RAINWATER HARVESTING FOR WATER CONSERVATION IN THE PREMISES OF UNIVERSITY OF MAIDUGURI, BORNO STATE, NIGERIA

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ABSTRACT

This study is on rainwater harvesting for water conservation in University of Maiduguri where both primary and secondary data were used. Rainfall data was obtained from Nigerian Metrological Agency (NIMET), and rainwater was captured, directed and collected in a research reservoir using U-shaped gutters and 4''PVC pipes, 45° and 90° elbows and "tees". The water harvested per rainfall event was gauged using a dipping stick calibrated at 10cm. The water collected using the research reservoir in the month of July alone (9850.1 liter per day)is 157602liters can be used in the building for over a year which is about 128% of the water use. This is because the water requirement by the building is just about 561 liters per day which is equalto 123420 liters annually. Meanwhile, the estimated water harvested using half the roof of the, that is 9125.2 liters per day is 547513.3 liters annually. This water can be used in the building for about three years and four months. Having considered the month with highest rainwater harvested (227168.4liters), an 8mx7mx5m = 280m^3 (280000 liters) capacity reservoir can contain the water harvested since the water is going to be used as it is captured. With good arrangement of the rainwater harvesting system and adequate reservoir that can contain the annual rainfall from the roof of the new Geography Complex, the rainwater captured from the roof of the building can serve the water need of the office complex and even beyond. The study recommends that: Building plans should have roofs with gutters of same materials as the roof so as to encourage rainwater harvesting without compromising the aesthetic value of buildings, all institutions and houses (public or private)with large buildings should be constructed with facilitiesneeded for harvesting rooftop rainwater, so as to reduce water scarcity, conserve water and the entire ecosystem, further research should be conducted on the quality of water harvested and the various uses the water can be effectively put to.

KEYWORDS: *Rainwater harvesting, conservation, rooftop, rainfall, reservoir*

1.0 INTRODUCTION

Water conservation has become an essential practice in all regions, even in areas where water seems to be abundant. In addition to saving money on utility bill, water conservation helps prevent water pollution and depletion of nearby lakes, rivers and groundwater of local watersheds. In Nigeria, less than 50% of the population was originally provided with piped water due to scarce resources (WHO, 2003).

Many methods have been suggested to increase the sources of water supply; and one of these alternative sources is rainwater harvesting. Rainfall harvesting for rural /urban centers has received little attention in Nigeria (Lade and Oloke, 2015). Rainwater harvesting is a technique of collecting and storing rainwater into natural or artificial reservoirs such as tanks, surface reservoirs and aquifers. Roof top rainwater harvesting mostly using surfaces like–tiles, metal sheets, plastics to intercept the flow of rainwater provides a household with high-quality drinking water and year-round storage. Other uses include water for cooking, bathing, flushing toilets, laundry, gardens, livestock, irrigation and recreations (Shitu *et al.,* 2012).

Water from roofs of buildings during rainy season constitutes a major problem in environmental management through erosion, drainage, flood and surface water pollution. Places like Maiduguri and other major towns within the Chad Basin comprising undulating plains, rain harvest provides an alternative way of managing excess rain water coming from roof of buildings and also serves as a means of floods and erosion control (splash and concentrated erosion) or a major type of land conservation that reduces water stagnation caused by inundations, inadequate run-off sewer systems and other problems of surface water management within the environment. Rainwater harvest also supplements other sources of water like surface and ground water sources, as well as reduces pressure on these sources.

Rooftop Rainwater harvesting technology helps to reduce water stagnation, drainage and erosion problems around the buildings. The greater attractions of a rainwater harvest system are accessibility, low cost and easy maintenance even at a household level (Mwengkahinda*et al.,* 2007). Rainwater harvest has proved to be an affordable and sustainable intervention in areas with dispersed population or where the cost of developing surface or ground water is high (Mati*et al.,* 2006). Rainwater harvest promotes profitable water savings in buildings (Hermann and Schmida, 2000). The research provides a design/construction and estimates and or analysis for rainwater harvesting from roof of The New Geography Department Complex (NGC) of University of Maiduguri in Borno State, Nigeria, as a concept of water conservation through rainwater harvesting in the University of Maiduguri.

