

## RAIN WATER HARVESTING AND STORAGE DESIGN FOR HOUSE HOLDS: CASE STUDY OF GIREI, ADAMAWA STATE, NIGERIA

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### Abstract

*Harvesting of rainwater has been in practice for years by both rural and urban dwellers. The aim of the research is to design a storage structure for rainwater harvest for household in rural areas of Girei. The average annual rainfall in the catchment area is about 765 mm. Rainwater harvesting requires a roof catchment area, conveyance systems, (gutters, screen, first flush and pipes), and a storage tank. The reason for this design is to make water available to rural households during low trough and no-rainfall for immediate domestic demand. When rain starts during raining season, rain drops on the roof catchment, through the gutter of 3.5 m and it's channeled through the screen funnel; for the first few minutes rain is conveyed through the first flush. Rain water that contains bird droppings, dirt's, and tiny leaves and stick particles. When it's filled it starts to convey clean water to the storage tank of about 11.25 m<sup>2</sup> for future use with 7.5 m<sup>2</sup> as the area of the reservoir, 1.4 m as the width, 5.5 m as the length and 1.7 m depth considered. This design applied appropriate technology to suit the rural dwellers. In this work, the ease of having immediate domestic water supply, rather than walking considerable distance while having low financial expenses has been achieved. The cost of constructing the storage system is approximately one hundred and twenty four thousand naira only; this amount is affordable for the family six.*

**Key words:** Rainwater harvesting, catchment area, storage tank, rural areas, water supply

### 1.0 Introduction

Water that is easily available and affordable is a prerequisite to good hygiene, sanitation and essential to the general welfare of all living things. In addition, access to a safe drinking water and sanitation is fundamental to gender equity with 71% of household water collected by women or girls [1]. Millions of people throughout the world do not have access to clean water for domestic purpose. In many parts of the world conventional piped water is either absent, unreliable or too expensive. One of the biggest challenges of the 21<sup>st</sup> century is to overcome the growing water demands which led to rain water harvesting (RWH). RWH has thus regained its importance as available alternative or supplementary water resource, along with more convectional water supply technologies [2]. Potential water shortages can be relieved if rainwater harvesting is practiced more widely.

Rainwater harvesting is a simple low cost technique that requires minimum specific expertise or knowledge and offers many benefits. Collected rain water can supplement other water sources when they become scarce or are of low quality like polluted surface water in the rainy season. It also provides a good alternative and replacement in times of drought or when the water table dropped and wells go dry [3, 4]. One should, however, realize that rainfall itself cannot be managed. Collected rainwater is a valuable supplement that would otherwise be lost by surface run off or evaporation, particularly in Adamawa State, Nigeria.

During the past years, rainwater harvesting has been re-introduced by local organizations as an option for increasing access to water in currently underserved areas (rural and urban). Unfortunately decision makers, planners, engineers and builders often overlook this action. The reason that RWH is rarely considered is often simply and due to lack of proper information on feasibility on both technical and otherwise [5]. During the past decades the technology has, however, quickly regained popularity as users realize the benefits of a relatively clean, reliable and affordable water source at home. In many areas, RWH has been practiced locally as part of the integrated water supply, where water supply is unreliable, or where local water sources dry up for a part of the year season. But rainwater harvesting can also be introduced as the sole source as it is flexible and adaptable to a very wide variety of conditions.

In Africa, rainwater harvesting projects have increased in recent years due to the increased number of polluted or dried out bore holes and wells or neglected water supplies in rural communities [6]. In Kenya, several rainwater harvesting projects have been established by the United Nation and the Catholic diocese. However, according to [7] the growing aridity and unpredictable climate in South Africa makes rainwater unsuitable; therefore only 1% of domestic water is supplied through rainwater harvesting.

Due to problems of both ground and surface waters, and the overall increased demand for water resources due to population growth of the study area, the communities in the area are approaching the limits of their traditional water resources. Therefore they have to turn to alternative or supplementary water resource. The problem situation becomes significant because solutions to them will in no small measure relieve people of the drudgery associated with collecting water from distant sources. Therefore, an examination of these problems will certainly help the people in knowing the amount of rainwater to be collected for use during dry season.

Adamawa State is blessed with rainfalls that vary from 765 mm per annum in the Northern parts to 2000 mm in the Southern parts [8]. Despite the high rainfall, water supply is still not enough in all the Urban and rural areas [8]. The aim of this project is to determine an appropriate rainwater harvesting system for domestic use in Girei Local Government Area of Adamawa State, Nigeria.

