rainwater harvesting for the woreda?
- e) What is the community's perspective towards rainwater harvesting technologies?

1.5 Significance of the study

The result of the study may provide educational information for Siyadebirna wayu woreda use of Rainwater as alternatives water supply sources. The following important information may contribute for the study woreda:-

- Evaluate the experience of rainwater harvesting practices.
- Setting appropriate rainwater harvesting system (technologies).
- Evaluate policy alternative.
- Re-design the experience of rainwater harvesting system into modern.

1.6 Limitation of the study

Since the study cover wide geographical area it is impossible addressing the total area of the woreda. The study is limited only one kebele and four sub-kebeles which have the critical water shortage problems in the woreda. The respondents answer the questioner by representing of the all member of their family. The analysis for micro/macro rainwater harvesting system was done by considering the same characteristics of natural land.

The study being conducted in importance and competence of rainwater harvesting as an alternate decentralized water supply, spatially and temporally compact and accurate data on rainfall is vital for its success. As such data is scarce the study has used data from rainfall stations in close proximity to the study area.

Additionally, by the causes of time and resource limitations the sample size is limited to 145 compounds. Also the roof area sample contain only personal house roof, it did not include public institutions like school, hospital and farmer unions.

1.7 Organization of the thesis

This thesis is organized with five chapters. **Chapter one** contain the general introduction part of Rainwater harvesting, statement of the problem, objectives of the research, the research questions, significance of the study as well as the limitation of the study.

Chapter two cover the recent literature reviews about Rainwater harvesting. The historical back ground of Rainwater harvesting, world countries that practice RWH, the applicable area and time of RWH, suitability and factors which affect RWH, how rainwater use, types of RWH and its components, water storage tank available on the market, how the storage capacity of the water tank determine, delivery (transportation) system of the collected water, advantages and disadvantages of RWH, effectiveness of the technology and about samsam rainwater harvesting tools all issues describe in details.

Chapter three generally deals about the materials and methodology study. It contains area of the research, data collection system and sample size determination.

Chapter four contains the core points of the study, which is the results and discussion part of the research. It contains the main finding points of the research. **Chapter five** is the last part of this thesis which contain conclusion and recommendation part of the research.

CHAPTER TWO

2.0 Literature review

2.1 Historical development of rainwater harvesting

Rainwater harvesting used as a climate adaptation policy that has been in use during various ages of manhood. Archaeological studies and historical information showed that the technology was in use for more than 10,000 years on all regions. In most cases it was largely used as an alternative water source in dry periods and it was existence plan for ancient civilizations. Rainwater harvesting can not only be used as an adaptation measure against periodic water scarcity and saving of drinking water use. It may reduce the city's external water demand, improve water stress on the area, decrease non-point source pollution, reduce treatable urban runoff volume, prevent flooding and help to alleviate climate change. Studies have shown that application of RWH results in a reduction of storm water runoff volume between 20 to 50 % (*Dr. Hofman, 2014*).

Rainwater harvesting has been practiced for over 4,000 years throughout the world, traditionally in arid and semi-arid areas, and has provided drinking water, domestic water and water for livestock and small irrigation. Today, rainwater harvesting has increased much on significance as a modern, water-saving and simple technology (*Che-Ani A, 2009*).

Rain Water Harvesting (RWH) is practiced in many forms throughout the World. While surface runoff is collected for agricultural purposes as well as for mitigating flash floods, roof runoff is used to supplement the potable water, mainly households (*Thamer Ahmed Mohammed, 2013; Che-Ani A, 2009*). Many countries around the world are still promoting the usage of harvested rainwater for potable and non-potable uses. Examples of these countries are USA, Germany, Australia, China, and Japan.

Obviously, it is nearly impossible to trace back to which civilization used the method of rainwater harvesting first, but evidence shows that different types of rainwater collection systems were used in 2000 BC in India, Mesopotamia, China, and modern day Israel. The capturing and storing of rainwater goes back thousands of years to when we first started to farm the land and needed to find new ways of irrigating crops. In hotter climates, catching that intermittent rainfall often meant the difference between life and death for communities. Although the need to conserve water fell away with greater urbanization in the last thousand years, we are once again returning to this ancient and vital part of greener living. (<https://www.renewableenergyhub.co.uk>)

2.2 Some of world countries practice rainwater harvesting

Middle East: has a rich history in the rainwater harvesting timeline. Dating back to 2000 B.C. people in the Negev Desert, which is modern-day Israel, survived by capturing water from the hillside and storing it in Cisterns (Wubetu, 2016). According to Heather Kinkade-Levario in Design for Water Rainwater Harvesting, Storm water Catchment, and Alternate Water Reuse, in tales of a war for the land east of Jordan, King Mesha of Moab used reservoirs to capture rain and gave his warriors the ability to survive in the dry heat. In the civilizations, rainwater harvesting cisterns were common on a home by home basis, based on a historical document of that time in the Middle East. Community cisterns were also common (J. Lange, 2012).

India: Many rainwater harvesting roots can be traced back to India. Ancient India also developed technology such as large reservoirs to hold rainwater and dams to divert and capture rainwater.

Ancient Rome: The Romans excelled in many technological advancements, including rainwater harvesting and aqueducts. They would build entire cities with the infrastructure to divert rainwater into large cisterns. The Romans would use this collected water for drinking, bathing, washing, irrigation, and for livestock.

North America: Ancient Native Americans used the natural flow of mountain rainwater runoff to collect and use throughout villages. In central Mexico, underground cisterns have been found that were used for collecting rainwater. In the 16th-17th century, early settlers began to use rainwater for laundry due to it being naturally soft. They were the ones who actually started using the term “hard water” and “soft water” because of the trouble that would occur from trying to use mineral-rich water for washing laundry. Soap would react with the hard water, causing a build-up to occur, unlike when they used soft rainwater, which allowed the soap and dirt to wash off easily.

Ethiopia: The history of water harvesting in Ethiopia dated back as early as the pre Axumit period (560 BC). It was a time when rainwater was harvested and stored in ponds for agricultural and water supply purposes. Anthropologists (Fattovich,1990) have documented evidences of the remains of ponds that were once used for irrigation during this period. A roof water harvesting set up is still visible in the remains of one of the oldest palaces in Axum; the palace of the legendary Queen of Sheba. Other evidences include the remains for one of the old castles in Gondar, constructed in the 15-16th century, which used to have a water harvesting set up and a pool that was used for religious rituals by the kings. In south of the country, the Konso people have had a long and well established tradition of building level terraces to harvest rain water to produce sorghum successfully under extremely harsh environment; low, erratic and unreliable rainfall conditions (Tulu, 2014).

The structural failures are connected with poor design, water loss due to evaporation and seepage, low technical capacity and subsequently low adoption by user. Another report indicated that there was only 22% functional water harvesting structures out of the constructed ones between the periods 2003-2004 in Amhara regional state. The most critical of all the problems is the water loss due to seepage resulting from poor lining materials of the harvesting storage structures (Fitsume Yemenu, 2014).

2.3 When and where rainwater harvesting is applicable?

Utilization of rainwater at present time is an option beside with more conservative water supply technologies, particularly in rural areas, but increasingly in urban areas as well. In large part of the world, runoff water harvesting is best known and practiced in the semi-arid areas where annual rainfall is in the range between 400 and 600 mm (Alem, 1999). RWH has proven to be of great value for arid and semi-arid countries or regions, remote and scattered human settlements.

Traditionally, in Uganda and in Sri Lanka rainwater is collected from trees, using banana leaves or stems as gutters; up to 200 liters may be collected from a large tree in a single rain storm. With the increasing availability of corrugated iron roofing in many developing countries, people often place a small container under their eaves to collect rainwater. One 20-litre container of clean water captured from the roof can save a walk of various kilometers to the nearest clean water source (Janette Worm, 2006).

Rainwater can be used to meet part of domestic water demand including both potable and non-potable. In urban areas, at a household, rainwater can be used for flushing toilets, watering gardens and washing floor and these uses are known as non-potable. While in rural areas, it becomes the main source of water for potable uses which include drinking, bathing and cooking (Thamer Ahmad Mohammad, 2010).

RWH is a popular household option as the water source is close by, convenient and requires a minimum of energy to collect. An advantage for household systems is that users themselves maintain and control their systems without the need to depend on other members of the community. Since almost all roofing material is acceptable for collecting water for household purposes, worldwide many RWH systems have been implemented successfully (Janette Worm, 2006).

2.4 Suitability and Factors that affect the rainwater harvesting

The main factors should be considered in the rainwater harvesting systems are Climate (rainfall pattern and rain intensity), technology, socio-economical factors, local livelihood, political system, and organizational management all play significant role in the final choice (Janette Worm, 2006).

Environmental applicability of rainwater harvesting depends on the amount and patterns of rainfall in the area, the duration of dry periods and the accessibility of other water sources. The rainfall pattern over the year plays a crucial role in determining whether RWH can compete with other water supply systems. Tropical climates with short (one to four months) dry seasons and multiple high-intensity rainstorms provide the most suitable conditions for water harvesting. Rainwater harvesting is also valuable in wet tropical climates (e.g. Bangladesh), where the water quality of surface water may vary greatly throughout the year. As a general rule, rainfall should be over 50 mm/month for at least half a year or 300 mm/year (unless other sources are extremely scarce) to make RWH environmentally feasible (Janette Worm, 2006).

According to, (Koenders, 2007) the minimum applying conditions for RWH are:

- If used for rooftop harvesting, an annual rainfall of at least 100-200 mm is required.
- Storage tanks can also be filled up by pumps and be used for domestic use or irrigation.

The most identical characteristic of DRWH is that it delivers water in the shortest distance (without walking). Annual output of rainwater depends on the rainfall, the roof size and the complexity of the harvesting system.

Roof water harvesting provides a safe and suitable source of water of limited quantity, which is best used as a source of good quality water (e.g. for drinking and cooking). Almost all water used by human beings derives from rainfall. Roof water harvesting differs from other water supply modes in that there is no need to transport water, since it is used within a few meters of where it falls as rain (Martinson, 2007).

Rainwater harvesting technology is suitable for use in all areas as a supplementing water source. It is most useful in arid and semi-arid areas where other sources of water are scarce.

There are many factors that must be considered during rainwater harvesting. From these factors the following are major factors that affect both the quality and quantity of the collected water. These are:-

- The amount of rainfall of area.
- The space available for an underground tank.
- The space and load bearing capacity for a raised tank.
- The environment condition of the area (industry, agriculture, urban etc.)
- The area and type of roof space that will be used for collecting the rainwater.
- The storage construction materials.

2.5 How the user use collected rainwater?

- ❖ Four types of user regimes can be recognized: (Janette Worm, 2006)

- A) **Occasional** - Water is stored for only a few days in a small container. This is suitable when there is a uniform rainfall pattern and very few days without rain and there is a reliable alternative water source nearby.
- B) **Intermittent**- There is one long rainy season when all water demands are met by rainwater, however, during the dry season water is collected from non-rainwater sources. RWH can then be used to bridge the dry period with the stored water when other sources are dry.
- C) **Partial** - Rainwater is used throughout the year but the 'harvest' is not sufficient for all domestic demands. For instance, rainwater is used for drinking and cooking, while for other domestic uses (e.g. bathing and laundry) water from other sources is used.
- D) **Full** - Only rainwater is used throughout the year for all domestic purposes. In such cases, there is usually no alternative water source other than rainwater, and the available water should be well managed, with enough storage capacity to bridge the dry period.

❖ Five styles of using domestic roof water harvesting (Martinson, 2007)

- A. **As the sole (independent) source of water** in situations where there is little seasonality in rainfall or where all other alternatives are impractical, unusually costly or socially unacceptable.
- B. **As the main source of water**, providing at least 70% of annual water use in situations where (usually higher cost) alternatives can be used to supplement it during dry periods.
- C. **As only a wet-season source** – whose benefit is greater convenience in water collection for a significant part of each year.
- D. **As a potable water only source** – providing 5 to 7 liters per person per day throughout the year.

- E. **Emergency source of water** – to be kept for when all other sources have failed, or for fire-fighting and other emergencies.

2.6 Types of water harvesting

There are different types of water harvesting system that are used in the world, the price varying with the complexity and size of the technology being installed. Almost all water harvesting system have one common thing, which is they used rainwater comes from the nature utilize it to supplement the main water supply system. Water harvesting techniques can be categorized into four groups, according to the available water source and the storage medium: (Koenders, 2007)

Rainwater or fog harvesting collects water directly where it falls as rain or snow, from ground surfaces or rooftops or by intercepting fog. Rooftop rainwater and intercepted fog are commonly of a good quality, but may be affected by air pollution, dirt on roofs or rust on metal sheets. If measures are taken to prevent the first polluted flush entering storage tanks, water can be fit for drinking and other domestic use with little or no treatment. Rainwater and fog harvesting are especially important in semi-arid areas, where it is necessary to store the maximum amount of water during the wet season for later use.

Surface water harvesting includes all systems that collect and conserve surface runoff after a rainstorm or in (intermittent) streams, rivers or wetlands for storage in open ponds or reservoirs. This usually provides water for irrigation, livestock and aquaculture. For domestic use, treatment is generally required.

Groundwater harvesting refers to techniques that increase the quantity of water that (artificially) infiltrates into the sub-soil (recharge) and / or keep groundwater available for longer periods. Options for increasing groundwater recharge include constructing small dams or bunds, terracing, contour trenching, sub-surface dams and planting trees. This can improve water for domestic use or for irrigation, livestock or aquaculture.

Waste or grey water harvesting refers to systems that collect and recycle waste water for small-scale agriculture. Besides the available water sources, water harvesting techniques also include options for collection, storage, treatment and use.

Rainwater harvesting also classified depend on the end user as follow:-

2.6.1 Domestic rainwater harvesting

Domestic rainwater harvesting is the activities of rainwater collection from the quality catchment area for utilization of domestic water supply. It reduces the dependence on the mains water supply system, and then a more multipart rainwater harvesting system can be

installed to provide for daily living requirements such as washing clothes and flushing the toilet.

2.6.2 Commercial rainwater harvesting

The savings for large scale commercial rainwater harvesting can be quite considerable compared to domestic systems. This type of rainwater harvesting used for commercial and industrial water demand. The difference for commercial buildings that have rainwater harvesting is mainly in the size the general technology remains the same. Rainwater harvesting systems in new builds are becoming far more commonplace with new government guidelines and the requirements of industry bodies.

2.7 Components of rainwater harvesting

Though every system will be different and employ various rainwater collection methods, mostly rainwater system will consist of the following elements: (Wubetu, 2016).

Catchment area:-the part of the land or roof where a portion or all of the precipitation which falls on it runs off its boundaries. It can be agricultural, rocky or marginal land or rooftop.

