RAINWATER HARVESTING AS A MEANS TO REDUCE THE PROBLEM OF WATER SCARCITY A CASE OF ARUSHA REGION

BY

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I45/84343/2012

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DECLARATION

This project work is my original work and has not been presented for a degree in any other university or Higher learning Institution

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DEDICATION

I dedicate this work to my lovely family for their love, support and encouragement during the entire period of my studies. I love you all and may God bless you abundantly.

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ABSTRACT

It is clear from the World water quantity that out of total available water, only 0.3% is available for human consumption. But today even this is getting polluted due to human activities like mining, industrialization has created acute shortage of potable drinking water. Rain water harvesting is one of the most ancient and easy methods that can be adopted at urban and rural level efficiently.

The main objective of this study was to quantify the amount of rainfall over Arusha region and to determine the maximum probable amount of water that can be harvested.

Arusha region covers total of 86,999 sq. km. of which 3,571 sq. km (4.1%) is water. It is the largest Region in Tanzania occupying 9.2% of the mainland. The last census in 2012 recorded a population of 1,694,310 individuals.

Monthly rainfall data for the stations within study area were obtained from Tanzania Meteorological Agency (TMA). Other data were obtained from Arusha urban water supply and sewerage authority (AUWSA) was used to determine amount of water supplied and demanded. National Bureau of Statistics (NBS) 2012 Population and Housing census was used to determine population of the study area and also to get the number of the main dwellers.

Estimation of missing data was done using arithmetic mean method and the single mass curve was used to determine data consistency or data homogeneity. Rainfall season was determined by the use of graphical analysis for annual cycle of rainfall over the Arusha region. The roof catchment area was estimated to be around 25-30m with standard size room of $3\times3m^2$ was considered, eave length of 0.6m and elevation angle of 22.5° was also considered. The average household size of the area was 4.5 and per capita water demand per person per day was estimated to be 30.5 liters and hence the minimum water demand was calculated. The amount of probable harvested rainwater was calculated using average monthly rainfall (mm), the runoff coefficient depending on the common roofing material of the study area and the total roof surface area (m^2). The storage reservoir that could sufficiently store the collected rainwater was estimated.

The results showed that the area experience two rainy seasons, March, April, May (MAM) and October, November and December (OND).

ABBREVIATIONS

ASL   Above Sea Level

AUWSA   Arusha Urban Water Supply and Sewerage Authority

KIA   Kilimanjaro International Airport

MAM   March, April and May

OND   October, November and December

PHC   Population and Housing Census

RWH   Rainwater Harvesting

TMA   Tanzania Meteorological Agency

CHAPTER ONE

1.0 INTRODUCTION

Water is our most precious natural resource and something that most of us take for granted. We are now increasingly becoming aware of the importance of water to our survival and its limited supply. The human beings require water for various purposes. The most part of the earth surface i.e. about 71 % is covered by water. Out of total volume of water available on the surface of the earth 97 % is saline water, 2 % water is in the form of ice and glaciers and only 1 % is fresh and potable water (Hattum et al., 2006).

Water is essential for all life and used in many different ways, it is also a part of the larger ecosystem in which the reproduction of the bio diversity depends. Fresh water scarcity is not limited to the arid climate regions only, but in areas with good supply where access of safe water is becoming critical problem. Lack of water is caused by low water storage capacity, low infiltration, larger inter annual and annual fluctuations of precipitation (due to monsoon rains) and high evaporation demand. (Sivanappan, 2006)

Rain water harvesting is a very traditional way of collecting water from surfaces that do not allow water to soak or penetrate e.g. rock outcrops, roofs of corrugated iron sheets, concrete etc. in seasonal rivers by construction of dams etc. Places where rain is sufficient the amount stored could be quite substantial (Fewkes et al., 2000).

The term harvesting was probably used first by Geddes of University of Sydney. He defined harvesting as the collection and storage of any form of water either runoff or creek flow for irrigation use. (Arunakar, 2006)

Rain water is normally soft, saturated with oxygen and corrosive. Micro organisms and other suspended matter in the air are entrapped but ordinarily the impurities are not significant. However, collecting reservoirs, cisterns, can be contaminated and wherever possible after an extended dry period the first rain flush should be discarded (Hatibu et al., 2000).

Olaruntade and Oguntunde (2009) found that rainwater harvesting provides a good alternative and replacement in times of drought or when the water-table drops and wells go dry, also in the most arid or semi – arid areas, the prevailing climate condition makes it of crucial importance to use the limited amount of rainwater as efficiently as possible, as people realize that it cannot be managed. Also collected rainwater is a valuable supplement that would otherwise be lost by surface runoff or evaporation.

1.1 Rainwater Harvesting definition and description

Rainwater harvesting (RWH) has long been used as a cheap and simple method for meeting water needs. With a few exceptions (desalination, deep aquifer extraction), it can be argued that virtually all methods of water supply are in a sense a type of rainwater harvesting. For most part, rainwater harvesting is seen only necessary in arid and remote places. Nonetheless, rainwater is an available and plentiful resource whose potential is largely untapped (Handia et al., 2002).