## **2.0 The Study Area**

The research area Girei, falls in the tropical climate of the country. It falls between (Latitude  $9^{\circ} 20'$  to  $9^{\circ} 27'N$  and longitude  $12^{\circ} 23'$  to  $12^{\circ} 27'E$ ) as shown in Figure 1. It has monthly mean sunshine of about 220 hours from January to April, but decrease to a mean value of 207 hours between May and September due to increasing cloud covers. The mean sunshine hours increases again to about 255 for a period between October and December. The average sunshine hours for the year stand at about 2750 hours approximately [9]. Upper Benue Valley has a tropical climate characterized by two distinct seasons. The two seasons are influenced by the inter tropical convergence zone (ITCZ). The movement of the ITCZ either to the north or South determines the occurrence of the rainy and dry seasons. Rainfall in upper Benue Valley starts from March and ends in October which implies that rainfall in Upper Benue lasts for eight months with peak rainfall in August and September; while March, April and October has low rainfall data [9]. The minimum rainfall experienced is 671.4 mm, while the maximum total rainfall data is 1,055.9 mm.

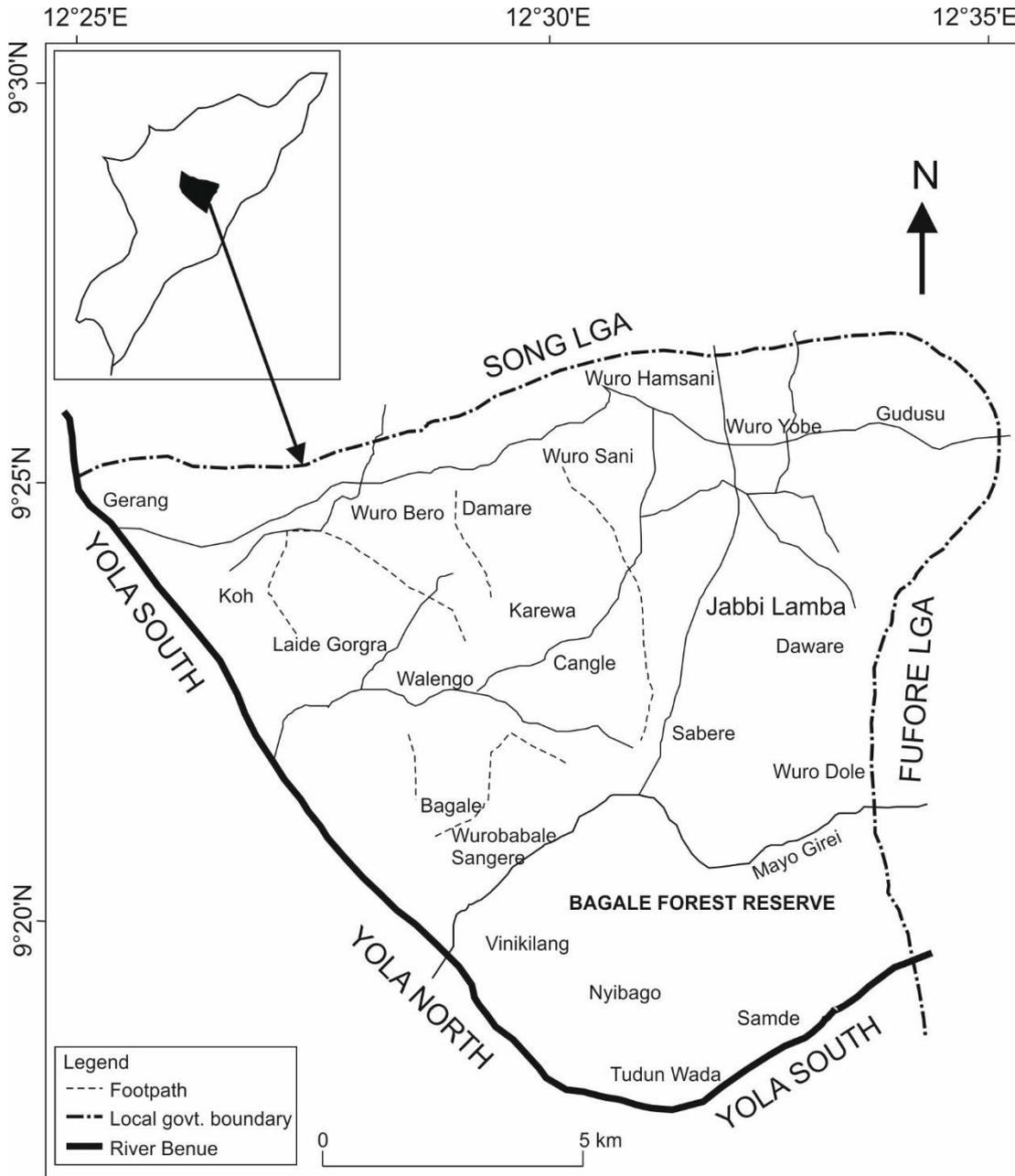


Figure 1: Map showing the study area

### 2.1 Rainfall variability in the study area

Figure 2 shows the total annual rainfall distribution over the research area. The wet period occurs from May to September with over 700 mm rainfall. The peak is usually recorded during the July – September period. The dry period occurs from November to April. The total annual precipitation of the area is on average 602 mm (taken over the period 2000 to 2015). The higher rainfall rate is observed between June and October each year; while the rest of the months are virtually dry (November to May). This will result in understanding the amount of water to be harvested in the research area.