Conveyance (pipes and gutters):- the part of rooftop rainwater harvesting which transport the water from the rooftop to the storage tanks. It has different types, size and arrangements.

Filter: - is used to stop debris in the water (such as leaves and dirt) from entering the water tank. For most average sized rainwater harvesting devices, different levels of filtering are required depending on the final use of the collected water. For instance, the water needs to be of higher quality if it is used for domestic rather than non-domestic. For systems that are submerged underground a pump is needed to get the water to where it needs to be used. Gravity fed systems will not need a pump, instead using a raised storage tank to feed the water to points of use by gravity though these are relatively occasional for domestic premises.

Storage tank:-the part of rainwater harvesting which water is store water until it utilized by users, like crops, animals, human being and other users. Water storage or holding tank is needed to store the collected water from the roof or other surfaces. The size of storages is varying depending on the space available and what it is used for. It can be underground or at the side of the house or building.

There are different types of rainwater harvesting tank on the market that can either be used on a roof, at ground level or underground, depending on condition. Most of the tanks available on the market are now made of polyethylene plastic that is long lasting and highly durable. The problem with polyethylene is that it can be affected by sunlight that can degrade the quality of the stored water in hotter weathers. Larger rainwater harvesting tanks tend to be made of polyethylene which is surrounded by something like a steel case.

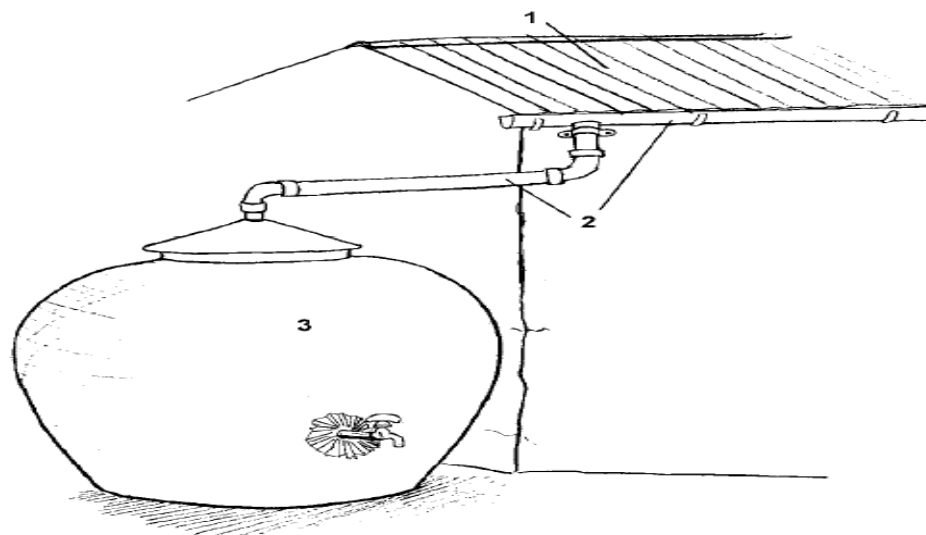


Fig 2.1 Three basic components of a rainwater harvesting system

- 1) Catchment
- 2) Delivery system
- 3) Storage reservoir

2.8 Water storage tanks available on the market

Concrete - Concrete tanks used for rainwater harvesting are heavy and mostly installed underground. Mostly it constructed underground, implies that it needs lot excavation of soil. The lime from the concrete can also leach into the water in the tank which makes it dangerous to use for drinking.

Metal - Metal tanks have always been a good alternative to concrete tanks as they are lighter, cheaper and easier to install. However, because of the material, they are extremely dangerous if stored water using for drinking. This is because over time the steel will corrode and rust which will pollute the purity of the water.

Plastic - Plastic or polyethylene tanks used for rainwater harvesting are definitely the most common. These are extremely popular because of their cost and quality.

Bladder - Bladder tanks used for rainwater harvesting are often used if the available space is small for a tank. Made from a flexible membrane that flexes when water enters, these rainwater bladders can take up a lot of surface area. The only time these bladders are useful is the available space for tank is minimum.

Fiberglass - Fiberglass tanks are stronger than metal and concrete. However, they tend to be a lot more expensive because of the manufacturing process.

Generally storage tank can be:-

- ✓ Above the soil surface as in surface reservoir or ponds.
- ✓ In soil profile as soil moisture (as ground water recharge), and
- ✓ Under ground in cisterns or as ground water in aquifers.

Mostly, the rainwater harvesting ponds (storage tanks) are constructed into two ways (Milton Austin, 1996):-

An embankment pond: - is made by building an embankment or dam across a stream or watercourse where the stream valley is depressed enough to storing the required amount of water.

An excavated pond: - is made by digging a pit or dugout in a nearly level area. Because the amount of stored water dependable on the size of digging pond.

2.9 Sizing storage reservoir

There are several methods for sizing storage reservoirs. From the several methods the following two are mostly common and widely usable (Janette Worm, 2006).

- 1) Demand side approach (dry season demand versus supply)
- 2) Supply side approach (graphical methods)

The first method is the simplest method and most widely used. The second method uses statistical indicators of the average rainfall for a given place. If rainfall is limited and shows large fluctuations then a design based on only one single statistical indicator can be misleading.

Method 1: Demand side approach (dry season demand versus supply)

This is the simplest method to calculate the storage requirement based on the required water volume (consumption rates) and occupancy of the building. This approach is only relevant in areas with a distinct dry season. The tank is designed to meet the necessary water demand throughout the dry season.

To obtain required storage volume the following equations can be used:

$$\text{Demand} = \text{Water Use} \times \text{Household Members} \times 365 \text{ days}$$

This equation provides the water demand in liters per year. Dividing by 12 months will give the required water demand in liters/month. The required monthly water demand multiplied by the dry period will give the required storage capacity.

$$\text{Required storage capacity} = \text{demand} \times \text{dry period}$$

Method 2: Supply side approach (graphical methods)

Another method to estimate the most appropriate storage tank capacity for maximizing supply is to represent roof run-off and daily consumption graphically. This method will give a reasonable estimation of the storage requirements. Daily or weekly rainfall data is required for a more accurate assessment. If there is sufficient rainwater to satisfy the demand throughout the year, then sufficient water storage tank required to bridge the periods of scarcity. There are three basic steps to be followed:

- Plot a bar graph for mean monthly roof run-off for a specific house or building in a specific location. Add a line for the demand per month.
- Plot a cumulative roof run-off graph, by summing the monthly runoff totals.
- Add a dotted line showing cumulative water use (water withdrawn or water demand).

2.10 Rainwater harvesting delivery systems

There are many ways of transportation system the stored water from the tank to the parts of customers. In taller buildings roof based tank that works by gravity feed is popular with commercial buildings rather than domestic. There are two main systems of deliveries of water from the storage tank (Environmental Agency, 2010).

Gravity feed systems: - These are normally positioned at the top of the building and use the power of gravity to drive the water to different parts of the house. They do not need any other power source such as electricity.

Pump feed systems: - The tank in this instance can be at ground level, or even under the ground, and a pump is then used to distribute the water around the house. Both systems work the essentially the same way in that they collect water from the roof by the guttering, it passes through a series of filters, and is then stored in a large tank ready for distribution.

A combined pump and gravity system: - The systems can also a combined pump and gravity system that moves the water to the top of the house to another tank where it can be stored before being distributed through the pipes. This basically pumps water first of all up to a storage tank in the loft where it is then distributed by gravity. The benefit of this is more energy efficient than a full pump system because it uses less electricity.

2.11 Advantages and disadvantages of rainwater harvesting

Some of advantages and disadvantages of rainwater harvesting is listed in Table 2.1 (Janette Worm, 2006).

Table 2.1 Advantages and disadvantages of rainwater harvesting

Advantages	Disadvantages
Simple construction: Construction of RWH systems is simple and local people can easily be trained to build these themselves. This reduces costs and encourages more participation, ownership and sustainability at community level.	High investment costs: The cost of rainwater catchment systems is almost fully incurred during initial construction. Costs can be reduced by simple construction and the use of local materials
Good Maintenance: Operation and maintenance of a household catchment system are controlled solely by the tank owner's family. As such, this is a good alternative to poor maintenance and monitoring of a centralized piped water supply.	Usage and maintenance: Proper operation and regular maintenance is a very important factor that is often neglected. Regular inspection, cleaning, and occasional repairs are essential for the success of a system.
Relatively good water quality: Rainwater is better than other available or traditional sources (groundwater may be unusable due to fluoride, salinity or arsenic).	Water quality is vulnerable: Rainwater quality may be affected by air pollution, animal or bird droppings, insects, dirt and organic matter.
Low environmental impact: Rainwater is a renewable resource and no damage is done to the environment.	Supply is sensitive to droughts: Occurrence of long dry spells and droughts can cause water supply problems.
Convenience at household level: It provides water at the point of consumption.	Limited supply: The supply is limited by the amount of rainfall and the size of the catchment area and storage reservoir.
Not affected by local geology or topography: Rainwater collection always provides an alternative wherever rain falls.	
Flexibility and adaptability of systems to suit local circumstances and budgets, including the increased availability of low cost tanks (e.g. made of Ferro cement, plastics or stone/bricks).	

2.11 Effectiveness of the technology

Rainwater harvesting is a multipurpose way of supplying usable water to consumers during a crisis period, recharging the groundwater and finally reducing the runoff and water logging during the season of heavy rainfall. Traditional knowledge, skills, and materials can be used for this system. During the rainy season, an individual can collect water on his rooftop and manage it on his own. Reserved rainwater on rooftops can be used for self-purposes or

domestic use. Water from different rooftops of a road can also be collected through a piped network and stored for some time (Sadia Rahman, 2014).

One of the biggest challenges of the 21st century is to overcome the growing water shortage (Janette Worm, 2006). Rainwater harvesting (RWH) has thus regained its importance as a valuable alternative or supplementary water resource, along with more conventional water supply technologies. Much actual or potential water shortages can be relieved if rainwater harvesting is practiced more widely.

In many areas of the world, increasing water scarcity and drought is a supreme problem, forcing cities and countries to focus on how to harvest and optimize the reuse of rainwater. In Denmark, water scarcity has not yet been a serious problem but climate change predictions indicate that continued drought periods will occur more frequently in the future (Hoffmann, 2015).

Rainwater harvesting (RWH) may be an effective alternative water supply solution in regions affected by water scarcity (Lorena Liuzzo, 2016). It has recently become a particularly important option in arid and semi-arid areas mostly because of its many benefits and cheap costs.

Rainfall harvesting technology has proved to be very effective throughout several Latin American countries and most of the Caribbean islands, where cisterns are the principal source of water for residences. The use of rainwater is very effective in declining the demand on the public water supply system in the British Virgin Islands. It also provides a convenient safeguard in times of emergency or shortfall in the public water supply. Also, because of the hilly or mountainous nature of the terrain in the majority of the British Virgin Islands, combined with isolated housing patterns, rainfall harvesting appears to be the most practical way of providing a water supply to some residents. (<https://www.dadychery.org/rainwater-harvesting-reasonable-for-haiti>)

Several benefits can be achieved by using rainwater to help cities keep a sustainable water balance through various treatment technologies. These ensure proper treatment of rainwater to allow for infiltration to the groundwater aquifers or discharge into the local water environments such as lakes or streams. Finally, in areas suffering from water scarcity, local rainwater harvesting and recycling can be a valuable source of non-potable water which can be used for watering plants, flushing toilets or washing clothes instead of using the precious drinking water (Hoffmann, 2015).

Small rainwater storage improves livelihood for 15 million people in China (Klaus W, 2009). Gansu Province is one of the driest, most mountainous and poorest regions in China. It has an annual precipitation of 330 mm while potential evaporation is as high as 1,500-2,000 mm. Rain is the only water available. This is an area lacking in three essentials: water, food and fuel. This causes insecurity in both human livelihoods and the environment. From 1988 to

1992, research was conducted to find the most suitable rainwater harvesting involvements to promote in the area. By the end of 1994, 22,800 updated water cellars with 2.4 million m² of new catchment area (tiled roof and concrete lined courtyard) had been built. A total of 28,000 families (141,000 people), 43,000 large livestock and 139,000 small animals got enough water to drink.

The UK sustainable homes policy now says that houses should have an underground tank that can be used to collect rainwater for various washing tasks. Most new builds in China and Brazil now incorporate rooftop rainwater harvesting technology although many countries are making it law to be greener when it comes to our most vital commodity. In many states in the US, until recently, rainwater harvesting was actively discouraged but new legislation is beginning to come in to make it possible for individual houses to incorporate the technology to save water for their homes. In Israel, they are beginning to install rainwater harvesting devices in schools as a way of teaching children the value of water conservation and in South Africa research is well under way to find new ways of employing catchment technology. The future of rainwater harvesting appears to be in fairly good shape and the great thing is that many modern systems can be installed with a minimum of effort. <https://www.renewableenergyhub.co.uk/main/rainwater-harvesting-information/history-of-rainwater-harvesting>.

2.12 SamSamWater rainwater harvesting tool

The samsamWater Foundation is founded by three enthusiastic hydrologists who want to help improve water and sanitation access in developing countries. They believe creating a reliable water supply and sanitation access are the first steps in sustainably improving livelihoods. When these basic needs are met, health, education and income will improve significantly likewise.

The rainfall data used for SamSam rainwater harvesting tool is based on the CRU CL 2.0 dataset which is described in New, M., Lister, D., Hulme, M. and Makin, I., 2002: A high-resolution data set of surface climate over global land areas. *Climate Research* 21:1-25.

The CRU CL 2.0 (Climatic Research Unit, average climatology) data-set comprises monthly grids of observed mean climate from 1961-1990, and covering the global land surface at a 10 minute spatial resolution. There are eight climatic variables available, and also the elevations on the grid: diurnal temperature range, precipitation, means temperature, wet-day frequency, frost-day frequency, relative humidity, sunshine, and wind-speed. In addition minimum and maximum temperature may be deduced from mean temperature and diurnal temperature range. https://crudata.uea.ac.uk/~timm/grid/CRU_CL_2_0.html.

The samsamwater RWH tool is selected because of its simplicity and the raw data required for analysis. The data inputs for the model are a satellite map of the study area from Google Earth,

Population, Per capita water demand, Roof area, Type of roof material and a rainfall data from satellites. The expected results from the model are Rainwater harvesting potential, Water availability, required storage and Dry and Wet year potentials.

CHAPTER THREE

3.0 Material and methodology

3.1 Description of study area

Siyadebirna Wayu woreda located in Semen Shewa Zone of Amhara National Regional State. The woreda is situated at 130 km from Addis Ababa along Sheno to Deneba. Geographically it is located at latitude 9.781 north and longitude 39.081 east. The Woreda has dega, kola and weyina dega climate condition. Some of the woreda kebeles has a critical water stress problems and the community are affected by water shortage and hygienic problems that generates from the water shortage.