Definitions for rainwater harvesting vary considerably depending on the source consulted. Some few definitions found in the literature are presented below:

- Rainwater harvesting, in its essence is the collection, conveyance, and storage of rainwater – The Texas water development board (2005).
- Rainwater harvesting is the collection of rainwater for beneficial use – capital region district water services (2007).
- Boers and Ben-Asher (1982) defined rainwater harvesting as a method to induce, collect, store, and conserve local surface runoff for agriculture in arid and semi- arid regions.
- Rainwater harvesting is defined as the collection of runoff and its use for the irrigation of crops, pastures and trees, and for livestock consumption (Prinz, 1996).
- Mbilinyi et al., 2005 defined RWH as the process of concentrating, collecting, and storing rainwater for different uses at a later time in the same area where the rain falls or in another area during the same or later time.

From these definitions, there is no doubt that rainwater harvesting is physical system that at the least collects, conveys and stores water. From there, though the definition diverge. In some cases, it is not rain per se that is collected, but runoff. Some definitions limit the

locations where rainwater harvesting can be implemented: on farns, or in "arid and semi-arid regions" (Medugu, 2009)

While rainwater harvesting has traditionally been limited to rural areas, where its sole purpose is as a water source, it could potentially provide additional benefit in an urban setting as cities and communities begin to integrate their water resources management of drinking water, stormwater, and wastewater, RWH provides an interesting case study of a sustainable technology that potentially affects all three resource areas (Mwenge-Kahinda, 2007).

Figure 1: Picture showing rainwater harvesting system in public school, Longido District-Namanga (source: Field survey, July 2013)

1.2 PROBLEM STATEMENT

The availability of clean, safe and sufficient amount of water to the daily activities of human being is very crucial. Water plays an important role in transforming or changing the lives of people to better and healthier one. Access to sufficient amount of water is a major problem to most people living in rural and urban areas. The aim of this research is to contributing ideas and knowledge on harvesting rain water so as to compliment the deficiency of water need faced in

the Arusha region. This can be supported by the report from the Arusha urban water supply and sewerage authority (AUWSA) that there is need for additional water sources to ensure adequate supply throughout the year including during dry seasons.

1.3 HYPOTHESIS

Access to clean, safe and sufficient amount of water for domestic purposes will reduce the cases of water related diseases such as cholera, typhoid, skin and eye infections etc. This will increase also productive time for mostly women in searching for water, thus help to boost the national and individual economy.

1.4 OBJECTIVES OF THE STUDY

1.4.1 Overall objective
The overall objective of this study is to quantify the amount of rainfall in the study area and to determine the maximum probable amount of water that can be harvested.

1.4.2 Specific objectives
    i.   To investigate the temporal characteristics of rainfall in Arusha region.

   ii.   To determine per capita water demand in Arusha municipality.

 iii.   To determine the probable harvestable water from the rainfall.

1.5 CASE STUDY AREA

1.5.1 General Information

Geographical location and climate

Arusha region is found in northern Tanzania. Arusha shares its northern border with the Republic of Kenya. To the northeast, Arusha region borders to Kilimanjaro region. Further east is Tanga region. To the south Dodoma Region is found, where the capital city of Tanzania is situated. To the west Shinyanga region is found and to the northwest Mara region. Arusha region combines both highland which include Mount Meru (4,566M ASL) and low land. Temperatures average

21º C and lowlands temperatures average 26ºC. Rainfall ranges from 250 mm to 1200 mm per annum.