1.1 Rainwater Harvesting

The collection of rainwater is known by many names throughout the world. It ranges from rainwater collection to rainwater harvesting to rainwater catchment. In addition, terms such as roof water collection or rooftop water collection is also used in other countries. (Mati *et al.*, 2006).According to Habitats (1992), 1mm of rainfall on a square meter of roofed area (corrugated iron sheets) gives 0.8 liters of water on the average after allowing for evaporation. Thus, to calculate the average rain that can be harvested per day in liters per day, the following relation is used:[Area of house roofed multiplied by monthly total rainfall/number of days in a month]0.8 and this gives the average rain that can be harvested per day in liters per day (l/d) (Habitats, 1992).

Rain water harvesting has become a worldwide practice to meet the increasing demand for fresh water. In Nigeria it is widely practiced mostly in the southern part as the rainfall is widespread for over 8 months in a year with mean intensity of 1800 to 2200 mm. Rain water harvesting is practiced at individual level, household level, community level and occasionally at local or state government level to augment the dwindling water supplies to urban centers (Sridhar *et al.,* 2001).

1.2 Water Resources Conservation

The goal of water conservation effort is to ensure the availability of water for future generations through the regulation of the withdrawal of fresh water from ecosystem that do not exceed the natural replacement rate; ensure conservation of energy as water pumping delivery and waste water treatment facilities consume a significant amount of energy (in some regions of the world over 15% of total energy consumption is devoted to water management); ensure Habitat conservation by minimizing human water use which help to preserve fresh water habitats for local wildlife and migrating water fowl (Vickers, 2002).

Water conservation can be achieved through the use of water saving technologies which include: Rainwater harvesting; low-flow shower heads sometimes called energy-efficient shower heads as they also use less energy; low-flush toilets and composting toilets; dual flush toilets (use up to 67% less water than conventional toilets); faucet aerators (which breaks water flow into fine droplets to maintain "wetting effectiveness"); raw water flushing (where toilets use sea water or non-purified water) (USEPA, 2010).

1.3 Rainwater harvesting in Nigeria

Rainwater harvesting has become a worldwide practice to meet the increasing demand for fresh water. In Nigeria, it is widely practiced mostly in the Southern part as rainfall is widespread for over 8 months in a year, with mean intensity of 1800 to 2200 mm. Rainwater harvesting is practiced at individual level, household level, community level and occasionally at local or state government level to augment the dwindling water supplies to urban centers (Sridhar *et al.,* 2001).

The inadequacy of public water system in urban areas and the ineffective functioning of water facilities in urban areas of Nigeria have made it impossible for most of the population to have access to sufficient potable water. About 52% of Nigerians do not have access to improved drinking water supply (Orebiyi *et al.,* 2010).

1.4 Aim and Objectives

The aim of the research is to use the concept of rainwater harvesting for water resource conservation in University of Maiduguri. Other objectives of the study are to:

i. Quantify the volume of rainwater harvested per rainfall event;
ii. Quantify the volume of rainwater draining from the New Geography Complex(NGC) roof the rainy season;
iii. Design collection and storage facilities for conserving the rainwater for period of scarcity (dry periods) and;
iv. Estimate the duration of the per capita consumption for dry (scarce) period of a hydrologic year for the NGC.

2.0 Methodology

2.1 Types of Data acquired

Rainfall data, water quantity estimated, per capita water use/requirement of the household, roof size/area = 836.1m^2(a gabbled roof with each of the two sloping sides equal to 6.78m and length equals to 61.66m), size/volume of storage tank/reservoir required (based on the average volume of rainfall for the wettest month).