The woreda known by its external agriculture products as well as by its beef cattle brand (Yejiru senga) production. The current status of the woreda water supply is not satisfy the demand of the community, because of the community of the woreda has hybrid agriculture (farming and cattle production). Most parts of the woreda utilized for the animal and domestic demand is the same source of water because of lack of alternative sources for the animal demand especially in dry season mostly from December to June.

In the developing world, rainwater harvesting for potable use is important both from the standpoint of water supply and health (Melby, 2006). Siyadebirna Wayu woreda has high rainfall intensity during the Ethiopian summer season from June to mid of September (above 700mm) and above 90% of the selected woreda kebele (sub-kebeles) farmers have their own house which roof is constructed with tin.

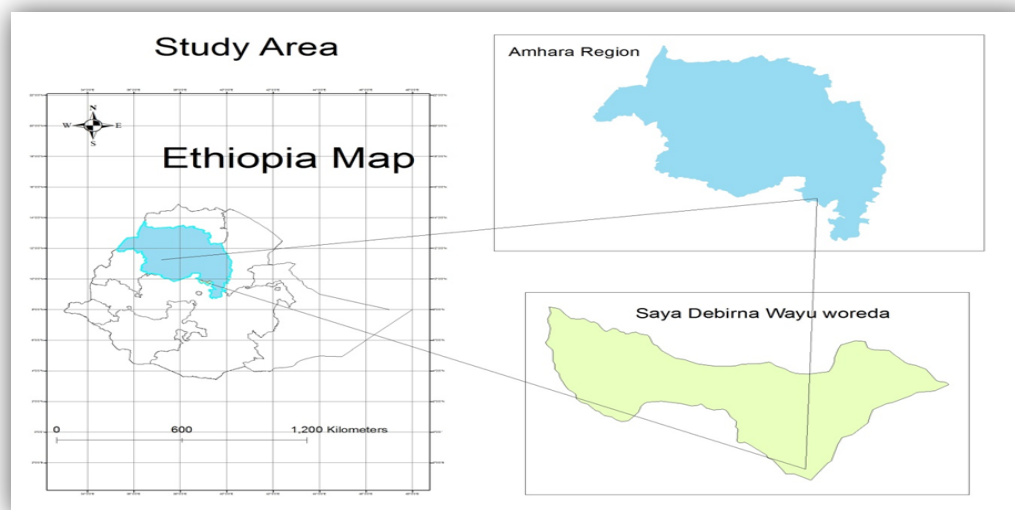


Fig 3.1 Geographical location of study area



Fig 3.2 Geographical situation of the study area

The research follows the following hierarchical conceptual frame work.

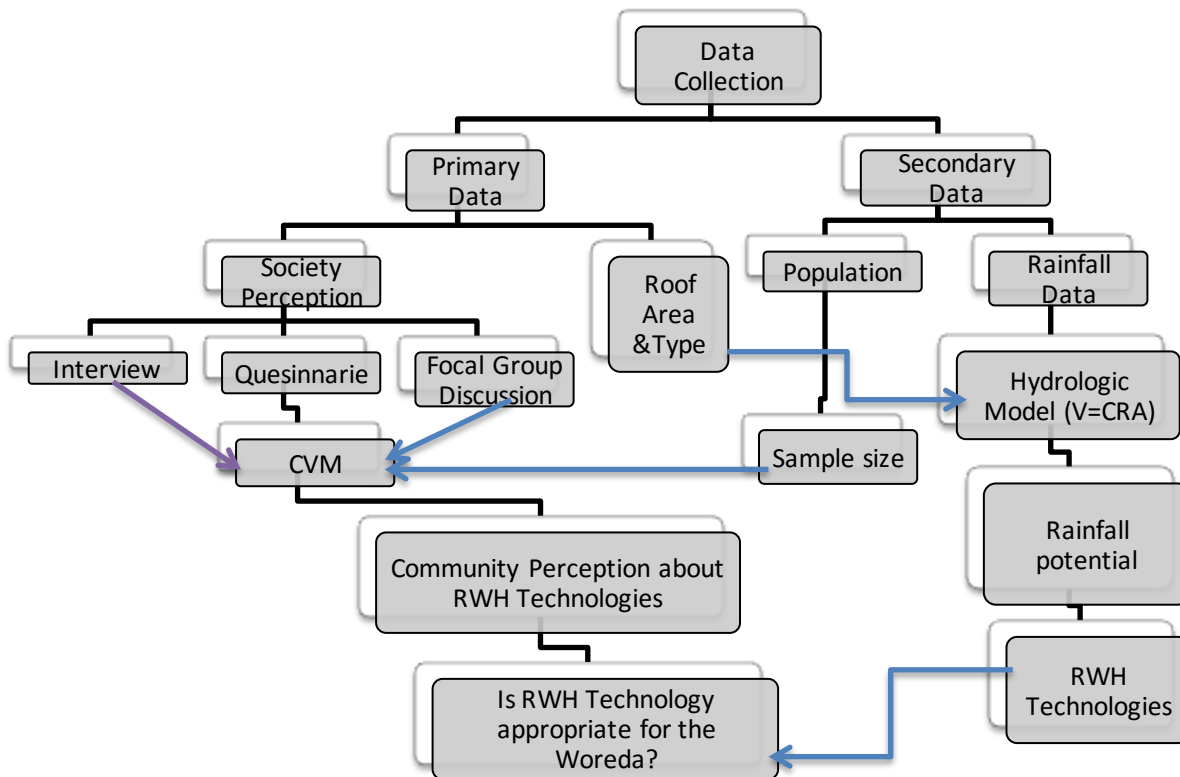


Fig 3.3 Frame work of the research

3.2 Sample size determination.

Determining the sample size for a study is a crucial component of study design. The purpose is to include sufficient numbers of subjects so that statistically significant results can be identified. Using too few subjects result in wasted research resources and statistically inconclusive findings which make it difficult to determine whether a particular treatment or intervention will be effective and to identify directions for future studies. Thus, using the appropriate number of subjects optimizes the probability that a study will yield interpretable results and minimizes research waste.

Here are the formulas used for Sample Size Calculator:

<https://www.surveysystem.com/sscalc.htm>

$$SS = \frac{Z^2}{C^2} * P * (1 - P)$$

Correction for Finite Population

$$\text{New SS} = \frac{SS}{1 + (SS - 1) / POP}$$

Where:

SS=Sample Size

Z = Z value (1.96 for 95% confidence level)

P = percentage picking a choice, expressed as decimal
(0.5 used for sample size needed)

C = confidence interval, (also called margin of error) is the plus -or-minus figure usually, expressed as decimal (± 6).

Pop=Population (316 Compounds taken)

Putting all these values into the above formulae, yields a sample size of **145** compounds are which used for this study.

3.3 Survey Design and Sampling Techniques

Before implementing the final survey, the focus group discussion was conducted with the woreda water bureau managers. During the focus group discussion kebeles which have the critical water shortage during the dry seasons were identified. The kebeles with critical water shortages are Ejersa kubeti, Siyadebir and Gashuamba. The geographical location of these kebeles is nearby cliff. The woreda water bureau has been pressured to drill the ground water well in these areas.

The sample for the study is drawn from the four sub-Kebeles of the Ejersa kubeti kebele and random samples of 145 households (compounds) were selected in the survey. The compound in each sub-kebele selected proportionally using simple random sampling. The sample is composed of 145 compounds from the total of 316 compounds. Accordingly the sample size from each sub-kebele Zinjero wuha, Kubeti, Gotet dega and Kebet amba are indicated in Table 3.1.

Table 3.1 Sample size selection

Name of sub kebeles	Total number of Compound	Share of compounds from the total compounds (%)	Number of sample taken
Zinjero wuha	70	22.15	32
Kubeti	65	20.57	30
Gotet dega	115	36.39	52
Kebet amba	66	20.89	31
Total	316	100	145

Sources: - Ejersa kubeti kebele administration

3.4 Data sources and methods of analysis

For this study both the primary and secondary data are used.

3.4.1 Primary Data

In primary data collection the researcher takes one compound as a single sample size i.e. all people and domestic animals live in that compounds takes by their living compound and houses also been taken in the same way.

For this research the primary data were collected by the following mechanisms:-

- ❖ By direct interview
- ❖ By focal group discussion
- ❖ By questionnaires
- ❖ By field survey

The distribution of suitable roof area for rain water harvesting system throughout the study area from the field survey has shown that more than 90% of the kebeles dweller has their own house with corrugated iron sheet roof.

The other important information that gets from the focal group discussion is roof rainwater harvesting will be one of the best alternatives water sources for the dwellers of the Kebeles. However, their main concern is the size and location of the technology to store and collect the rainwater.

The areas of roof which are available in the study areas are given in Table 3.2.

Table 3.2 Number of corrugated iron sheet roof and area of roof

R. No.	Number of tin (Corrugated iron)	Print foot area of houses (m ²)
1	32	4.8 x 6.8 = 32.6
2	42	5.8 x 7.8 = 45
3	50	6.8 x 8.8 = 59.8
4	60	7.8 x 9.8 = 76.4
5	70	8.8 x 10.8 = 95
6	80	9.8 x 10.8 = 105.84
7	100	10.8 x 11.8 = 127

Source: - Local Carpenters above 20 year experienced

The above expression only contains the area of main house. The researcher sees the experience of the community construction of the house during the data collection period, they construct other supplementary house used for other purpose (like for storing of agriculture products, animals shelter) through connecting in all directions of main house for protection and safety of their property and minimizing the construction costs. So, the available roof area of the study area is more than the above described area.

Other primary data that collected from the questionnaires and focal group discussion was the health problems that related with water shortages. The information found from the woreda health offices indicates that the diseases which related with water and hygienic were frequent for which the community pay large sum of cost for its health.

The study has also found out that the community is forced to minimize the number of beef cattle due basically to lack of water in the closer locations.

Water demand of the specific study sub kebeles was collected by direct interviews and questionnaires. Most of the study areas used the fetched water with their animals.

3.4.2 Secondary Data

The secondary data used for this research are collected from different written documents, literatures, websites, institution and bureaus.

Rainfall data

The study uses 10 metrological stations which have 17-24 year daily rainfall data. Daily rainfall for 10 stations has been collected from the National Meteorological Service Agency (NMSA). The metrological station distribution is not even in the study area. Among 10 stations 9 stations are outside the study area border 1 station is found inside the study woreda. The stations from outside the study area are used due to unavailability of the required data inside the study woreda. The rainfall distribution of the study area main rainy season in different year is presented in Table 3.3.

Table 3.3 Rainfall amount in rainy seasons

Year	Month				Total rainfall (mm)
	June	July	August	September	
1995	33.4	290.3	260.6	51.6	635.9
2000	44.8	271.4	254.9	97.3	668.4
2005	80.3	327.9	229.7	79.6	717.5
2010	54.4	304.7	310.2	126.6	795.9
2015	89.2	125.9	252.7	92.1	559.9
2017	60.4	306.6	360.8	89.4	817.2

Sources: - Own calculation

3.5 Rainwater and community

The community and rainwater have strong and un-separable relation. Especially peoples whose livelihood is sustained by rain-fed agriculture. The community of the study area practices rainwater harvesting in every year to satisfy their water demand during the rainy seasons only. During the rainy season the community in the study area involve in agricultural activities than any other activities. Which make them left with little time and enthusiasm to collect rainwater for use at dry season. Most community family gives priority for agricultural activities rather than water collection. They collect rainwater from their rooftop by installing small gutters and jar (storage materials) as shown Figure 3.4.



Gutter

Fig 3.4 Traditional household rainwater collection system

3.6 Health and water

All living things health dependable on water directly or indirectly, implies that all living things available on our environment need water for survives their life healthy. From these living

things the human is the special one which required water for continue the life on the earth, without water the human being live only a few days. Human health is directly dependable on adequate water. During the field survey of the researcher seen different water related problems on the research field on the community. The woreda health offices and some health center of selected kebeles improve this information by their annual reports as indicates in Table 3.4.

Table 3.4 Ten top causes of morbidity for Deneba Health center (year 2010 E.C)

No	Name disease	Total number of cases
1	Acute Febrile illness(AIF)	837
2	Acute upper respiratory infections	534
3	Pneumonia	477
4	Diarrhea (non-bloody)	272
5	Helminthiasis	224
6	Urinary tract infection	194
7	Trauma(injury, fracture etc.)	181
8	Dental and gum diseases	152
9	Typhoid fever	151
10	Infections of the skin and subcutaneous tissi	141

Source: - Deneba Health center

Some of the diseases occur by shortage of the water and available until field survey itch which occur as pandemic, eye problems and hygiene problems are commonly available. The report on Table 3.4 contains only number of people which go to the health center and take medication. There are other people affected by disease taking cultural medication. Therefore, the numbers of people will increase which affect by disease.

Water consumption

The water consumption of the study area increased highly during dry seasons. The reason behind this is the communities of the study area use the fetched water with their animals. The community gives priority for their animals drink rather than hygiene. The variations of water consumption throughout the year of Kebet amba got presented in Table 3.5.

Table 3.5 Water consumption of kebet amba

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average water consumption (L/compound/d)	200	200	200	200	200	150	40	40	50	80	80	100

Source: - Local water committee of Kebet amba got

CHAPTER FOUR

4.0 Results and Discussion

This portion contains the results that generates from the primary and secondary data. Depend on the results the discussion part of the thesis also present in this part.

4.1 Water demand analysis according to GTP II

The baseline of the water demand analysis is GTP II, because it reaches the end time for complete. According to Ethiopian GTP II standard, national potable water supply coverage in rural part of the country is 25l/c/d within 1km radius. The average family size of the study area is 7 persons per family. Besides each family have 4 cattle and 2 equine on average. Having an average water demand of 35l/cattle/day and 16.5l/equine/day (Zinash Sileshi, 2004).

The water demands according to GTP II standards for 7 persons 175l/day and for animals demand 173l/day. In this paper the water demand analysis is done by considering the overall (animal and human) water demand in single compounds. Total water demands (animals and human demand) of the study area are calculated as follows.

- ✓ Average daily human water demand according to GTP II is $7 \times 25 \text{ l/c/d} = 175 \text{ l/day}$
- ✓ Average daily cattle water demand is $35 \times 4 = 140 \text{ l/day}$
- ✓ Average daily equine water demand is $16.5 \times 2 = 33 \text{ l/day}$

Therefore, the average total daily water demands of the study area is 348l/day say 350litre. From which the monthly average water demand is 10.5 m^3 of water in a single compound.