1.5.2 Area and population

Arusha region covers total of 86,999 sq. km. of which 3,571 sq. km (4.1%) is water. It is the largest Region in Tanzania occupying 9.2% of the mainland. The last census in 2012 recorded a population of 1,694,310 individuals. The major ethnic groups include the Maasai, the Arusha the Meru, the Iraq, the Hadzabe and the Barbaig who all have unique cultural heritages.
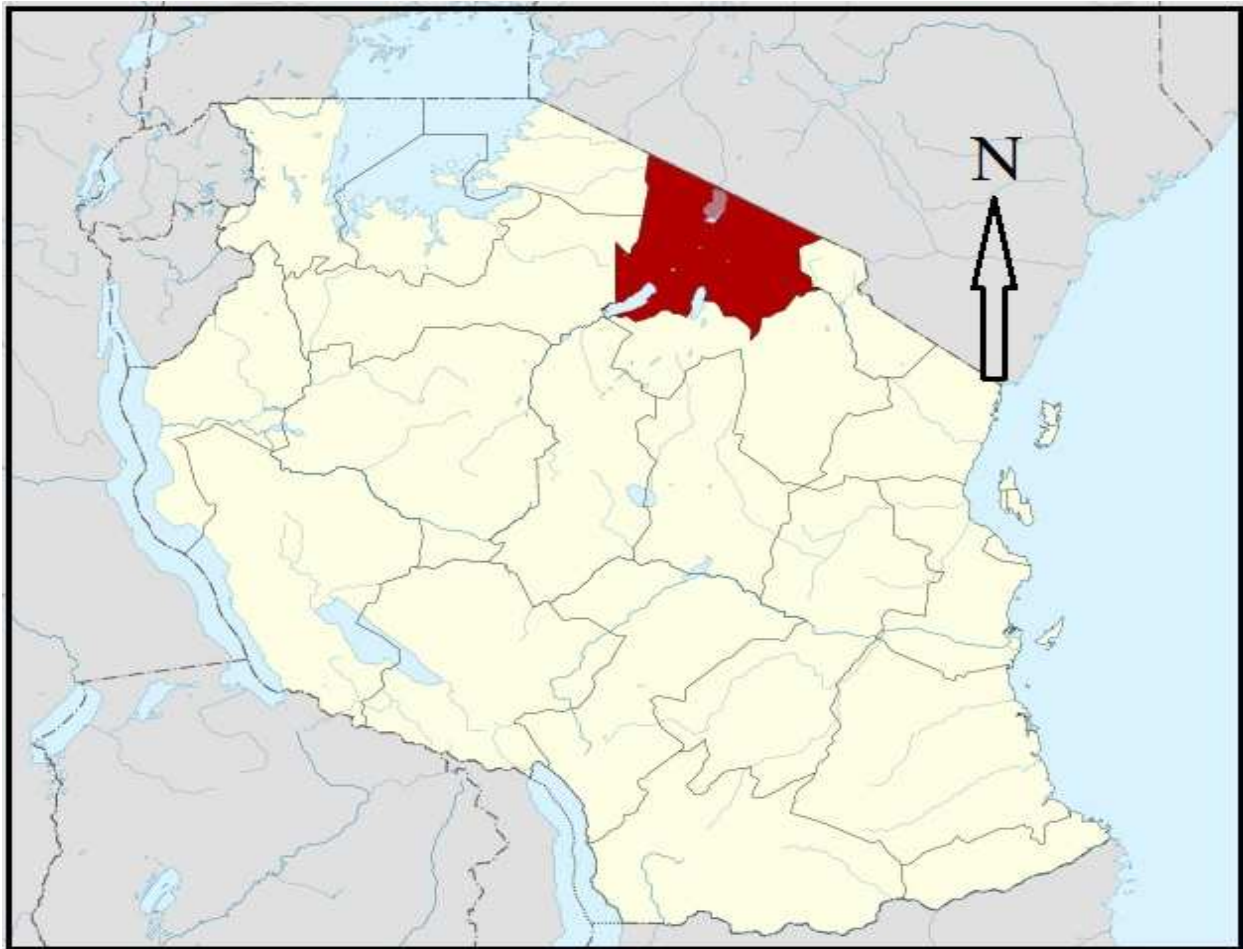

Figure 1.1: Map of Tanzania showing the case study area (source: 630px Tanzania_Arusha_location_map.svg.png)

CHAPTER TWO

2.0 LITERATURE REVIEW
2.1 Importance of Rainwater Harvesting

Rainwater harvesting means the activity of direct collection of rain water which can be recharged in to the ground water to prevent fall of ground water level or storing in surface or underground water tank. It is most suited in today's context due to following reasons (Jothiprakash et al., 2009).

- It is the most scientific and cost effective way of recharging the ground water and reviving the water table.
- It offers advantage in water quality for both irrigation and domestic use.
- It provides naturally soft water and contains almost no dissolved minerals or salts, arsenic and other heavy metals.
- It can be done at individual as well as in a community level. This way we can be self sufficient in terms of domestic water requirements and not just dependent on the actions initiated by government or any other local body.

Collecting rainwater as it falls from the sky seems immensely sensible in areas struggling to cope with potable water needs. Rainwater is one of the purest sources of water available as it contains very low impurities. Rain water harvesting systems can be adopted where conventional water supply systems have failed to meet people's needs.

Rain is a primary source of water for all of us. There are two main techniques of rainwater harvesting:

- Storage of rainwater on surface for future use.
- Recharge to groundwater.
- Directly collected rainwater can be stored for direct use or can be recharged into the groundwater.

All the secondary sources of water like rivers, lakes and groundwater are entirely dependent on rain as a primary source (Janette et al., 2006).

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Water harvesting is the deliberate collection and storage of rainwater that runs off on natural or manmade catchment areas. Catchment includes rooftops, compounds, rocky surface or hill slopes or artificially prepared impervious/ semi-pervious land surface (Hedcon, 2001). The amount of water harvested depends on the frequency and intensity of rainfall, catchment characteristics, water demands and how much runoff occurs and how quickly or how easy it is for the water to infiltrate through the subsoil and percolate down to recharge the aquifers (Medugu, 2009). Moreover, in urban areas, adequate space for surface storage is not available, water levels are deep enough to accommodate additional rainwater to recharge the aquifers, rooftop and runoff rainwater harvesting is ideal solution to solve the water supply problems (Li et al., 2010).