2.2 Sources of Data Collected

The primary data–volume of water harvested and per capita consumption were obtained from the research reservoir constructed using dipping stick and the information generated using the interview conducted by this research, while the secondary data–Rainfall and population records, roof plan of the building were obtained from the Nigerian Meteorological Agency, Department of Geography and Physical Planning Unit of the University of Maiduguri respectively.

2.3 Sampling Technique and Procedure

Random sampling was used in population and per capita water use estimation and information on the external toilets usage using interview conducted on 10 respondents (Lecturers in the University, with toilets in their individual offices), while purposive sampling was used in the estimation of rainfall and the corresponding water quantity harvested monthly and for the whole rainy season in 2015.

3.0 Methods of Data Analysis

3.1 Rainwater Harvesting System Settings

The rainwater from the atmosphere falls on the roof of the building was intercepted by U-shaped ceiling gutters(3” in size) which discharges into 4” PVC Pipes/downspouts constructed vertically on the building columns spaced at 3.7meters each using an orifice created on gutter at each downspout point. The vertical pipes/downspouts are also connected to horizontal pipes of the same diameter using (4”) 45° and 90° elbows and Tees” which finally empties into the reservoir.

Figure 1: Elevation of the building showing the Rainwater Harvesting System

(Source: Field measurement data)

3.2 Storage of Harvested Water

A research reservoir of volume 25.75m^3 (25750 liters) was constructed. The reservoir has two compartments (lower and upper) of depths 0.9m and 1.6m, and volumes 2.646m^3(2.1mx1.4mx0.9m) and 23.1042m^3(3.8mx3.8mx1.6m) respectively. The reason for the two components is that; there was an existing reservoir which was expended to collect more water for the research purpose. A dipping stick was used for measuring the water harvested per rainfall event.

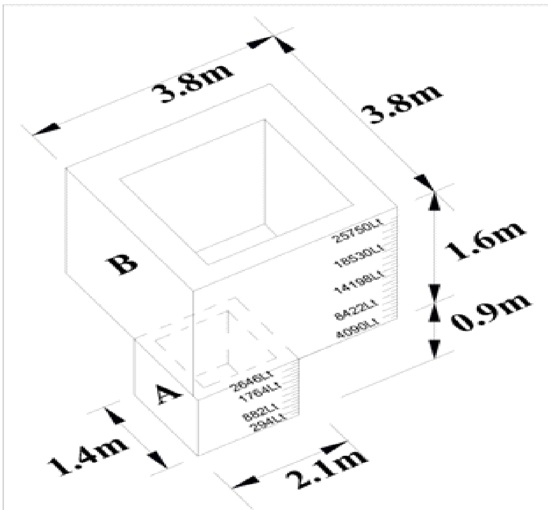

Figure 2: Showing graphic picture of the double cell ground reservoir and calibrations/dimensions
(Source: Field measurement data)

3.3 Dipping Stick Calibrations for the Research Reservoir

The research reservoir has two compartments (lower and upper) of depths 0.9m and 1.6m, and volumes $2.646m^3$(2.1mx1.4 mx0.9m) and $23.1042m^3$(3.8mx3.8mx1.6m) respectively. Each calibration is at 10cm meaning for 0. 9m depth of lower reservoir there are 9 graduations and for the 1.6m depth of upper reservoir there are 16 graduations each showing the volume of water collected.The following relation is used to obtain water volume at each level:

Vol_n= Vol_{n-1} + Total Vol/9 for the lower reservoir andVol_n= Vol_{n-1} + Total Vol/16 for the upper reservoir.

Where n = number of graduation from the foot of the stick,

n-1 number preceding n,

9 and 16 are number of times each volume is divided for easy estimate of fractions (for example; a level that is greater than 3 full graduation and less than 4, a rule/tape is used to measure the fractional value, say 7, and the volume of water at that 3.7 level will be that of 3^{rd} + 7/10 of the 4^{th} graduation).