4.2 Current water supply situation of the study area

The current average water supply coverage of the study area is around 143l/compound/day, this amount of water collected from different water sources includes ground water and springs. This indicates that water supply coverage of the area is around 42.85% only. During the dry season of the study area all local rivers and surface water sources dried. The serious water shortage season of the study area is around five months (January to May). The collected water from different sources used for total demands during the dry season.

The primary data collected from the study area has shown the following three main situations of the water supply system:-

- A) The water sources for the animals and human demand are separable. This is confirmed by 35.46% of the respondents. For animal demand children are found to go an average of 5km to 6km with the average time consumption 1 to 2 hours.

- B) From the total respondents 14.18% the water sources for animal and human are different, but the animal drink at home. This situation of the study area is the water sources of the animal and human are separable, but the community drink their livestock (animals) by fetching the water from abyssal places. The reason behind this is the water source location is not suitable for animal movements.
- C) 50.36% of the respondent used the same sources of water for both animals and human demands. This situation of the study area water sources of the animals and human are similar. The collected (fetched) water is used for both animals as well as human demands. So the total demand analysis of this research is done by considering the total demands of the water that required in a single farmer compound (animal demands and human demands).

4.3 The demand gap

The main goal of this research is to find the best alternative water sources, which can satisfy the additional amount of water from available alternative sources. Quantity of additional water required to fulfill the gap:-

- A) By considering the total demand (animal and human demands) 207 liter of additional water required per day per compound (6.21m^3 of water required per month).
- B) By excluding the animal demand and assume all amount of water delivered now used for human demands 32 liter of additional water is required per day to fulfill the GTP II standards (960 liter (0.96m^3) of water required per month per compound).

The amount of additional water required for this five months dry season is 37.26m^3 say 38m^3 per compound including 20% of water loss.

4.4 Alternative water sources available in the study area

In the study area the following alternative water sources are available.

- A) Spring water sources are available in the lowland part of the area. The communities which live in the lowland part use these springs for small irrigation purposes in addition to water supply. Therefore, using of these springs as alternative water sources for the highland part of the area will be the cause of conflict as well as reduction of agriculture products from the irrigation activities. In addition to this the location of springs are the bottom part of the abyssal places, it required high energy to transfer the water.
- B) Grey water is one of the alternative water sources generated from the water supply system. The quantity of which depends on the water supply coverage. The community of the study area manage the wastewater generated from the domestic water demand is

reuse for different purpose. From these the following are the most common in the study area:-

- ✚ For preparation of fuel from animal waste
- ✚ For cleaning of their houses
- ✚ For minimizing the dust from their compound
- ✚ For drinking of small animals like sheep

The community prepared their fuel from the animal waste during the dry season for using it on the rainy season. During the summer season they store the animal waste in specially prepared pits. The amount of grey water generates in the study area is small, so it does not use for alternative water sources. But the communities continue its trend of grey water reuse for managing of wastewater.

- C) Rainwater is the one of the water sources which the community used for agriculture products and for domestic water supply system during the rainy season. During rainy season lot of rainwater lost without advantages. The proper management of the rainwater for the study area is the key activities for solving the problems of water shortages which occur in the dry season.

4.5 Rainfall analysis of the study area

4.5.1 Rainfall pattern

In a more ample manner, the Ethiopia climate seasons could be classified in three seasons. These are given as:

Bega: - which is generally the dry season that covers the period from October to January.

Belg: - refer to a small rain season that covers the period from mid-February to mid-May.

Kiremt:- refer to the main rainy season that cover the period from June to September.

The study area has dual rainfall patterns, Kiremt more rain available with long period as well as belg, which small amount of rain in available. About 65 to 75 Percent of the main annual rainfall occurs in “Kiremt” season over the principal cropping zone. In “Bega” season, the rainfall varies between 10 to 400 mm; this is about 25 to 600 mm in “Belg” season and about 10 to 1200 mm in “Kiremt” season (NMSA, 2013). The average monthly rainfall of the study area present in Table 4.1 and Figure 4.1 detail.

Table 4.1 Monthly average rainfall of Deneba station

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average monthly RF(mm)	18.4	19.6	58.1	58.7	38.4	75.0	305.5	285.5	76.6	12.7	7.5	5.0

Source: - Own analysis

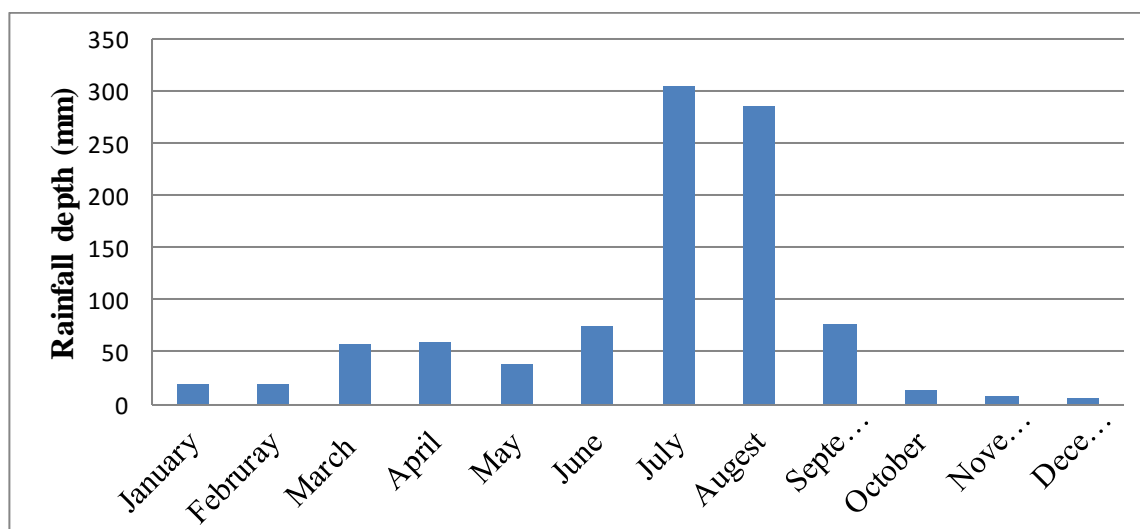


Fig 4.1 Graph of average monthly rainfall of Deneba station

The rainfall analysis was done by taking 24 years daily rainfall data. (see the detail information on Annex 1, (Table 2)).

4.5.2 Effective rainfall (Runoff)

Effective rainfall or Excess rainfall is the part of rainfall that becomes direct runoff at the outlet of the watershed (catchment). The effective rainfall is the part of rainfall that is neither retained on the catchment nor infiltrated in to soil.

During extended warm dry periods rainfall less than 5 mm may not add any moisture to the soil reservoir as most of it is evaporated before entering the soil. Therefore, if rainfall is less than 5mm the Farm west calculator does not enter a value for effective precipitation. In addition, only 75% of the rainfall over 5mm is considered to be effective precipitation. <https://farmwest.com/node/934>

The equation used in the Farm west calculator is: **Effective Precipitation (mm) = (RAIN - 5) x 0.75**

The detail information and results of effective rainfall present in Table 4.2 and Figure 4.2.

Table 4.2 Effective rainfall of the study area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Average monthly RF(mm)	18.4	19.6	58.1	58.7	38.4	75.0	305.5	285.6	76.6	12.7	7.5	5.1	961.2
Effective RF(mm)	10.1	11.9	39.8	40.3	25.1	52.5	225.4	210.4	53.7	5.8	1.6	0.0	675.9

Source:-Own calculation

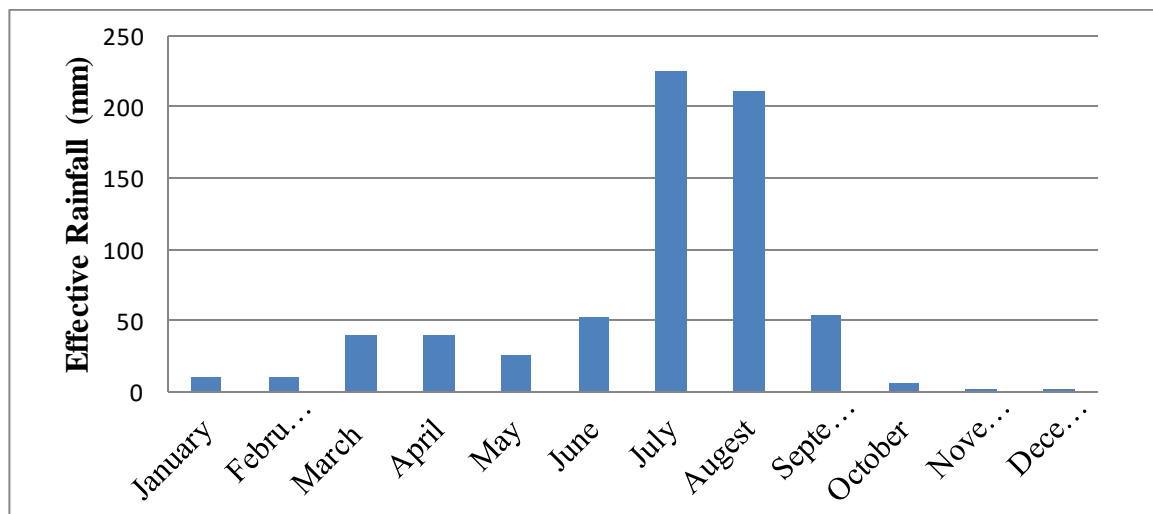


Fig 4.2 Graph of effective rainfall of the study area

Figure 4.1 and Figure 4.2; show that the study area has two rainfall patterns. From June to September the longest and high amount of rainfall, whereas from February to May the shortest and small amount of rainfall occur.

4.5.3 Thiessen polygon method

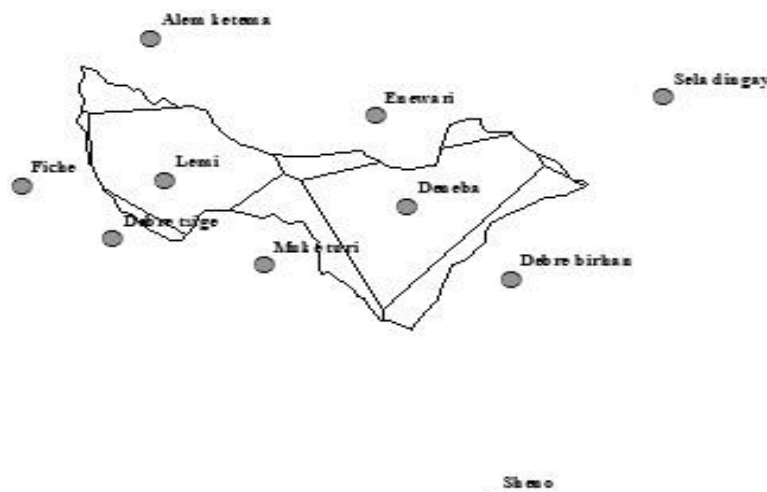
This is the weighted mean method. The rainfall is never uniform over the entire area of the basin or catchment, but varies in intensity and duration from place to place. Thus the rainfall recorded by each rain gauge station should be weighted according to the area, it represents. Thiessen polygon is one of the methods to determine the areal depth of precipitation for the catchment under consideration from several point rainfall data records. This method involves determining the area of influence for each station after locating all available rainfall stations and amount within and surrounding the catchment on a base map. This method is more suitable under the following conditions:

- When rainfall stations are few compared to the size of the basin.
- In moderate rugged areas.

The catchment area is drawn to scale and these 10 stations are pointed on it. These stations are joined so as to get a network of triangles. Perpendicular bisectors are drawn to each of the side of the triangles. These bisectors form a polygon around each station. If the boundary of catchment cuts the bisectors then the boundary is taken as the outer limit of the polygon. The bounding polygon are called Thiessen polygon. Mean, minimum and maximum annual rainfall results from GIS by different methods are presented in the Table 4.3.

Table 4.3 Average annual rainfall results

Methods	Values (mm)		
	Minimum	Mean	Maximum
IDW	745.039	948.816	1245.213
Kriking	747.285	971.768	1239.473
Trend	789.271	938.385	1087.498

**Fig 4.3 Gauge station used for analysis**

Circular black points which show in Figure 4.3 are the locations and names of Gauge stations used for Thiessen polygon analysis (see detail information in Annex 1, Table 1).

4.5.4 Rainfall Intensity

The rainfall intensity (I) is the average rainfall rate in mm/hr for duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for design and a time of concentration calculated for the catchment area, the rainfall intensity can be determined from Rainfall-Intensity-Duration curves. For drainage areas in Ethiopia, you may compute the rainfall intensity at any required time using the 24hr rainfall depth, which is known as a rainfall intensity-duration-frequency (IDF) relationship.