2.2 Advantages of RWH

- To meet the ever increasing demand for water. Water harvesting to recharge the groundwater enhances the availability of groundwater at specific place and time and thus assures a continuous and reliable access to groundwater.

- To reduce the runoff which chokes storm drains and to avoid flooding of roads.

- To reduce groundwater pollution and to improve the quality of groundwater through dilution when recharged to groundwater thereby providing high quality water, soft and low in minerals.

- Provides self-sufficiency to your water supply and to supplement domestic water requirement during summer and drought conditions.

- It reduces the rate of power consumption for pumping of groundwater. For every 1 m rise in water level, there is a saving of 0.4 KWH of electricity.
- Reduces soil erosion in urban areas
- The rooftop rainwater harvesting is less expensive, easy to construct, operate and maintain.

- In saline or coastal areas, rainwater provides good quality water and when recharged to ground water, it reduces salinity and helps in maintaining balance between the fresh-saline water interfaces.

- In Islands, due to limited extent of fresh water aquifers, rainwater harvesting is the most preferred source of water for domestic use.

- In desert, where rainfall is low, rainwater harvesting has been providing relief to people.

2.3 Design Consideration for RWH

Three most important components, which need to be evaluated for designing the rainwater harvesting structure, are:

- Hydrogeology of the area including nature and extent of aquifer, soil cover, topography, depth to water levels and chemical quality of ground water
- Area contributing for runoff i.e. how much area and land use pattern, whether industrial, residential or green belts and general built up pattern of the area
- Hydro-meteorological characters like rainfall duration, general pattern and intensity of rainfall.

2.4 Components of RWH

2.4.1 Catchments

The catchment of a water harvesting system is the surface which directly receives the rainfall and provides water to the system. It can be a paved area like a terrace or courtyard of a building, or an unpaved area like a lawn or open ground. A roof made of reinforced cement concrete (RCC), galvanized iron or corrugated sheets can also be used for water harvesting.

2.4.2 Coarse Mesh
This is placed at the roof to prevent the passage of debris.

2.4.3 Gutters

These are channels all around the edge of a sloping roof to collect and transport rainwater to the storage tank. Gutters can be semi-circular or rectangular and could be made using:

- Locally available material such as plain galvanized iron sheet (20 to 22 gauge), folded to required shapes.
- Semi-circular gutters of PVC material can be readily prepared by cutting those pipes into two equal semi-circular channels.
- Bamboo or betel trunks cut vertically in half.

The size of the gutter should be according to the flow during the highest intensity rain. It is advisable to make them 10 to 15 per cent oversize.

Gutters need to be supported so they do not sag or fall off when loaded with water. The way in which gutters are fixed depends on the construction of the house; it is possible to fix iron or timber brackets into the walls, but for houses having wider eaves, some method of attachment to the rafters is necessary.

2.4.4 Conduits

Conduits are pipelines or drains that carry rainwater from the catchment or rooftop area to the harvesting system. Conduits can be of any material like polyvinyl chloride (PVC) or galvanized iron (GI), materials that are commonly available.

2.4.5 First-Flushing

A first flush device is a valve that ensures that runoff from the first spell of rain is flushed out and does not enter the system. This needs to be done since the first spell of rain carries a relatively larger amount of pollutants from the air and catchment surface.

2.4.6 Filter

The filter is used to remove suspended pollutants from rainwater collected over roof. A filter unit is a chamber filled with filtering media such as fibre, coarse sand and gravel layers to remove debris and dirt from water before it enters the storage tank or recharges structure. Charcoal can be added for additional filtration.

10 CM GRAVEL LAYER
10 CM CHARCOAL LAYER
25 CM SAND LAYER
25 CM GRAVEL LAYER
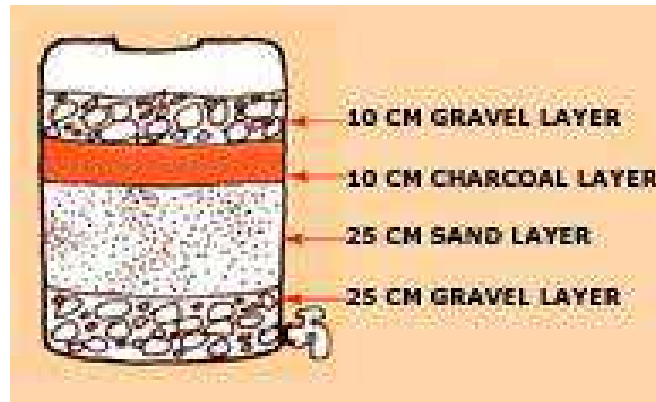
- **Charcoal water filter**

A simple charcoal filter can be made in a drum or an earthen pot. The filter is made of gravel, sand and charcoal, all of which are easily available.