Below are the estimates of the calibrations to obtain the volume in m^3 and liters of water at each graduation for the lower and upper research reservoirs using the above formulae:

a) Lower reservoir;
$Vol_1 = Vol_{1-1} + 2.646/9 = Vol_0 + 0.294 = 0.294m^3$ = 294 liters and down to
$Vol_9 = Vol_8 + 0.294 = 2.646m^3$= 2646 liters

b) Upper reservoir;
It is important to note that the lower reservoir must have been filled to the brim before having anything in the upper reservoir. Therefore, to get Vol_1 of the upper reservoir, a value ($2.646m^3$ or 2646 liters) equal to the volume of the lower reservoir is added. Hence;
$Vol_1 = Vol_{1-1} + 23.104/16 = Vol_0 + 1.444 + 2.646 = 4.09m^3$ = 4090 liters
$Vol_{16} = Vol_{15} + 1.444 = 25.750m^3$ = 25750 liters.

Volumes A and B (Figure 2).

Volume A = 1.2m x 1.4m x 0.9m = $2.646m^3$ = 2646 liters

Volume B = 3.8m x 3.8m x 1.6m = $23.104m^3$ = 23104 liters

Total Volume = 2.646 + 23.104 = 25 $75m^3$ = 25750 liters

3.4 Rainfall and Rainwater Harvest Analysis

The amount of rainwater that can be harvested from a corrugated iron

Sheet roof can be estimated using the model given by Habitat (1992):

$H_w = (A_b.R_m/N_d)$ 0.8 in liter/day

Where: H_w = Harvested rainwater from a roof surface in liter/day

A_b = Area of building roof in m^2 = 177.1 m^2

R_m = Amount of rainfall in a month in mm

N_d = Number of days in a month

0.8 = Constant of 1mm rainfall harvest minus evaporation.

Estimates are shown in chapter four.

4.0 RESULTS AND DISCUSSIONS

4.1 Monthly Rainfall Records for 2015

Table 1: Monthly Rainfall Records for2015

S/N	Month	Rainfall(mm)
1.	January	0.0
2.	February	0.0
3.	March	0.0
4.	April	5.7
5.	May	5.8
6.	June	133.5
7.	July	271.1
8.	August	185.7
9.	September	192.4
10.	October	26.5
11.	November	0.0
12.	December	0.0
Total		821.3

(Source: NIMET Maiduguri Station)

The rainfall is distributed within the span of 7 months with June, July, August, and September having the highest amount. The month of July is the peak having an average intensity of 271.7mm.

4.2 Results of Rainwater Harvest

Table 2: Rainfall and corresponding water Harvested Using the Research Reservoir:

Month	Rainfall (mm)	Water
July	271.7	157602
August	185.7	88694
September	192.4	113676
Total	649.8	359972

From the result, about 79.1% (649.8/821.3 x 100) of the 2015 rainfall (821.3mm) was captured within the 3 months = 359972 liter. It is important to note that part of the water to be harvested is lost due to splashing, evaporation, overshooting gutters, leaking gutters/pipe and absorption of water by the research reservoir(due to honey comb/porosity), but the records were taken immediately before and after each rainfall to reduce some of the losses.

It is impossible to collect 100 percent of the rainfall from a surface due to splashing, Evaporation, overshooting gutters, leaking gutters/pipes and first flush diverts. Therefore, it could be deduced from the result that, each 1mm rain falling on the roof of the NGC provides 438.3 liters of water. Also, since there are 35 rainy days in the three months of July, August and September (79.1% of the season), it can be deduced that 10284.9 = 359972/35 liters per rainy day of water was captured using the research reservoir.

Table 3: Rainfall and corresponding Estimate of water Harvested forv2015 Rainy Season using Habitat (1992) Model

Month	Rainfall (mm)	Water Harvested(l)
April	5.7	3812.6
May	5.8	3879.5
June	133.5	89295.4
July	271.7	227168.4
August	185.7	155263.8
September	192.4	160865.6
October	26.5	22156.7
Total	921.3	662442

From the result, it can be seen that 662442 liters of water was estimated for the 2015 rainy season with a rainfall intensity of 821.3mm. This implies that each 1mm of rainfall gives 666.6 liters of water. This also implies that 11040.7 liters per day equivalent to 3011.1liters per day was estimated to have been harvested using the Habitat (1992) Model from the NGC roof.