Depend on Ethiopia drainage manual the IDF curve table and graphs in different return periods are shown in Table 4.4 and Figure 4.4.

$$RR_t = \frac{t(b+24)^n}{24(b+t)^n}$$

Where: - RR_t=Rainfall depth ratio R_t: R₂₄

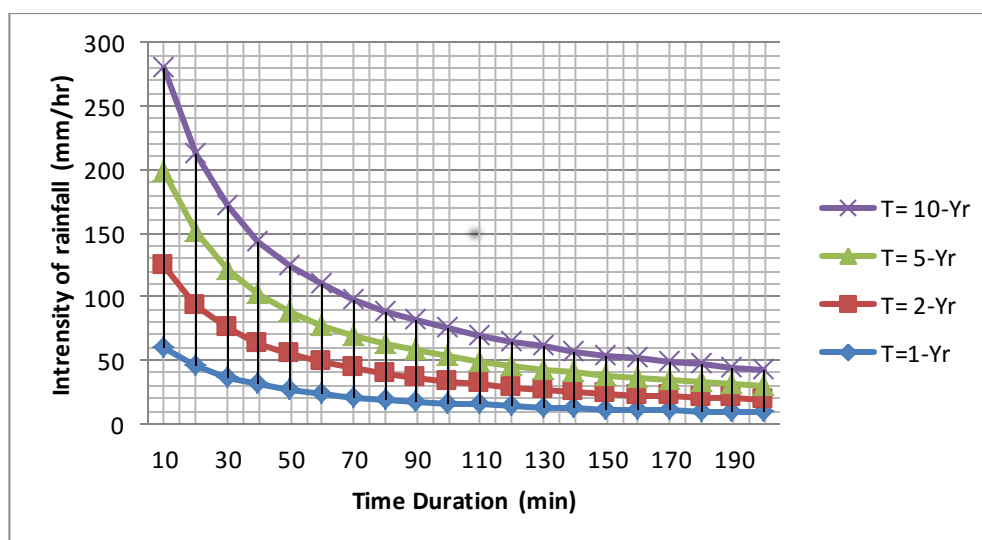
R_t =Rainfall depth in a given duration, 't'

R_{24} =24 hr rainfall depth

'b' and 'n' are coefficients $b=0.3$ and $n=(0.78 - 1.09)$

Table 4.4 IDF curve table

Duration(min)	T=1-Yr	T= 2-Yr	T= 5-Yr	T=10-Yr
10	60.18216	63.60394	75.0964	81.5911
20	45.44145	48.02512	56.70268	61.6066
30	36.65314	38.73713	45.73646	49.69197
40	30.79636	32.54735	38.42826	41.75173
50	26.60388	28.1165	33.19681	36.06783
60	23.4491	24.78234	29.26021	31.79078
70	20.98597	22.17917	26.18668	28.45143
80	19.00751	20.08822	23.71792	25.76916
90	17.38214	18.37044	21.68976	23.56559
100	16.02218	16.93316	19.99277	21.72185
110	14.86688	15.71217	18.55117	20.15557
120	13.87281	14.66158	17.31074	18.80786
130	13.00805	13.74765	16.23169	17.63548
140	12.24866	12.94508	15.2841	16.60595
150	11.57627	12.23446	14.44508	15.69436
160	10.97657	11.60067	13.69677	14.88133
170	10.43826	11.03174	13.02505	14.15152
180	9.952247	10.5181	12.4186	13.49262
190	9.51119	10.05197	11.86824	12.89466
200	9.109051	9.626966	11.36644	12.34947



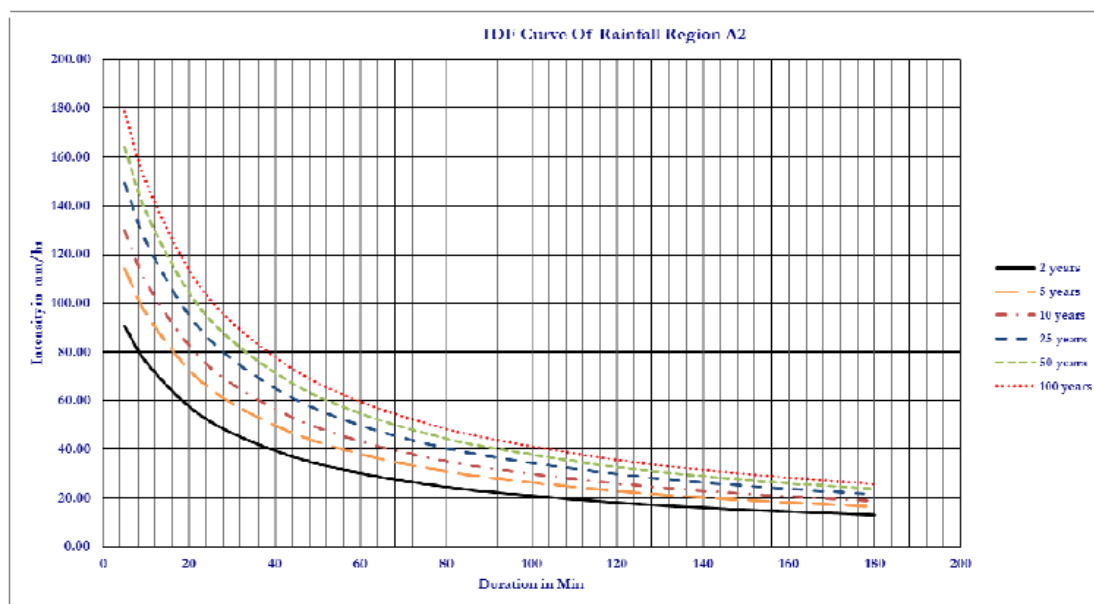


Fig 4.4 IDF curve of the study area vs ERA

4.6 Runoff coefficients

The runoff coefficient is a factor dependent on the collection surface, by which the accumulated rainfall is multiplied to obtain the actual rainfall runoff introduced into the drainage system. Alternatively, the runoff coefficient is the factor by which, depending on the type of surface, the effective impermeable area is calculated. For example, it is 0.9 for metal or tile roofs and up to 0.3 for green roofs. <https://www.graf-water.com/rainwater-harvesting/all-about-rainwater-harvesting/lexicon/be-griff/runoff-coefficient.html>

Runoff coefficients for common catchment surfaces are shown in Table 4.5. The runoff coefficient value used for rainwater harvesting is the minimum values, for identifying the minimum volume (yield) of water collected from the catchment.

Table 4.5 Runoff coefficients (Persyn, 2004).

Runoff coefficients		
Character of surface	High	Low
Roof		
Metal, gravel, asphalt shingle	0.95	0.75
Paving		
Concrete, asphalt	0.95	0.70
Brick	0.85	0.70
Gravel	0.70	0.25
Soil		

Flat (2% slope or less), bare	0.75	0.20
Flat (2% slope or less), with vegetation	0.60	0.10
Lawns, sandy soil		
Flat (2% slope or less)	0.10	0.05
Average (2% to 7% slope)	0.15	0.10
Lawns, heavy soil		
Flat (2% slope or less)	0.17	0.13
Average (2% to 7% slope)	0.22	0.18

Water harvesting potential (m^3) = [Rainfall (mm) x Area of catchment (m^2) x Runoff coefficient]/1,000¹

$$\text{Water harvesting potential (m}^3\text{)} = \{\text{Rainfall (mm)} * \text{Area of catchment (m}^2\text{)} * \text{Runoff coefficient}\} / 1000$$

4.7 Potential for Rainwater

4.7.1 Rooftop Rainwater Harvesting

Rooftop rainwater harvesting system uses the community house roof as catchment area. The houses roof is constructed by corrugated iron sheet with average area of 62m², but this area is only the main house. In addition to the main house other supplementary house are attached with main house for different purpose. The roof catchment distribution of the study area is 93.6%. The available roof and the compound of the community are suitable for applying the roof rainwater harvesting system. The amount of water harvested from the single house roof in different months is listed in Table 4.6.

Table 4.6 Potential of rooftop RWH

Month	Effective rainfall (mm)	RF	Runoff coefficient (C)	Average roof area(m ²)	Amount of water harvested(m ³) V=[C*RF*A]/1000
January	0				0
February	0				0
March	39.83				1.98
April	40.28				2.00
May	25.07				1.24
June	52.47				2.60

¹ “1000 Conversion factor from millimeter to meter.”

July	225.39	0.8	62	11.18
August	210.41			10.44
September	53.71			2.66
October	0			0
November	0			0
December	0			0
Total	647.16			

4.7.2 Courtyard rainwater harvesting

Rainwater is collected from compacted, paved surfaces or where plastic sheet will be laid out on ground surfaces to direct water to an over ground or underground storage structures. The standard of the rural area of a single courtyard is 25m by 40 m. On other hand a single family has an average of 1000m² of the land for their living. From 1000m² area a family can prepare 15% (150m²) to 25% (250m²) of their compound for rainwater harvesting catchment by laying plastic or by other impermeable materials and protect it for such purpose. The amount of water collected from courtyard 150m² and 250m² catchment areas by laying plastic on the rainy season shown in Table 4.7.

Table 4.7 Potential of Courtyard RWH

Month	Effective Rainfall depth(mm)	Runoff coefficient	Amount of water harvested (m ³)	
			15% of the compound(150m ²)	25% of the compound (250m ²)
June	52.47	0.6	4.72	7.87
July	225.39		20.29	33.81
August	210.41		18.94	31.56
September	53.71		4.84	8.06
Total	541.98	Total	48.78	81.3

Source: - own analysis

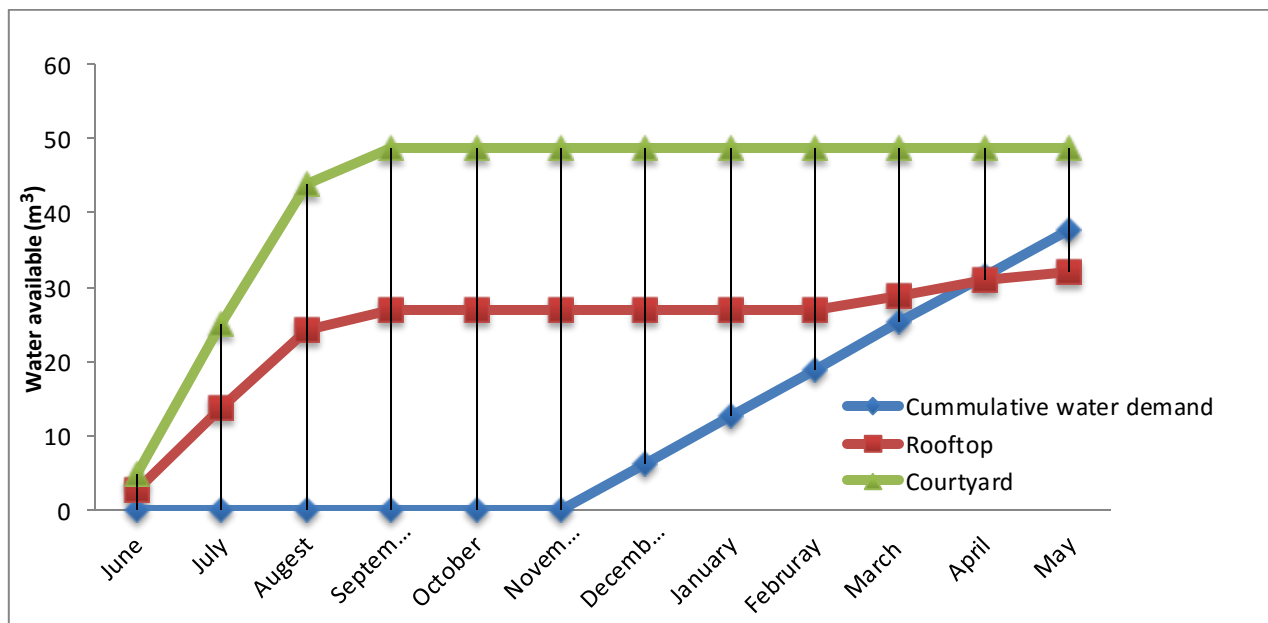


Fig 4.5 Mass curve diagram for rooftop and courtyard

Figure 4.5 indicates that in both case (rooftop and courtyard with area of 150m^2) rainwater harvesting system the reservoir full at September. The beginning time for the rainwater use from the water tank is end of November. For rooftop rainwater harvesting little shortage of water may occur after the month April, implies that harvested water amount cannot cover the all five dry periods (6.3m^3 per month) demand. In rooftop rainwater harvesting certain amount of water can be collected from March to May. Whereas, the amount of water collected from courtyard is enough for the critical dry period of the study. The water collection activities for the courtyard take place during the main rainy season, because the other season rain may have discontinuity. In courtyard rainwater harvesting system the laid plastic doesn't expose for sunshine, it may affect the durability of the plastic. Therefore, during the dry and discontinuity rain season the plastic must be stored in suitable places. It is expected that a courtyard rainwater harvesting plastic sheet will be laid so that it gives some height for the plastic is important in order to protect the system from runoff disturbances.

4.7.3 Micro/Macro Catchment Rainwater harvesting

Macro/Micro rainwater harvesting is a method of harvesting runoff water from a small/large natural catchment. During this type of rainwater harvesting system the area of catchment and pond size is dependable on number of dweller of the specific villages. The rainwater harvesting can take place during only the main rainy season because of the other rain season does not generate runoff. Depend on the study area villages distribution the required catchment area and amount of water harvested calculated detail in Table 4.8.

Table 4.8 Potential of Micro/Macro RWH

Name of sub kebeles	Month	Effective Rainfall depth(mm)	Runoff coefficient	Area (m ²)	Amount of water harvest (m ³)
Zinjero wuha	June	52.47	0.3	16,040	252.4856
	July	225.39			1084.577
	August	210.41			1012.493
	September	53.71			258.4525
Total					2608
Kubeti	June	52.47	0.3	14,896	234.4779
	July	225.39			1007.223
	August	210.41			940.2802
	September	53.71			240.0192
Total					2422
Gotet dega	June	52.47	0.3	26,353	414.8226
	July	225.39			1781.911
	August	210.41			1663.48
	September	53.71			424.6259
Total					4284.84
Kebet amba	June	52.47	0.3	15,129	238.1456
	July	225.39			1022.978
	August	210.41			954.9879
	September	53.71			243.7736
Total					2459.885

4.8 Summary of RWH systems potentials

Table 4.9 Summary of RWH potentials

System of RWH	Rainfall (mm)			Runoff coefficient		
	Minimum	Average	Effective	Roof top	Courtyard laid by plastic	Natural land
	745	948	707	0.75	0.6	0.3
	Amount of water to be collected (m ³)			Area (m ²)		
Rooftop	34.6425	44.082	32.8755	62		
Courtyard						
15% of Compound	67.05	85.32	63.63	150		
25% of compound	111.75	142.2	106.05	250		
Macro/Micro	16,185.42	20,595.68	15,359.86	72,418		

Sources: - own analysis

The amount of water collected from the minimum rainfall by different system shown in Table 4.9 can fulfill the additional water required for the critical dry seasons (five months) of the study area. The amount of water collected from rooftop (33m³), Courtyard with area 150m² (63m³), Micro/Macro (15,360m³) is enough for fulfill the additional water for the critical dry period of the study area with the demand of 6.3m³ per month.

For the applicable of the rainwater harvesting technology the following issues must be consider. The technology must use minimum available resources for generate enough amount of water for the dry season. Therefore, the rainwater harvesting system apply in that specific study area is the major two system (Rooftop and Courtyard), because of the catchment area used for rainwater harvesting system already available and take small land resources for the collection of enough water for the critical dry season. They are easy for operation, maintenance and control. The combined rainwater harvesting also can applicable (rooftop and courtyard). If the available rooftop area does not enough for collecting the required amount of water, the community can add additional area by plastic.

Whereas Micro/Macro catchment rainwater harvesting system needs large amount of communal lands around 7.2 hectares. It may also have influence on the agriculture products. Select low productive lands for the micro/macro catchment are advisable in order to minimize the effect of catchment on agriculture products. The main challenge of the micro/macro rainwater harvesting system is the availability for catchment and protection of this catchment from animal and human contamination.

4.9 SamSamWater - Rainwater Harvesting Tool (results)

The rainwater harvesting potential of the study area is also analyzed using samsamwater rainwater harvesting model (tool) in which a model needs location map from Google earth, roof area, type of roof material and per capita water demand as an input and delivers the RWH potential for the study area. The model uses a runoff coefficient of 0.9 for the metal/corrugated iron sheet, 0.7 for the flat roof and 0.2 for thatched roof.

4.9.1 Rooftop catchment

Details on the results and calculations can be seen in the Table and figure which shown below.