- **Sand filters**

Sand filters have commonly available sand as filter media. Sand filters are easy and inexpensive to construct. These filters can be employed for treatment of water to effectively remove turbidity (suspended particles like silt and clay), color and microorganisms.

In a simple sand filter that can be constructed domestically, the top layer comprises coarse sand followed by a 5-10 mm layer of gravel followed by another 5-25 cm layer of gravel and boulders.

CHAPTER THREE

3.0 DATA TYPE, SOURCES AND METHODOLOGY
3.1 Rainfall Data

This data was obtained at the Hydrological Section of Tanzania Meteorological Agency (TMA). Practically the whole of the annual rainfall falls during the rainy seasons between October, November and December (OND) and March, April and May (MAM).

The monthly rainfall data at the study area for the past 33 years has been used in this study. The monthly rainfall data was used in estimating the volume of water to be stored in order to meet the daily water demand throughout the year.

Three rainfall stations were involved, these include Arusha met station, Babati met station and Kilimanjaro international airport (KIA) station. The table below indicates the spatial distribution of the three stations used.

Table 3.1 Spatial distribution of rainfall stations and data period.

Station name	Longitude	Latitude	Initial	Data Period
Arusha	36.62ºE	3.33ºS	AR	1979 - 2012
Babati	35.75ºE	4.22ºS	BA	1979 - 2011
KIA	37.07ºE	3.42ºS	KJ	1979 - 2012

3.2 Methodology

The methodologies applied in this study include:

3.2.1 Estimation of Missing Data and Data Quality Control
This was done to ensure that before doing data analysis, the data has no gaps to achieve the objective of the study. It is designed to ensure that Meteorological and climatological data meets certain standards and involves looking for errors in the acquired data ranging from storage media problem to data inhomogeneity or inconsistency.

The arithmetic mean method was used. It involves replacing the missing values by the long term mean for the particular month and station.

$$\bar{X} = \frac{1}{N}\sum_{i=1}^{N} X_i$$ ……………………………………………………………………. (3.1)

Where $\bar{X}$ is the long term mean

X_i is the individual data points and

N is the total number of observations.

The process of testing homogeneity of data or data consistency was done using a mass curve method. In single mass curve method, cumulative seasonal rainfall totals were plotted against corresponding time (years). A straight line graph exhibit homogeneous data set.

3.2.2 Graphical Analysis for Annual Cycle

Monthly mean rainfall values were computed by plotting the monthly rainfall observation values against months of the year for each station.

3.2.3 Calculation of Roof Catchment Area

Because of their sheer size, roofs will catch a significant amount of water. The roof catchment area for single storey homes is usually greater than the floor area of the building if there are eaves.

As a guide to collection capacity, consider that each 1mm of rain = 1 Liter (L) of water per square meter (M²) of roof area.

3.2.4 Minimum Water Demand

The minimum volume of water required was computed using statistical analysis. The number of households in a region was determined and this helped to establish per capita water demand per person per day. Then the household size which was area specified together with per capita water demand per person per day was used to calculate minimum water demand.

Consider the equation below;

$$X_{min} = \frac{D_v \times D_n}{1000} \text{Liters} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.2)$$

Where: X_{min} is the minimum water demand.

D_v is the daily volume of water in cubic meters

D_n is the number of days per month

3.2.5 Harvestable Water

The probable amount of water that can be harvested can be given by the following equation

$$H_{RW} = \frac{P}{1000} \times C_d \times A_d \times \eta \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.3)$$

Where;

H_{RW} is the rain water harvesting potential, that gives the amount of harvestable rainwater per roof area for a specific location.

P is the average monthly rainfall (mm)

C_d is the runoff coefficient depending on the common roofing material used.

A_d is the total roof surface area in square meters.

η is the rainfall reliability (assumed to be 0.67 for East Africa depending on the monsoon, (Rockstorm, 2002).

3.2.6 Water Storage Capacity

The size of storage tank needed for a particular application is mainly determined by the amount of water available for storage (it is a function of roof size and local average rainfall), the amount of water likely to be used (a function of occupancy and use purpose) and the projected length of time without rain (drought period).

The amount of storage needed to store the harvested water is determined by the amount of water harvestable in a month and per capita water demand for the study area. The harvestable water is given as the excess water above the minimum water demand. Therefore by subtracting the

minimum water demand from the harvestable amount of water for the months with excess water, the capacity of storage is obtained.

This can be given by the following equation;

$$Q = H_{RW} - M \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.4)$$

Where;

Q is the capacity of the storage system

H_{RW} is the harvestable rainwater for a given month

M is the minimum water demand for the particular month.