4.3 Design of Gutter and Ground Reservoir for prospective water Harvest

From the rainfall records obtained, the month of July has the highest rainfall of 271.7mm and rainwater harvested was 157602 liters (practically) and 227168.4liters (theoretically). Therefore, an 8m x 7m x 5m reinforced concrete reservoir with a capacity 280 m^3 (280000 liters) can contain the rainwater harvested, Meanwhile, a ground reservoir of total volume 25.75m^3 = 25750 liters of double compartments (upper and lower) with a volumes 2.646$m^3$and 23.104m^3 was used for the research. It is important to note that structural and hydraulic analysis/design should be carried out for the reservoir. A u-shaped gutter of the same material as the roof was used to collect, direct, and discharge the roof water in to vertical pipes (4" diameter) for aesthetics and economy as it also serve as the eve angle the roof.

4.4 Population and Per Capita Requirements Estimations

Based on estimates of basic water requirement carried out by W.H.O, a minimum of 50 liters per capita per day (l/c/d) was recommended to take care of basic food hygiene, laundry/bating under most conditions. Lactating mothers will require taking 7.5 liters per day in order to maintain their diet requirement, depending on weather condition in the different parts of the world. This water needs to be of a quality that represents a tolerable level of risk. However, in an emergency situation, a minimum of 15 liters is required, 15 l/c/d for bathing, and 10 l/c/d for cooking/food preparation (Howard and Bartram, 2003).

Table 4: Estimates of water requirement for the NGC

Respondent	1	2	3	4	5	6	7	8	9	10	Mean
A(liters/day)	15	15	15	30	15	15	15	15	30	15	18
B(liters/day)	0	0	0	15	0	0	15	15	0	0	4.5
C(liters/day)	60	100	50	60	80	60	100	80	100	70	76
D(liters/day)	25	40	30	40	20	25	30	25	35	80	35

The NGC has staff strength of 32 and student population of about 570. There are 20 offices with toilets and two external toilets for male and female students and/visitors. An interview was conducted by this research on 10 respondents (about 50% of the staff strength) and the relation below was used to obtain the total water requirement for the building in liters per day:

That is, water use of the building = [(Mean of A + mean of B) 20 +mean of C +mean of D]

Where A = water need for office users (l/d)

B = water requirement for visitors using office toilets (l/d)

C = water requirement for external toilets in (l/d)

D =water requirement for other uses (l/d).

The capacity of the toilet flush tank for the NGC is 0.015 m^3 = 15 liters. This value was used to arrive at the approximate estimates carried out in the interview.

Total water requirement for the building in liters per day = (18+4.5) 20 + 76 + 35

= 450 + 76 + 35

= 561 liters/day

= 123420 liters annually.

The annual water requirement of the building is obtained from 561 x 220. Where 220 = the number of working days in a year in Nigeria after removing weekends and publicholidays.

5.0 CONCLUSION

Benefits such as reduced dependency on other conventional water sources like dams/water treatment plants, wells and boreholes (which means reduced amount of stress on such other sources and the elimination of the need to expand them due to the increasing population) are some of the reasons why Rainwater Harvesting should be encouraged.

About 79.1% (649.8/812.3 x 100) of the 2015 rainfall (821.3mm) was captured within 3 months of July, August and September which gives 359972 liters and there are 35 rainy days in the 3 months. It can be deduced that 10284.9 liters = 359972/35 liters per rainy day = 3912.7 liters per day of water was harvested using the research reservoir. Also, each 1mm of rain falling on the roof of the New Geography Complex, provides 438.3 liter of water. 123420 liters of water annually, equivalent to 561 liters per day is required for use in the building. In the month of July alone, 157602 liters of water was harvested using the research reservoir. This quantity of water provides about 128% of the water requirement of the NGC. On a final note, this quantity serves the building for well over a year. Lastly, zero runoff should be our goal as water is one of our most precious resources and yet we allow it flow away.