Table 4.10 Location, roof type and roof size of the study area

Location	Amhara, Ethiopia	Roof size:	62 square meters
Latitude	9.80562 degrees	Roof type:	metal/iron sheet
Longitude	39.16240 degrees	Runoff coefficient:	0.9
Water demand	210 liters per day		

Source: - Samsanwater-rainwater harvesting tool

Table 4.10 shows the detail location of the study area, water demand, roof type and size and runoff coefficient which samsamwater–rainwater harvesting tool uses for that specific roof type.

The location of the study area for all rainwater harvesting system which include in this thesis is similar, the only difference of water demand, roof size and roof type. Table 4.10 can use for all rainwater harvesting system. For rooftop and courtyard rainwater harvesting system the water demand calculated as per compound (210 liters per day per compound) by assumption of private pond construction. Whereas, for micro/macro rainwater harvesting system the water demand analysis done by considering the demands of the whole study area compounds (66,360litres per day).

Rainfall

The average rainfall at this location varies between 12 mm in the driest month (December) and 280.6 mm in the wettest month (August). The total annual rainfall in an average year is 1187 mm. As mention earlier the study area is the same, implies that rainfall used for all rainwater harvesting system is similar. In other word, rainfall which indicates in Figure 4.6 used for rooftop, courtyard and micro/macro catchment rainwater harvesting systems.

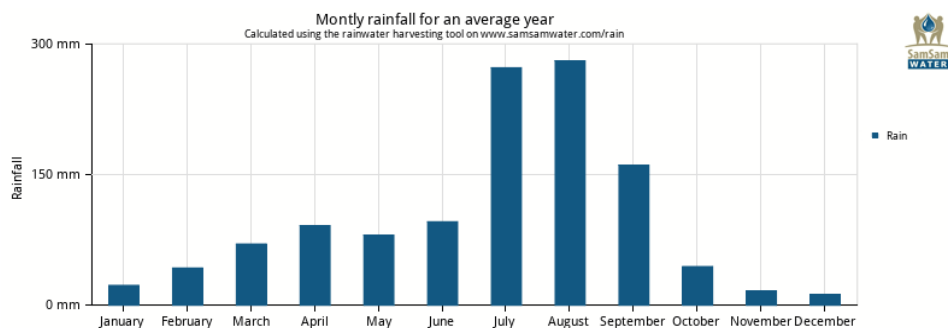


Fig 4.6 Monthly rainfalls for an average year

Water availability

A metal roof has a runoff coefficient of 0.9, which means that 90% of the rain can be harvested. Based on this runoff coefficient and a roof area of 62 square meters a volume of 670 liters ($12 \text{ mm} \times 62 \text{ m}^2 \times 0.9$) of water can be collected in the driest month (December) and 15,657 liters ($280.6 \text{ mm} \times 62 \text{ m}^2 \times 0.9$) in the wettest month (August). The total yearly amount of water that can be collected from the roof is 66,200 liters (66m^3) in an average year.

Water demand

The water demand is 210 liters per day, which equals to about 6,300 liters per month. The total water demand is 76,700 liters (76.65 m³) per year. The amount of water that can be collected from the roof (66m³) is less than the water demand (76.65 m³). Only a part of the water demand can be fulfilled using a rainwater harvesting system. Figure 4.7 express the excess amount of rainfall is available during the months of July, August and September. The remaining month rainfall does not enough for their demand.

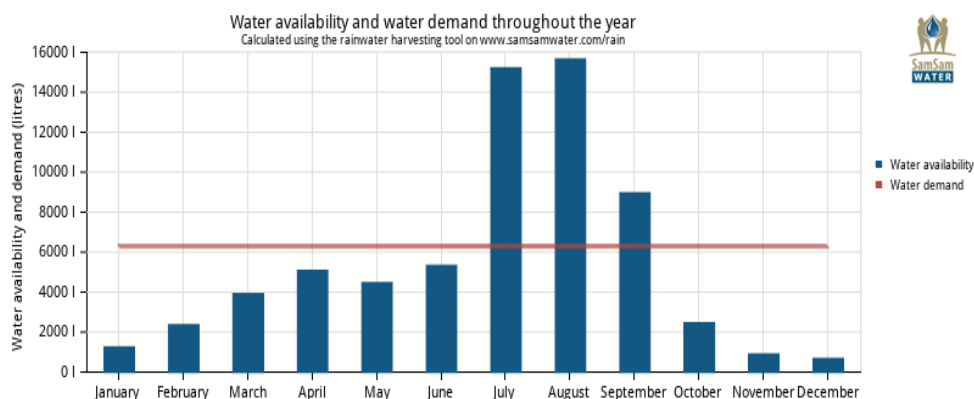


Fig 4.7 Water availability and water demand throughout the year for rooftop

Required storage

The total amount of water that can be collected from this roof, 66,200 liters, is not enough to fulfill the total yearly water demand of 76,700 liters. However, it might still be worthwhile to construct a rainwater harvesting system. With a storage reservoir of 23,100 liters (23.1 m³) a rainwater harvesting system could provide 181 liters of water per day, which is 86% of the total demand. As shown in Figure 4.8, the storage reservoir will be full in September and then slowly drain until it is (almost) empty at the end of June.

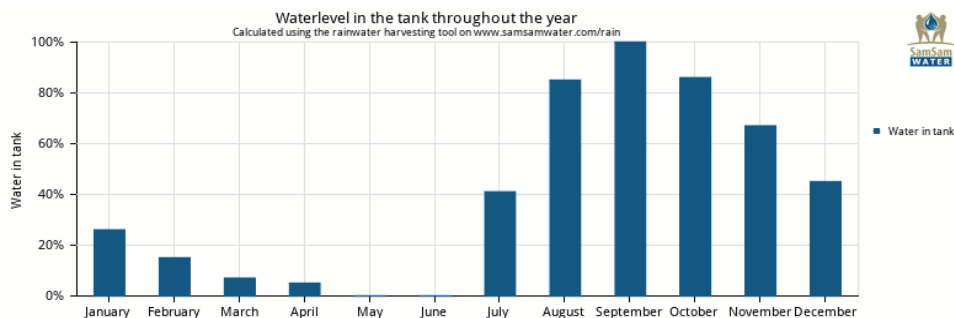


Fig 4.8 Water level in the tank throughout the year for rooftop

Dry and wet years

This calculation is based on the average monthly rainfall. The actual rainfall differs from month to month and year to year. The amount of available water and filling of the tank might therefore be different and change from year to year. When constructing a rainwater harvesting system it is important to take this into account.

Situation in a dry year: during a dry year, there is less rain to fill the system. The system can provide a smaller amount of water compared to an average year. All rain is stored, so constructing a larger reservoir won't help.

Situation in a wet year: during a wet year there is more water available and constructing a larger tank will increase the water availability in this situation.

4.9.2 Courtyard catchment

Details on the results and calculations can be found below.

Water availability

A flat roof (courtyard) has a runoff coefficient of 0.7, which means that 70% of the rain can be harvested. Based on this runoff coefficient and a courtyard area of 150 square meters a volume of 1,260 liters ($12 \text{ mm} \times 150 \text{ m}^2 \times 0.7$) of water can be collected in the driest month (December) and 29,463 liters ($280.6 \text{ mm} \times 150 \text{ m}^2 \times 0.7$) in the wettest month (August). The total yearly amount of water that can be collected from the courtyard is 124,600 liters (125 m^3) in an average year.

Water demand

The water demand is 210 liters per day, which equals to about 6,300 liters per month. The total water demand is 76,700 liters (76.65 m^3) per year. During 7 months of the year (March, April, May, June, July, August and September) the amount of water that can be collected from the courtyard laid by plastic is larger than the water demand. This excess water can be stored to be used in the months where the water availability is smaller than the demand. Figure 4.9 indicates one great issue; the collection possibility of excess (large) amount of water in the study area is high. From courtyard rainwater harvesting system with area of 150 m^2 is excess than the yearly water demand of the study area. This indicates that there is high potential of rainwater in the study area.

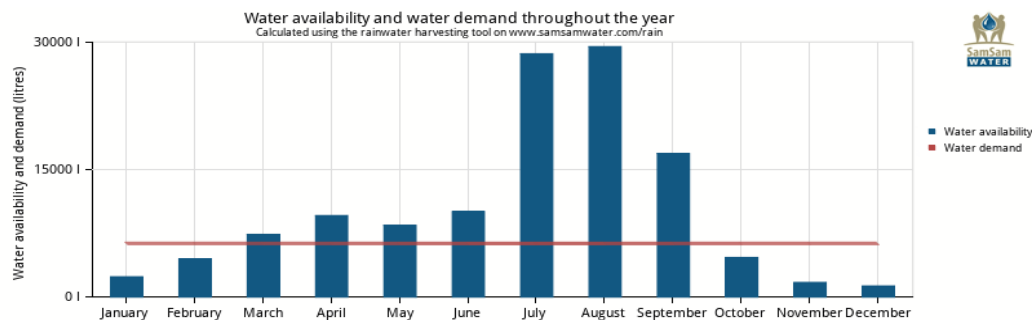


Fig 4.9 Water availability and water demand throughout the year for courtyard

Required storage

A storage reservoir (tank) can be constructed to collect and store the water during the wet months so this water can be used during the dry months. For this location, roof size and water demand the optimum size of a storage reservoir (tank) is 17,400 liters (17.4 m³). The storage reservoir will be full in July, August and September and then slowly drain until it is (almost) empty at the end of February as shown in Figure 4.10.

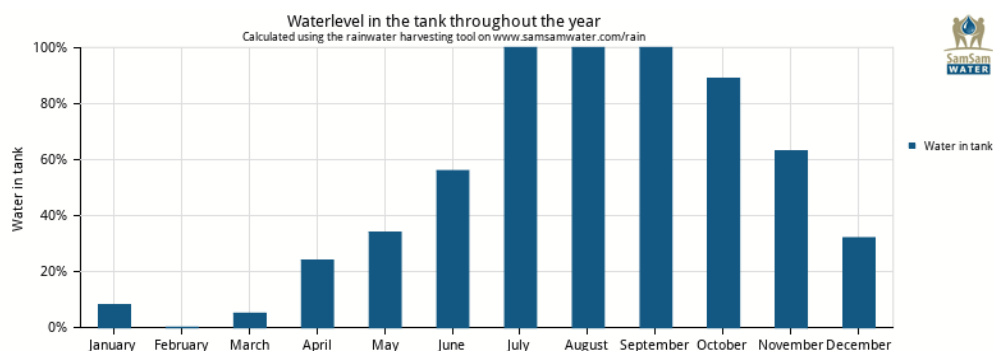


Fig 4.10 Water level in the tank throughout the year for courtyard

Situation in a dry year: to have enough water in a dry year it is necessary to construct a larger tank for the rainwater harvesting system. A rainwater harvesting system with a reservoir of 37,900 liters (37.9 m³) should provide enough water all year round in this situation. It should be decided whether or not the rainwater harvesting system should be sized to this situation or not.

4.9.3 Micro/Macro catchment (natural land)

Details on the results and calculations can be found below.

A thatched roof (natural land) has a runoff coefficient of 0.2, which means that 20% of the rain can be harvested. Based on this runoff coefficient and a roof area of 72,418 square meters a volume of 173,803 liters (12 mm x 72,418 m² x 0.2) of water can be collected in the driest

month (December) and 4,064,098 liters (280.6 mm x 72,418 m² x 0.2) in the wettest month (August). The total yearly amount of water that can be collected from the natural land is 17,190,600 liters (17,191m³) in an average year.

Water demand

The water demand is 66,360 liters per day, which equals to about 1,990,800 liters per month. The total water demand is 24,221,400 liters (24,221.4 m³) per year. The amount of water that can be collected from the roof (17,191m³) is less than the water demand (24,221.4 m³). Only a part of the water demand can be fulfilled using a rainwater harvesting system. The excess rainfall occurs in the months of July, August and September as shown in Figure 4.11.

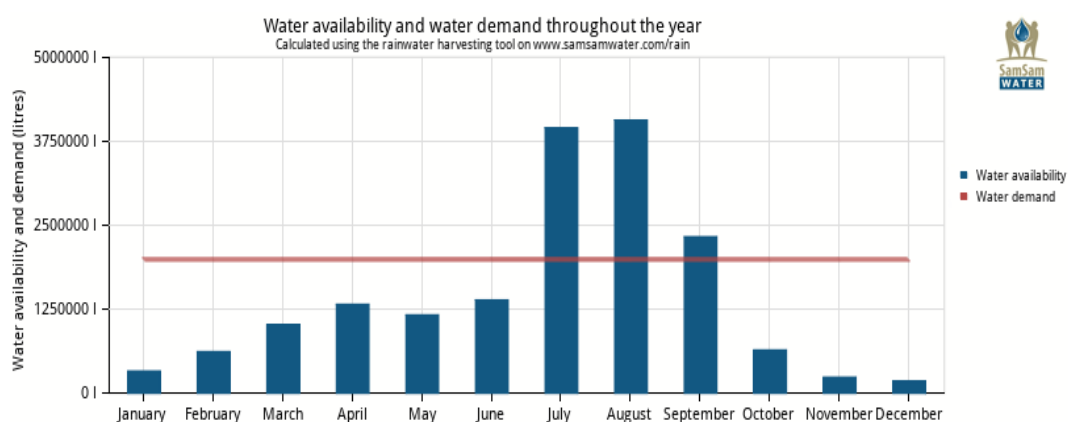


Fig 4.11 Water availability and water demand throughout the year for micro/macro

Required storage

The total amount of water that can be collected from this roof, 17,190,600 liters, is not enough to fulfill the total yearly water demand of 24,221,400 liters. However, it might still be worthwhile to construct a rainwater harvesting system. With a storage reservoir of 6,005,400 liters (6,005.4 m³) a rainwater harvesting system could provide 47,097 liters of water per day, which is 71% of the total demand. The storage reservoir will be full in September and then slowly drain until it is (almost) empty at the end of June as shown in Figure 4.12.