CHAPTER FOUR

4.1 RESULTS AND DISCUSSION

In this chapter is where the results obtained from the data analysis are illustrated and discussed. The discussion of data analysis are based on the contest of estimation of missing data and data quality control, Graphical analysis for annual cycle, calculation of roof catchment area, minimum water demand, probable harvestable water and storage capacity estimation.

4.2 Estimation of Missing Data and Data Quality Control

The stations with missing data were replaced by the use of long term mean. The amount of missing data point was less than 10% for the three stations therefore the data were still feasible for further analysis after filling the missing values. Babati station had 384 data points with 34 missing data which is equal to 8.8%. Arusha station had 396 data points with 1 missing data, which is equal to 0.3% and the Kilimanjaro International Airport station had nil missing data which translating to 0%. Therefore from the analysis it concluded that the amount of missing data for the three stations was less than 10% hence viable for further analysis.
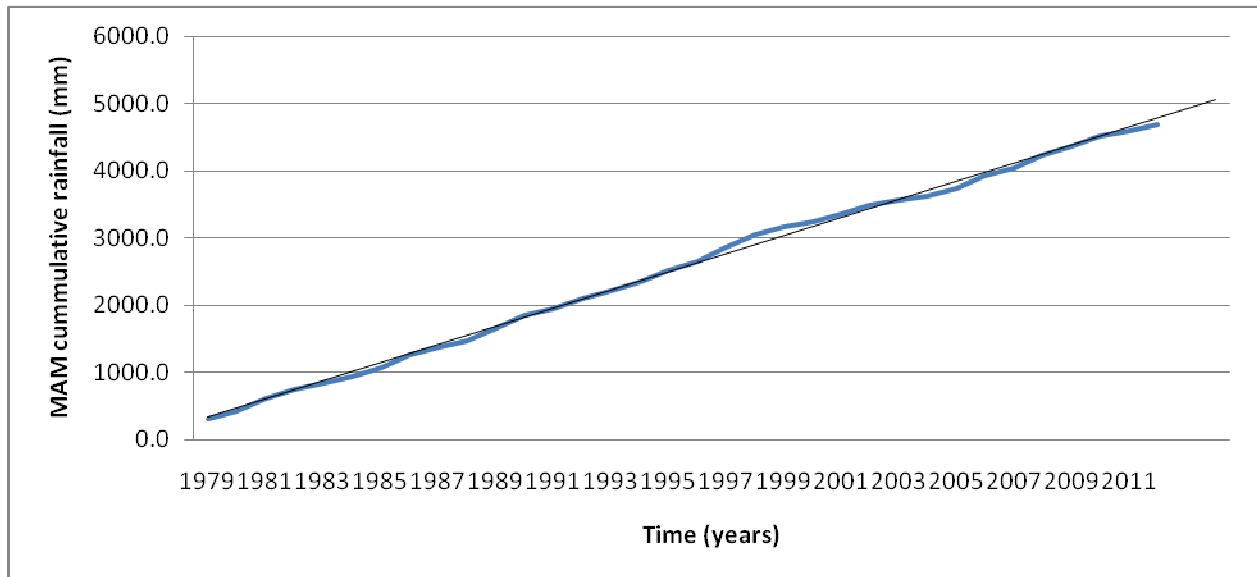

Figure 4.1: Single mass curve for Arusha rainfall station during March, April and May

4.3 Graphical Results for Annual Cycle

Babati rainfall station was averaged over 32 years (1979-2011), Arusha rainfall station was averaged for 33 years (1979-2012) and KIA rainfall station was averaged for 33 years (1979-2012). The results are as shown below;
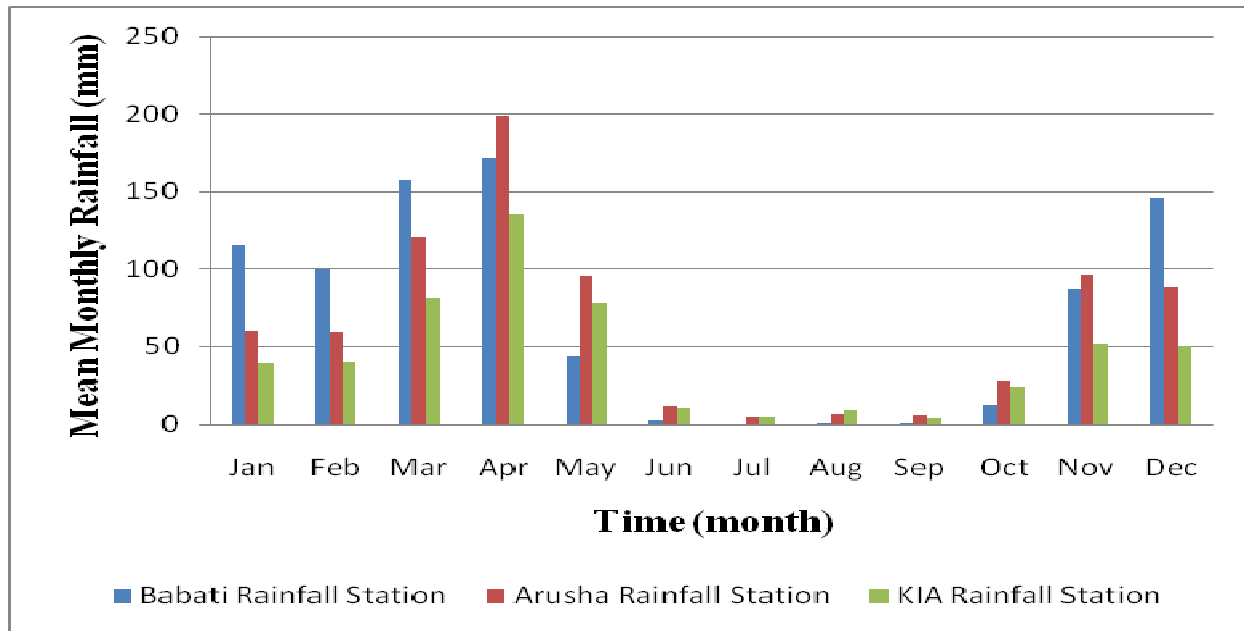