6.0 RECOMMENDATIONS

i. Institutions and houses (public or private) with large buildings could be constructed with facilities needed for harvesting rooftop rainwater so as to reduce water scarcity, conserve water and ecosystem especially in Arid and Semi-Arid regions.

ii. Building plans should have roofs with gutters of same materials as the roof so as to encourage rainwater harvesting without compromising the aesthetic value of buildings.

iii. Structural and hydraulic design/analysis should be conducted when using reinforced concrete ground reservoir for safety, economy and increased life span of the structure.

iv. If PVC tanks are used it should be buried in the ground durability. A small bucket with rope or pump (manual or automated) should be used to lift water from the ground reservoir and covers provided for hygiene.

v. The well head (reservoir head) should be raised at least 1m above the ground to avoid contamination with spilled/splashed water.

vi. Further research should be conducted on the quality of water harvested and the various uses the water can be effectively put to.

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Table 5: 2015 Daily Rainfalls of Maiduguri Metropolis

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	TR	0.0	0.0	18.6	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	7.2	7.5	6.4	0.0	11.7	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.1	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	17.0	28.9	0.0	19.8	8.1	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	7.02	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	7.5	26.0	0.0	0.0	3.4	0.0	0.0
7	0.0	0.0	0.0	0.0	TR	10.6	0.0	6.04	12.3	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	5.36	10.7	0.0	2.1	0.0	0.0
9	0.0	0.0	0.0	0.0	2.3	0.0	14.81	12.3	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	TR	0.0	0.0	0.0	1.2	0.0	0.0
11	0.0	0.0	0.0	TR	TR	50.2	4.17	0.0	0.0	TR	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.6	0.0	TR	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	7.7	0.0	16.9	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	2.8	0.0	15.2	33.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	5.4	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	TR	0.0	32.8	0.0	0.0	TR	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	23.32	11.5	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	1.6	0.0	10.1	0.0	0.0	33.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	15.42	0.0	39.8	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	15.84	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	2.1	0.0	11.9	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	TR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	15.7	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.6	6.6	25.12	23.3	5.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	2.8	0.0	4.2	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0. 0	0.0	1.8	0.0	24.9	0.0	5.0	0.0	0.0	0.0
30	0.0	0.0	0.0	1.3	1.1	2.1	0.0	15.1	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	TR	0.0	24.79	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	5.7	5.8	133.5	271.7	185.7	192.4	26.5	0.0	0.0

(Source: NIMET, 2015)

Table 6: Rainwater Harvested in July

S/N	Date	Day	Water harvested(l)
1	02/07/2015	Thursday	4334
2	O4/07/2015	Saturday	7311
3	04/07/2015	Saturday	9898
4	05/07/2015	Sunday	4044
5	06/07/2015	Monday	14953
6	08/07/2015	Wednesday	3085
7	09/07/2015	Thursday	8533
8	11/07/2015	Saturday	2982
9	18/07/2015	Saturday	18896
10	19/07/2015	Sunday	13432
11	21/07/2015	Tuesday	8882
12	22/07/2015	Wednesday	9122
13	25/07/2015	Saturday	9045
14	26/07/2015	Sunday	14469
15	29/07/2015	Wednesday	14338
16	31/07/2015	Friday	14278
Monthly total			157602

(Source: Field work, 2015)

Table 7: Rainwater Harvested in August

S/N	Date	Day	Water harvested
1	02/08/2015	Sunday	3690
2	07/08/2015	Friday	3481
3	08/08/2015	Saturday	6178
4	09/08/2015	Sunday	7646
5	12/08/2015	Wednesday	13594
6	13/08/2015	Thursday	9742
7	15/08/2015	Saturday	8759
8	19/08/2015	Wednesday	6613
9	23/o8/2015	Sunday	6874
10	26/08/2015	Wednesday	13438
11	30/08/2015	Sunday	8679
Monthly total			88694

(Source: Field work, 2015)