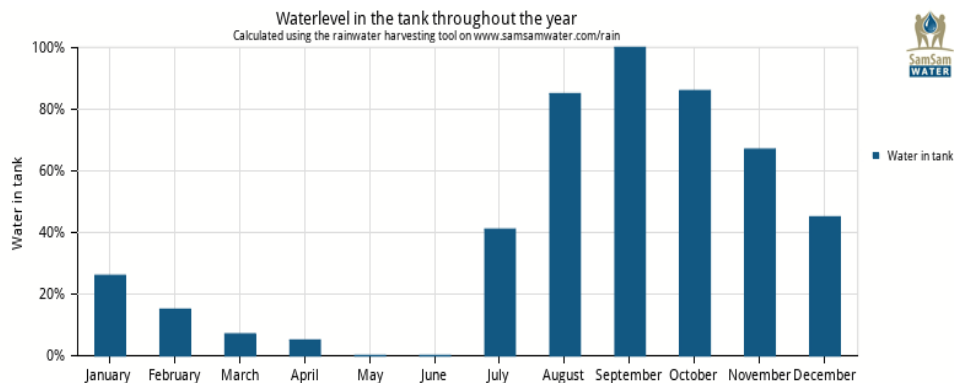


Fig 4.12 Water level in the tank throughout the year for micro/macro

Situation in a wet year: during a wet year there is more water available and constructing a larger tank will increase the water availability in this situation. With a storage reservoir of 6,930,100 liters (6,930.1 m³) a rainwater harvesting system could provide 95% of the total demand.

4.10 Summary of SamSamWater - Rainwater Harvesting Tool (results)

All results of samsamwater-rainwater harvesting tools shows the total amount of water that can be collected from all rainwater harvesting system (included in this paper) is not enough to fulfill the total water demand of a year. However, it is worthwhile to construct a rainwater harvesting system. The aim of this research also not yearly water demand, it finds the additional water required for the critical dry period of the study area (five months) as supplementary water sources.

Amount of water collected from rooftop (66m³), Courtyard with area 150m² (125m³), Micro/Macro (17,191m³) is more than enough for fulfill the additional water for the critical dry period of the study area. Therefore, the communities adapt rainwater harvesting technologies in different ways (communal and individual) to minimize the problems of water shortages.

Average time loss by collection of water is 2.5 hour per day. This implies that the communities loss 450 hours in six months for collecting the water only. Assume that there are 10 working days in each month 150 pure working time lost during six months. Labor costs of the study area vary from 100birr up to 250birr per 8 hours duration. The minimum amount of money that the community loss by collecting water is $150 \times 100 / 8 = 1,875$ birr. When apply the rainwater harvesting technologies in this specific area save large amount of time, money and health of the communities. Another crucial issues addressed by the researcher number of terminated student is high during the critical dry seasons. The school leader put that the water shortage will be the main cause. Because the students go long distances for drinking animals then they tired and some of the students sleep in class.

Most study area farmer collects their agricultural products by together in the communal places during meher season and they keep turn for separation of output. The fire accident is occurring in this place with in time the damage of the all agricultural product is high. Before five years ago the fire accident is occurs in the study area, at that time the community try to control the fire by soil rather than water. The reason behind this is there is no water available in that area. Rainwater harvesting is also importance for the fire protection.

The other point consider in rainwater harvesting system is water loss controls. First task for control of water losses is identifying the points which water loss will be occur. In rainwater harvesting system the water losses may occur in collection time as well as after collection which is storage (seepage) losses. The water loss during the collection time is difficult for control, so use the minimum rainfall depth for calculate the amount of water collected from that specific area. Water seepage loss comes from poor construction of the water tank. Therefore, the water storage tank must construct as water tight, good quality of the materials and structure. The evaporation loss can control by cover.

Water demand is increase with the growth of population, the growth of population also increase the urbanization activities of the area. Urbanization growth decreases the natural pervious lands. Runoff generation of the impervious layer is high. Therefore, rainwater harvesting used as the base of the storm water management as well as independency of domestic water supply system for that specific study area.

Overall information or data collected from the study area (by interview and FGD) during the data collection periods indicates that 60% of the community washes his cloths for the big holidays and for specific programs. Especially the cloths which used for working does not wash before the work is completed. Any person takes shower after disease for protection of the re-existences of that disease or to minimize explosion for other disease. But, if there is enough water the person can protect that disease before coming and minimize the cost of medical. Therefore, rainwater harvesting has a significance role for the protection of disease related to hygiene.

4.11 Pond (storage) size

The volume of pond/storage/determined using different methods, for this research uses the methods which describe in the literature part.

Method 1: Demand side approach (dry season demand versus supply)

The critical dry periods of study area are **five** months starting from January to May. The small amount of rainfall may occur through February to April. The occurrence of the rainfall in this period is discontinuously. During these small rainfall period the roof rainwater harvesting is strongly advisable.

$$\text{Demand} = \text{Water Use} \times \text{Household Members} \times 365 \text{ days}$$

This equation provides the water demand in liters per year

$$\text{Required storage capacity} = \text{demand} \times \text{dry period}$$

The critical period = 5 month = $5 \times 30 = 150$ days

- 1) By considering required additional water only = 210l/day

The water storage tank/pond/ must contain **31,500liter = 32m³** of water without loss.

- 2) By considering total water required = 350l/day

The total amount of water must be store **52,500litre = 53m³** store in water storage without loss.

- 3) By considering water required for livestock = 180l/day

The amount of water must be store in the storage tank is **27,000litre = 27m³** of water must be store without loss.

The rainwater harvesting system will be applying as individual (family) size as well as community size. The amount of water described in pond (storage) size must be kept without loss. During the construction of pond addition of loss or construct best structure for protection of water loss must give big attention. The storage system of the water is classified as communal or private depend on the end user of the water.

- ❖ **Communal (Public) pond**:-this type of ponds use for many people by common. It needs the all people participation and large amount of land.
- ❖ **Private pond**: - this type of ponds is constructed in each compound and the family live in that compound uses the store water.

The study area village's arrangements are scattered, so the selection of appropriate water tank (pond) capacity depend on the distribution of the community is the main task for micro/macro rainwater harvesting system. Private pond is easy for operation, but the cost will be high.

4.12 Cost estimation

The cost of rainwater ponds is dependable on the types of materials used for construction and types of ponds or storages that used to store water. From the total installation cost of rainwater harvesting 2/3 cost is taken by the storage tank construction. For underground water storage tank the excavation cost is large, the volume of soil and the capacity of the pond is equivalent.

The choice of tank will depend on the range and price of locally available commercial options and on the cost and availability of building materials. A tank is referred to as an above-ground storage reservoir and a cistern as a below-ground storage reservoir.

According to (Hune, 2002), Underground tanks with low-cost linings have great potential for storing rainwater from roofs and ground surfaces and can be constructed with a limited amount of skilled labor. Underground tanks are cheaper than above-ground tanks because the soil profile provides structural support. The hemispherical shape allows uniform distribution of water pressure and facilitates lining.

Underground tanks should be located where there is no risk of root penetration and far enough from pit latrines and rubbish pits to avoid contamination. The soil should be stable and not prone to shrinking or swelling. The area surrounding the tank should be provided with a hard surface to reduce water infiltration and minimize the risk of tank collapse due to high pore water pressures.

The size of the tank to be installed depends on many factors, particularly the roof size for collection, the rainfall amount and distribution, the length of the dry season, the household demand and the availability and distance of alternative supplies.

The excavation for a tank should be done carefully so that the surface is uniform, and it should be smoothed before applying the lining. An effective lining can be made with cement and soil, but the texture of the soil is very important and the mixture should not be weaker than 1:7. It should be well mixed and applied carefully. Sand-cement mortar can also be used for lining but is expensive as the ratio of cement to sand is 1:3. After applying the lining, the surface should be sealed with cement water slurry (nil) and should be well cured by keeping it wet for 3-4 weeks.

Polythene linings can be used with rectangular tanks, but heavy device polythene is needed to minimize the risk of holes and leakage. Careful sealing of joints with cement is necessary to avoid seepage, and shading to keep out sunlight.

Roofing of tanks is important to keep out dirt, insects, etc., and to reduce losses by evaporation. Polythene is not suitable as it is destroyed by sunlight and wind. A cement-sand (1:3) mortar spread on hessian cloth nailed to a timber framework is effective. If the outer edge is built up with a concrete rim, it is possible to collect rainwater from the roof and divert it into the tank. Hemispherical roofs made from burned bricks are strong and long lasting, but a skilled mason is needed for construction.

Design criteria

The following points must be taken into consideration when designing a storage tank:

Seepage

The structural failures are connected with poor design, water loss due to evaporation and seepage, low technical capacity and subsequently low adoption by user. Another report indicated that there was only 22% functional water harvesting structures out of the constructed ones between the periods 2003-2004 in Amhara regional state. The most critical of all the problems is the water loss due to seepage resulting from poor lining materials of the harvesting storage structures (Fitsume Yemenu, 2014).

In order to minimize the loss of water due to seepage, different designs and the use of impervious materials must be considered. The cheapest possible way of reducing seepage in ponds is by puddle the soil. The use of such materials as cement, gypsum and plastic lining can also reduce seepage, though the cost and availability of such materials are major constraints.

Evaporation

If water is exposed to direct sunshine and wind, a large proportion of it can be lost by evaporation. These losses can be minimized by providing the storage tank with an appropriate cover.

Length of the dry season

Since the purpose of the tank is to store water for use during the dry months, the longest expected dry season in the various climatic zones will determine the size of the required storage tank. A smaller tank will suffice in areas with a prolonged rainy season and short dry season.

Daily consumption

The size of the storage tank to be built will also be dependent on anticipated use, the number of users and the estimated daily consumption. The provision of water close to the house is also likely to increase the level of consumption.

Construction costs

Experience shows that several designs could be suitable for a given area. The utilization of locally available construction materials will minimize costs and could in turn help the spread of the technology. However, care must be taken because what is cheap may not necessarily be durable.

Underground water tanks were preferred, because it was assumed that the ground itself would provide support, it would eliminate the need for reinforcing and it would reduce the cost of materials used. Secondly, the method of construction would be user-friendly and could be managed by the users with their own skills and knowledge. Lastly, an underground water tank would offer the possibility of collecting water from ground surfaces where houses do not have iron roofs.

Tank linings

An endeavor was made to find an alternative method of lining the excavated tank to prevent seepage.

Tank roofing

To reduce the loss of water by evaporation and also to minimize the risk of pollution, roof of tanks will provided with a roof using a variety of materials.

Table 4.11 Construction cost of 1 m³ underground tank with lining of sand-cement

Cost estimation for m ³ volume of pond					
S.No	Item work	Unit	Quantity	Unit cost (birr)	Total cost (birr)
1	Materials				
	Cement	qnt (bag)	3	180	540
	Sand	m ³	1	300	300
	Aggregate	m ³	1	250	250
	Stone	m ³	0.5	300	150
2	Labor				
	Excavation	m ²	1.2	Community	
	Skilled	day	2	200	400
	Unskilled	day		Community	
3	Cover				
	Mortar	m ³	1	400	400
Total cost					2040

CHAPTER FIVE

CONCLUSION and RECOMMENDATION

5.1 Conclusion

The main objective of this study is identifying the importance of rainwater harvesting as alternative water supply sources for decentralized water supply scheme in Siyadebirna Wayu Woreda. Among identified kebeles which has critical water shortages Gotet dega sub kebeles which found in Ejersa kubeti kebele is known by special up to regional state. Also lot of people loss their life. The water supply coverage of the specific selected sub-kebeles is 43%. The woreda try to solve this problem by construction (drilling) of deep groundwater wells. The geographical arrangements of the selected sub-kebeles were difficult for the construction of the groundwater well. Most constructed groundwater wells available on these specific sub-kebeles are non-functional. There is also has financial shortage for delivery of water from the high potential water sources. Therefore, the woreda can minimize the available water shortage by applying the small and modern rainwater harvesting system.

The communities of the study area try to dig traditional hand dug well in their compound, now a day such wells are abandoned due basically of lack of accessing water at the depth they can capable of digging. There are two more major alternative water sources available in the study area, which are spring and rainwater. The location of spring water sources is difficult to transport and deliver the water for the communities which locate in highland area. Besides, the communities which live in lowland area uses spring water for small irrigation for generation of livelihood. Therefore, use of these spring water as alternative water source for highland will face water use challenges. The challenges are economic for transport water, cause of conflict and cause of reduction in small irrigation activities. Among available two alternative water sources rainwater is best and sustainable water source for the study area. Rainwater harvesting (RWH) in study areas is a strategy that brings many benefits and may serve to handle with current water shortages.

The study area has dual rainfall pattern throughout the year. These are the longest and large amount of rainfall available in summer season (from June to September) and small amount of rainfall is available during Belg season (February to April). Rainwater harvesting has excessive potential in Siyadebirna wayu woreda in these summer season months. The rainwater potential for the Belg season affected by longest dry period, (October to beginning of February). Therefore, in most the time rainwater harvesting activities for the study area must take place during summer season. The minimum rainwater potential to be collected from different rainwater harvesting systems are 33m^3 from rooftop, 63m^3 from courtyard with area

of 150m^2 and $15,360\text{m}^3$ from micro/macro (natural land) catchments. Except rooftop rainwater harvesting system the amount of water that can be collected from the main rainy season (summer) of the study area is found to suffice the five consecutive months after the end of summer with demand of 6.3 m^3 .

Both rooftop and courtyard rainwater harvesting technologies can be applicable in individual (households) level and the collected water quality is high. Micro/macro catchment rainwater harvesting system can be applied at community level. However, the quality of water from such community ponds will be affected by agricultural activities like fertilizers and pesticides. This warrants special management of the catchment as well as the water usage.

The community in the study area have been adopting rainwater harvesting during the summer season the main of which is roof water harvesting. This also plays a great role for applying the rainwater harvesting technologies. In other hand, the willingness to accept the technologies is abundant. The society encourages for construction of rainwater harvesting system is high.

Rainwater harvesting in Siyadebirna wayu woreda, has larger success with respect to environmental and social impact besides its economically sustainability. Rainwater harvesting importance in the woreda shall not be recognized from the site being arid and semi-arid, but also it shall be recognized that the woreda topography is so rugged that other water accessing possibilities are difficult to implement sustainably.

The amount of harvested water from rainwater harvesting system may not fulfill the yearly water demand of the community. Water collected from the rain used as bridge until the next rain season comes. Intermittent and partial managements of rainwater uses are advisable, otherwise limits the demand of water for that specific area. Or installation of large catchment area with high runoff coefficient is importance to satisfy the yearly water demand of the community.

There is a great need to harvest rainwater from roofs for domestic use in order to reduce the burden, mainly borne by women and girls, while fetching water from distant and rugged places. There is also a growing potential for harvesting rainwater in view of increasing number of corrugated iron roofs by the community.

Generally, rainwater harvesting has importance with respect to productive time and labor utilization; economical water stress, paramount health benefit besides the basic workload reduction on the female society of the community.

5.2 Recommendations

Based on the major findings, the following recommendations have been forwarded:-

Field observation and discussion made with the user community indicate that the willingness to accept and willingness to pay is high, “whatever we pay” they said and also some of the community has potential of economic for construction of the rainwater harvesting system individually. Therefore, the organizations and groups which concern work with together to facilitate this technology.