Figure 4.2: Mean monthly rainfalls for Babati, Arusha and KIA stations

From the results shown above, the region exhibit two seasons of rainfall with long rains commencing from January to May. The short rain starts from October to December. The amount of rainfall during the months of January to May was observed to be higher than the amount of rainfall from October to December for all the three stations. The wettest month for all the three stations was April followed by March for the MAM season. Rainfall amount for Arusha station during March was 120mm, babati station was 157.5mm and KIA was 81.4mm. For the month of April Arusha station recorded rainfall amount of 198.7mm, babati station recorded rainfall amount of 171.6mm and KIA station recorded 135.3mm.

During the OND season the wettest months were November and December. Amount of rainfall recorded at Arusha station on November was 96.4mm, babati station recorded rainfall amount of 86mm and KIA station recorded 51.5mm. on the month of December Arusha station recorded rainfall amount of 87.4mm, babati 145.7mm and KIA 49.8mm.

The observations above showed that Arusha region experience a bimodal type of rainfall. Hence it is during these two seasons that potential rainfall water can be harvested.

4.4 Calculation of Roof Catchment Area

The catchment area is the first point of contact for rainfall. For the vast majority of tank-based rainwater harvesting systems, the catchment area is the roof surface. The important factors to consider when planning for a RWH system include:

4.4.1 Roofing Material

The material of the roof is not as important as contaminants that may be on the roof. From the literature it is recommended a metal roof because they easily shed contaminants. From the data obtained at Tanzania Housing Board (THB), it was found that approximately 97% of houses were roofed with iron sheet, 2% of houses were roofed with dried grass, 1% of houses were roofed with tin material and 0.1% of houses were roofed with tiles as shown in the figure 4.1 below.
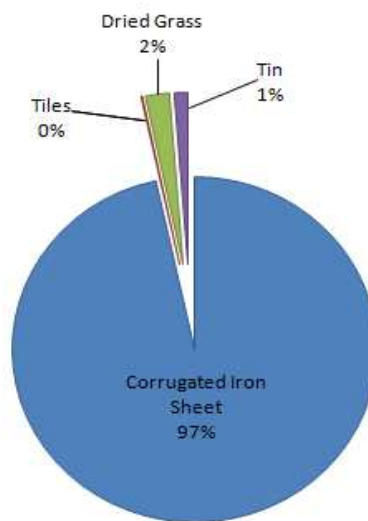

Figure 4.3: Percentage distribution of the main roofing material over Arusha region

From the figure 4.3 it was found that approximately 97% of the houses used corrugated iron sheets as roofing material, 2% of houses were roofed by dried grass, 1% of houses were roofed using tins and approximately 0% was roofed using tiles.

This indicated that the most used type of roofing material is iron sheet and therefore is the most considered for water harvesting in the region.

4.4.2 Slope of the Roof
The slope of the roof affects how quickly water will runoff during a rain event. A steep roof will shed runoff quickly and more easily clean the roof of contamination. A less-steep, flatter roof will cause the water to move more slowly, raising the potential for contamination to remain on the catchment surface. The roof below has a steep slope followed by a more gradual slope.

4.4.3 Sizing a Catchment Area
The size of the catchment area or roof will determine how much rainwater that can be harvested. The area is based on the "footprint" of the roof, which is calculated by finding the area of the building and adding the area of the roof's overhang.

The size of the catchment area was taken to be around 25 – 30m², this is due to varying of the actual surface area from house to house.

4.5 Minimum Water Demand

From the 2012 population and housing census (PHC) results showed that the average number of household in the study area is 4.5. This can be used to establish per capita water demand per person per day and also per month.

The table below shows the estimated daily water demand per household per day.