Table 8: Rainwater Harvested in September

S/N	Date	Day	Water
1	1/09/2015	Tuesday	10684
2	03/09/2015	Thursday	15016
3	04/09/2015	Friday	11406
4	07/09/2015	Monday	7074
5	15/09/2015	Tuesday	18987
6	20/09/2015	Sunday	18987
7	21/09/2015	Monday	25750 (spills)
8	26/09/2015	Saturday	2896
9	29/09/2015	Tuesday	2876
Monthly Total			113676

(Source: Field work, 2015)

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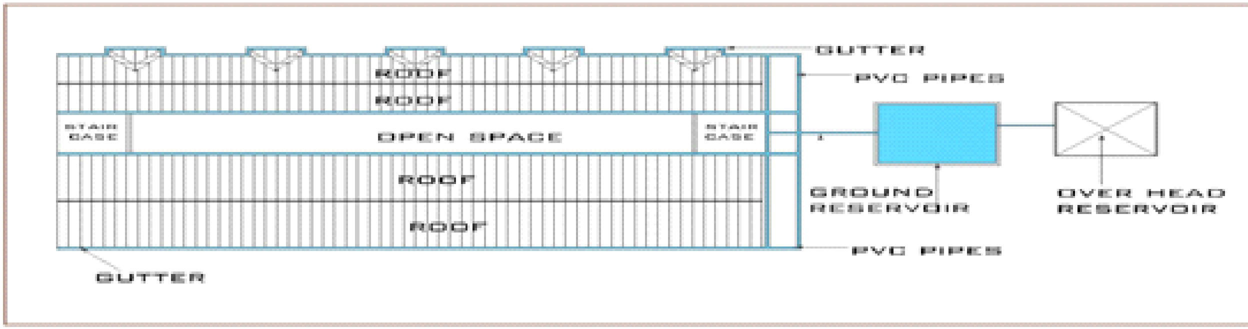

Figure 2: Plan of the building used for the research

(Source: field measurement data)

Table 3.1 Monthly rainfall of Maiduguri from 2001 to 2015

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2001	0.0	0.0	0.0	TR	37.1	119.3	110.1	244.4	216.8	TR	0.0	0.0
2002	0.0	0.0	0.0	2.2	0.0	49.7	11.4	178.6	125.8	26.4	0.0	0.0
2003	0.0	0.0	0.0	4.3	12.8	89.1	202.3	251.1	79.0	14.7	0.0	0.0
2004	0.0	0.0	0.0	0.0	60.9	69.5	124.9	307.3	41.7	11.8	0.0	0.0
2005	0.0	0.0	0.0	0.0	25.0	75.2	124.8	209.9	294.3	107.5	54.4	0.0
2006	0.0	0.0	0.0	TR	38.7	78.9	155.3	156.9	82.8	34.2	0.0	0.0
2007	0.0	0.0	0.0	1.6	32.0	371.6	252.6	185.5	24.6	0.0	0.0	0.0
2008	0.0	0.0	0.0	0.0	26.1	82.3	155.4	264.4	68.9	TR	0.0	0.0
2009	0.0	0.0	0.0	7.6	30.7	10.2	79.1	185.7	210.9	81.7	0.0	0.0
2010	0.0	0.0	0.0	4.8	1.6	138.8	251.7	96.4	141.0	26.5	0.0	0.0
2011	0.0	0.0	0.0	2.7	32.6	93.6	138.2	198.6	157.4	1.9	0.0	0.0
2012	0.0	0.0	0.0	4.8	70.6	66.7	212.9	71.2	17.3	0.9	0.0	0.0
2013	0.0	0.0	0.0	0.0	2.0	10.7	100.0	70.9	48.8	1.6	0.0	0.0
2014	0.0	0.0	7.5	TR	1.6	29.8	126.5	96.0	43.8	0.0	0.0	0.0
2015	0.0	0.0	0.0	5.7	5.8	133.5	271.7	185.7	192.4	26.5	0.0	0.0