The woreda create awareness about the potential of rainwater and give short training for the community. The woreda install rainwater harvesting schemes in selected area for facilitate the community.

The communities which have not corrugated iron sheet apply rainwater harvesting by courtyard system. The availability of corrugated iron sheet may suitable for domestic water collection, but it does not mandatory for application of rainwater harvesting technology.

The woreda agriculture bureau and water bureau must be practiced the modern rainwater harvesting system rather than traditional.

References

- Adrienne LaBranche, H.-O. W. (2007). *Virginia rainwater harvesting manual*.
- Alem, G. (1999). Rainwater Harvesting in Ethiopia: An overview. Addis Ababa.
- Awawdeh M., A.-S. S.-Q. (2012). Rainwater harvesting assessment for a small size urban area in Jordan. *International Journal of Water Resources and Environmental Engineering*.
- Cain, N. L. (2014). A Different Path: The Global Water Crisis and Rainwater Harvesting. *The Journal of Sustainable Development*.
- Caleb Christian Amos, A. R. (2016). Economic Analysis and Feasibility of Rainwater Harvesting Systems in Urban and Peri-Urban Environments: A Review of the Global Situation with a Special Focus on Australia and Kenya. *Journal of water*.
- Che-Ani A, S. N. (2009). Rainwater Harvesting as an Alternative Water Supply in the Future. *European Journal of Scientific Research*.
- Dr. Hofman, D. M. (2014). *Rainwater harvesting, a sustainable solution for urban climate adaptation?* Netherlands.
- Dr.G.Ravikumar. (2013). Rainwater Harvesting (RWH) - A Review. *International journal of innovative research and development*.
- Environmental, A. (2010). *Harvesting rainwater for domestic uses: an information guide*.
- F. M. Schets, R. I. (2010). Rainwater harvesting: quality assessment and utilization in The Netherlands. *Journal of Water and Health*.
- Fitsume Yemenu, T. H. (2014). Review of Water Harvesting Technologies for Food Security in Ethiopia: Challenges and Opportunities for the Research System. *Journal of Natural Sciences Research*.
- Garrison, N. (2011). *Capturing Rainwater from Rooftops: An Efficient Water Resource Management Strategy that Increases Supply and Reduces Pollution*.

- Gnadlinger, J. (2003). *Rainwater Catchment and Sustainable Development in the Brazilian Semi-Arid Tropics (BSATs) - An Integrated Approach*. Mexico City.
- Hoffmann, B. L. (2015). *Sustainable Urban Drainage Systems: Using rainwater as a resource to create resilient and liveable cities*. State of green.
- Hune, P. M. (2002). *Low-cost methods of rainwater storage, Results from field trials in Ethiopia and Kenya*. Nairobi, Kenya: Regional Land Management Unit, RELMA.
- Isaac Idowu Balogun, A. O. (2016). Assessment of rainfall variability, rainwater harvesting potential and storage requirements in Odeda Local Government Area of Ogun State in South-western Nigeria. *Cogent Environmental Science*.
- J. Lange, S. H. (2012). Potentials and limits of urban rainwater harvesting in the Middle East. *Hydrol. Earth Syst. Sci*.
- Janette Worm, T. v. (2006). *Rainwater harvesting for domestic use*. The Netherlands.
- Katambara, Z. (2013). Quantifying Rooftop Rainwater Harvest Potential: Case of Mbeya University of Science and Technology in Mbeya Tanzania. *scientific Research*.
- Khoury-Nolde, N. (2007). *Rainwater Harvesting*.
- Klaus W, U. (2009). Rainwater harvesting for water security in rural and Urban ares. In K. s. Jessica Calfoforo Salas, *Rainwater harvesting: a lifeline for human well-being*.
- Koenders, B. (2007). *Smart Water Harvesting Solutions*. Netherland.
- Kulkarni, S. J. (2016). Review on Studies, Research and Surveys on Rainwater Harvesting. *International Journal of Research and Review*.
- Lorena Liuzzo, V. N. (2016). Reliability Analysis of a Rainfall Harvesting System in Southern Italy. *water*.
- Mandal, B. K. (2014). Construction and Evaluation of Rainwater Harvesting System for Domestic Use in a Remote and Rural Area of Khulna, Bangladesh.

- Martinson, T. T. (2007). *Roofwater Harvesting A Handbook for Practitioners*. Netherlands.
- Milton Austin, H. D. (1996). *Ohio Pond Management Handbook*.
- Mul, J. S. (2009). Sustainability of Rainwater Harvesting Systems in Rural Catchment of Sub-Saharan Africa. *Springer Science + Business Media*.
- N. Nagaraja, U. P. (2011). Cost Effectiveness of Rainwater Harvesting for Groundwater Recharge in Micro-Watersheds of Kolar District of India: The Case Study of Thotli Micro-Watershed. *Agricultural Economics Research Review*.
- Ramon Farreny, T. M.-P. (2011). Roof selection for rainwater harvesting: Quantity and quality assessments in Spain. *ELSEVIER*.
- S. Ward, F. A. (11th International Conference on Urban Drainage, Edinburgh, Scotland, UK, 2008). Rainwater harvesting: model-based design evaluation.
- Sadia Rahman, M. T. (2014). Sustainability of Rainwater Harvesting System in terms of Water Quality. *Scientific World Journal*.
- Thamer Ahmad Mohammad, A. H. (2010). Modeling and reliability of rainwater harvesting system at educational institution.
- Thamer Ahmed Mohammed, M. J. (2013). Study on potential uses of rainwater harvesting in urban areas.
- Tseko Malambo, Q. H. (2016). Rooftop Rainwater Harvesting as an Alternative Domestic Water Resource in Zambia. *Journal of Geoscience and Environment Protection*.
- Tulinave Burton Mwamila, Z. K. (2016). Strategies for Household Water Supply Improvement with Rainwater Harvesting. *Journal of Geoscience and Environment Protection*.
- Tulu, T. (2014). *Rainwater Harvesting Practices in Ethiopia*.
- Wubetu, A. (2016). The Role of Rain Water Harvesting for Food security in Ethiopia (A Review). *Journal of Biology, Agriculture and Healthcare*.

Yemenu, F. (2014). Review of Water Harvesting Technologies for Food Security in Ethiopia: Challenges and Opportunities for the Research System. *Journal of Natural Sciences Research*.

Yie-Ru Chiu, Y.L.(2015). Designing Rainwater Harvesting Systems Cost-Effectively in a Urban Water-Energy Saving Scheme by Using a GIS-Simulation Based Design System. *journal/water*.

Zinash Sileshi, A. T. (2004). *Water resources for livestock in Ethiopia: Implications for research and development*. Addis Ababa.

<https://www.renewableenergyhub.co.uk>. Accessed 10 December 2018.

<https://www.dadychery.org//rainwater-harvesting-reasonable-for-haiti> Accessed 25 December 2018.

<https://www.renewableenergyhub.co.uk/main/rainwater-harvesting-information/history-of-rainwater-harvesting>. Accessed 15 January 2019.

https://crudata.uea.ac.uk/~timm/grid/CRU_CL_2_0.html. Accessed 20 January 2019.

<https://www.surveysystem.com/sscalc.htm>. Accessed 05 February 2019.

<https://farmwest.com/node/934>. Accessed 10 February 2019.

<https://www.graf-water.com/rainwater-harvesting/all-about-rainwater-harvesting/lexicon/begriff/runoff-coefficient.html>. Accessed 14 February 2019.

Annexes

Annex 1 Rainfall data

Table 1 Gauge stations used for analysis

R.No	Name of station	Elevation	Longitude	Latitude	Year of data	Average annual RF
1	Alem Ketema	2280	39.033	10.033	1995-2018	1058
2	Debre Berhan	2750	39.5	9.6333	1995-2018	883.56
3	Debre Tsige	2640	38.826	9.6375	1995-2018	743.6
4	Deneba	2600	39.2	9.7667	1995-2018	940.56
5	Eneware	2561	39.15	9.83	2000-2018	965.41
6	Fiche	2784	38.733	9.7667	1995-2018	1145.7
7	Lemi	2500	38.9	9.8167	1995-2018	1245.4
8	Muke Turi	2649	38.871	9.542	1995-2018	792.38
9	Seladingai	2870	39.617	9.95	2006-2018	1078.7
10	Sheno	2870	39.285	9.3245	1995-2018	886.72

Table 2 Rainfall data of Deneba station

Year	Months												Annual RF
	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	
1995	0	13.6	39.1	111	27.6	33.4	290.3	260.6	51.6	0	0	21.6	848.8
1996	56.1	8.6	90.5	48.8	67.9	208.6	348.7	288	46.8	0	19.5	0	1183.5
1997	59.8	0	29.9	25.9	12.4	104.2	313.8	215.3	44.6	55.3	33	0	894.2
1998	44.1	19.1	48.6	70.6	84.6	64.1	321.3	276.3	118.6	17.6	0	0	1064.9
1999	9.4	0	54	4.7	5.2	48.7	399.7	354.3	74.3	38.8	0	0	989.1
2000	0	0	20.3	76.3	32.4	44.8	271.4	254.9	97.3	8.3	5.8	0	811.5
2001	0	5.3	134.3	14.2	62.6	72.6	360.2	209.9	0	0	0	14	873.1
2002	40.7	47.2	71.3	18.2	0	29.2	198.6	156	20.1	0	0	11.9	593.2
2003	25.7	102	162.8	197.4	0	96	286.9	287	120.2	0	1.3	13.6	1292.9
2004	9.7	9.2	55	89.9	0	131.4	247.7	252.4	119.6	8.2	6.9	2	932

2005	44.2	0	45.2	61.9	36.2	80.3	327.9	229.7	79.6	0	0	0	905
2006	26.6	27	96	42.8	69.8	74.8	431.6	251.8	104.1	16.7	0	8	1149.2
2007	8.3	46.3	66.1	73.1	14.1	62.3	349.6	474.4	80.7	3.2	0	0	1178.1
2008	6.2	0	0	21.5	16.2	87.1	391.1	252	44	4.5	46.7	0	869.3
2009	23.7	8	30.9	28.2	27.5	21.6	322.7	332	38.1	45.8	9.2	15.1	902.8
2010	4	54.4	87.3	112.4	77.5	54.4	304.7	310.2	126.6	0	22.2	15.4	1169.1
2011	30.1	0	78.8	44.4	38.4	68.2	299.3	286.7	67.9	0	2.5	0	916.3
2012	0	0	57	103.9	46	70.7	326.7	417.1	109.9	0	0	0	1131.3
2013	0	0	32.7	53.3	26.1	68.4	231	241.1	85	47.1	0	0	784.7
2014	0	27.5	34.3	26.7	59.7	37.8	324.4	296.7	87.8	8.4	2.5	0	905.8
2015	0	54.7	36.2	0	62.8	89.2	125.9	252.7	92.1	12.7	3.4	9.4	739.1
2016	16.6	7.1	52.1	122.7	81.5	119.1	321.5	272.4	54	12.6	0	0	1059.7
2017	0	21.2	36	11.5	62.3	57.1	231	320.9	54	8.5	3.4	0	809.4
2018	0	27.5	13.9	49.7	11.5	119.1	306.6	360.8	Not yet recorded.				889.1

Annex 2

Questionnaires for the study

This research is conducted for academic purpose and its objective is to evaluate the rainwater harvesting importance and competence in Siyadebirna wayu woreda.

Your answers are completely confidential, your name is not written on this form, and never be used in connection with any of the information you told to us.

Thank you for your cooperation!

By:- Chirotaw Teshome

PART I, General about water

1. What are the sources of water supply for your kebele (got)?

- A) Surface water (rivers,lake,pond)
 B) Ground water sources (well, hand pump) C) Others (spring)
2. Are the drinking water sources and animal water sources separable?
 A) Yes B) No
3. If the answer for question #2 is no how the animal demand satisfied?
 A) By fetching from the same water sources
 B) By traveling long distances from the village
4. If your answer for question #3 is A, how many animals used this fetched water? Fill the following table.

Type of animals	Quantity (number of animals)	Amount of water they drink
Ox		
Cow		
Sheep		
Goat		
Donkey		
Horse		

5. How long does it take to go water sources, get water, drink animals and come back?(— minutes)
6. How many jericans (20-25 liter) you fetch per day in single household?—————
7. Who usually goes to this source to fetch water or for drink animals?
 A) Children above ten years B) Children below 18 years C)Women D) Men
8. How many times you wash your clothes?
 A) Every week B) Every two week D) Once in a month
 C) At any time which comes dirty E) By only big holidays
9. How you take shower?
 A) Every 5 days B) Every week C) Every two weeks D) Once in a month
 D) As importance F) For big holiday and program only
10. Do you think that the water shortage has the effluences on your economic activities? List them?
11. Do you think that the water problem has effluences on your health? List them?
12. Is there any rainwater harvesting technology conducted before now? If there what are their limitation?
13. Which month has the critical water shortage in your kebeles?
 A) From September to December B) From December to March C) From March to May
 D) From December to May

Part II. Willingness to pay

1. How many birr you pay per month if all demand is delivered in your compound?

2. How many birr you pay per month if the non-domestic water demand is delivered in your compound including Animal demands?
3. Which illness is occurred in your family repeatedly? How the treatment taken?
4. Is there any relation between shortage of water and illness of your family?

Part III. Socioeconomic characteristics of the respondents

1. Gender? A. Male B. Female
2. Age? _____ years
3. Marital status (please tick one) A. Single B. Married C. Separated/divorced
4. What is your highest educational attainment? (please check and give the highest level)
 - A. No formal schooling B. Elementary C. High school D. College
 - E. Master's F. Higher than Master's degree
5. What is your occupation? (Multiple response possible)
 - A. Unemployed/housewife B. Self-employed C. Government employee
 - D. Private employee E. Laborer/mechanic/tailor/skilled worker F. Farmer
6. House hold size _____ (No. of family members)
 - No. of children (those less than 15 years) _____
 - No. of adults (15-50 years) _____
 - No. of elders (those higher than 50 years) _____
7. What is your average yearly income (farm income)? (use the following table)

Crop type	Quantity (Kg)
Wheat	
Teff	
Pea	

8. Do you have other business (you or your family) other than agriculture (off-farm activity) to support your livelihood? A. Yes B. No
9. Have you house which roof is tin? How much it?
10. How many animals you have? Use the following table

Type of animals	Quantity
cow	
ox	
sheep	
goats	
horse	
donkey	

11. How many of them you prepared for market, especially Ox and Cow?

Discussions ideas for focal group discussion

1. What is the current status of water supply coverage and hygiene in the woreda?
2. What are the solutions prepared for the future?
3. What are available water sources in the woreda and their potential?
4. What are the challenges for delivered water from the best sources to other villages, kebeles?