Table 4.1 Approximate daily water consumption

Activity	Water usage (L/H/day)
Bathing	20
Cloth washing	20 – 30
Dish washing	5 – 10
Food washing	10
Food preparation	10
Drinking	2
Total	67 - 82

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From the table 4.1 the minimum amount of water needed per household (H) per day is (4.5 ×
(67—82) = 301.5 up to 369) liters household per day.

Again consider the table 4.2 which shows the average pattern of rainwater usage by daily activity
per head (h) per day.

Table 4.2 Typical average rainwater utilized by activity

Rainwater usage	Volume (L/h/day)
Cooking	10
Dish washing	6
General washing	12.5
Drinking	2
Total	30.5

From table 4.2 above, the average amount of water used per head (h) per day is (4.5 × 30.5) =
137.5 liters.

4.6 Probable Harvestable Rainwater

This was obtained from the estimated catchment area, runoff coefficient and the amount of
rainfall received at the study area. The formula below was used in the calculation

Catchment area (m²) x rainfall (mm) x 0.623 = Harvestable water (m³). The amount obtained was
subtracted by 15% which account for the loss (due to evaporation and spill off).

Table 4.3: The mean volume of harvestable rainwater for the three stations

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAM Total	OND Total
Arusha	59.8	58.4	120	198.7	95.5	11.3	5.0	6.9	5.4	28.3	96.4	87.4	414.2	212.1
Babati	115.4	99.6	157.5	171.6	43.5	2.9	0.2	0.8	1.4	12.5	86.8	145.7	372.6	252.2
KIA	38.6	39.8	81.4	135.3	77.7	10.5	4.9	8.9	4.2	23.8	51.5	49.8	294.4	125.1
Mean	71.3	65.9	119.6	168.5	72.2	8.2	3.4	5.5	3.7	21.5	78.2	94.3	360.4	196.5

Table 4.3 shows the amount of water that can be harvested during the two wet seasons. For Arusha station amount of water that can be harvested was found to be 626.3m³, for babati it was 624.8m³ and for KIA was 419.5m³.

The highest mean rainwater that can be harvested was 16.5m³ on the month of April followed by 11.6m³ on the month of March. On average the probable harvestable rainwater in the study area was found to be 49.6m³ in the two wet seasons of MAM and OND. The amount was obtained as the mean for three stations. This amount is equivalent to ($49.6 \times 1000 = 49600$ liters) of harvestable water.

4.7 Storage Capacity

The estimation of minimum volume of storage is a very important aspect of RWH design. It entails sizing of the tank required to store enough water to satisfy the appropriate demand as required by the user(s). The minimum volume of storage is a function of many variables embedded in the supply (rainfall, catchment area, co-efficient of runoff) and demand pattern.

The capacity of storage tank can be designed according to the amount of rainwater that will likely to be harvested. From section 4.6 above the amount of water that likely to be harvested appear to be 49600 liters so from this amount the storage tank can be designed.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

In this chapter is where the conclusion and recommendation of the study on rainwater harvesting in Arusha region. The conclusion is given from the results obtained as well as giving the way forward in terms of outcome.

5.1 Conclusion

The study showed that MAM season received more rainfall than the OND season. The wettest months were April followed by March for the MAM season and December followed by November for the OND season. Therefore these are the period which RWH can be practiced. The harvested water can be utilized during the dry period of the year.

The most dominant roofing material was corrugated iron sheet with approximate 97% rest of 3% shared by other types of roofing material such as tiles, dried grass and tins.

The amount of probable harvested rainwater was found to be approximately 49600liters for both wet seasons of MAM and OND. This amount

5.2 Recommendation

There should be more studies on the water quality of the harvested rainwater. This should cover water treatment for safety usage, good water drainage to ensure no water stagnation which is a threat to human life, use of safe roofing materials such as corrugated mild steel and tiles since other types of roofing materials such as asbestos sheeting, metallic paints and other unsafe roofs can interfere with human health.

More studies on the type of storage material should be done as the storage tanks depend on the environment in which is going to be used. Environment in which the tank is constructed plays an important role in the degree of shrinkage and cracking. It is shown that tanks constructed in a hot and dry environment and tanks that are allowed to set at different rates are much more susceptible to cracking.

Local and central government should invest more on the techniques of RWH so as to supplement other sources of water especially in region where adequate supply of potable water is a problem.

ACKNOWLEDGEMENT

I thank God, the Almighty creator for the guidance and knowledge throughout my studies at University of Nairobi.

My sincere thanks should also go to Dr. Opere and Dr. Mutemi for their valuable contribution and encouragement in completing this research project. Thanks also extend to all staff and non staff of the entire department of Meteorology for providing me with necessary materials whenever I needed them.

I would also like to thank the staff and management of the Climat section of Tanzania Meteorological Agency for providing me with rainfall data of my study area to work on.

Thanks to Tanzania Meteorological Agency for their support and sponsorship to pursue this course.

Last but not least thanks goes to all my course mates for their support and encouragement during the entire period of my studies.

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