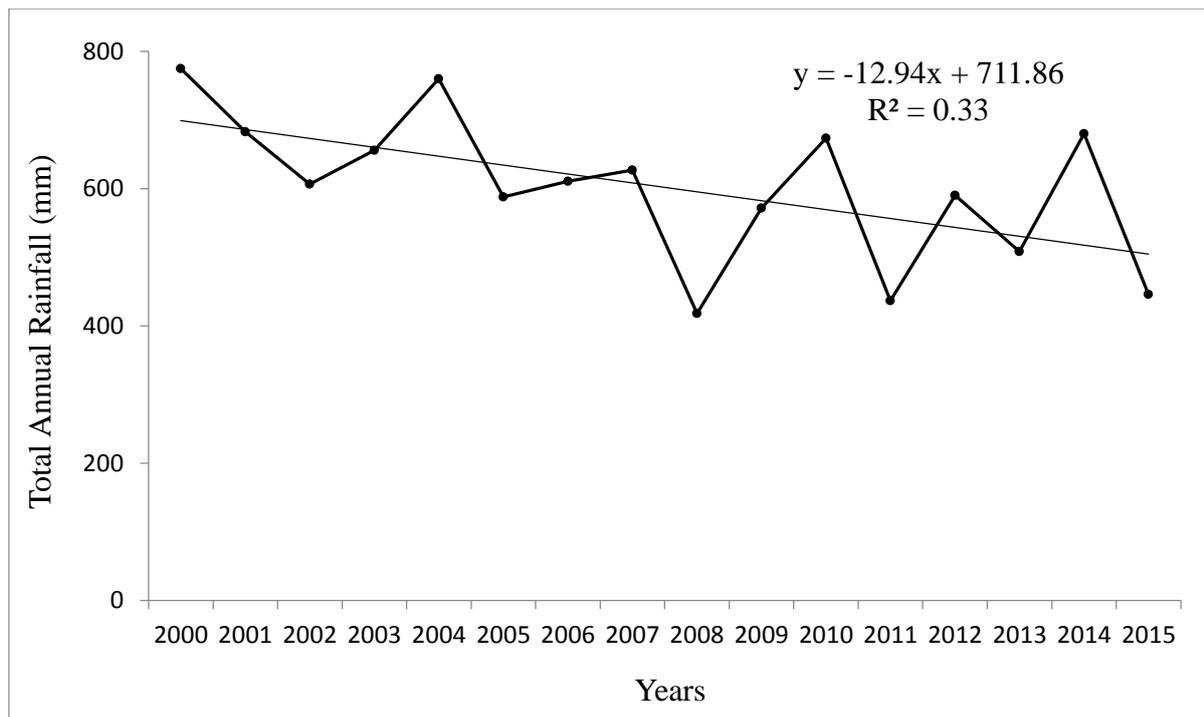


Figure 2: Rainfall variability for the period 2000 to 2015 in the research area

The variability of the precipitation over the research area shows that the rainfall is decreasing over the years, however, the variation is negligible with the  $R^2$  of 0.33. Similar climate variability was assessed by [10, 11] on the River Benue Basin, north eastern Nigeria, they observed similar pattern.

### 3.0 Material and Methods

The methods adopted in this research includes field measurement of roof catchment areas of houses, household interviews using a pre designed questionnaire, data analysis of past rainfall data and roof catchment design of the study area from Physical Planning Unit of the Modibbo Adama University of Technology (MAUTECH), Yola.

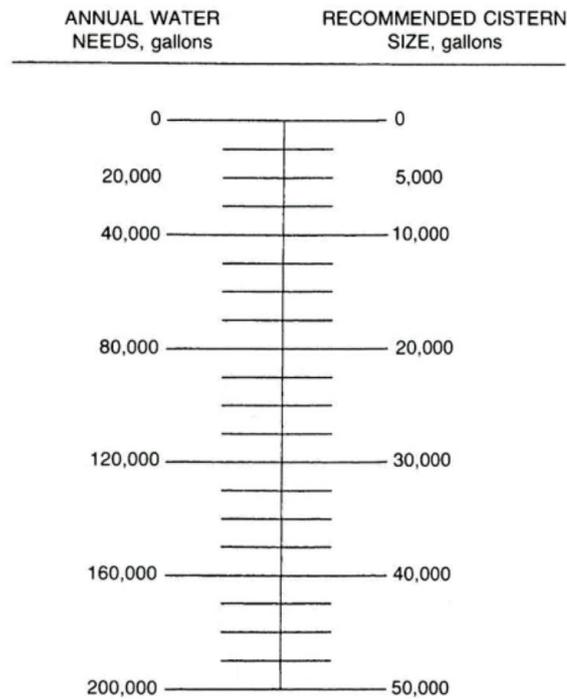
A study of water resources and storage practices was carried out at Girei local government area, to determine the sources of water and to assess the existing rainwater harvesting as well as water storage practices and information on quality and quantity of rainwater stored. A total of fifty households were randomly sampled, and responses to questions on a variety of issues included socio economic data, water collection and storage practices, rainwater harvesting and health related issues. Sixteen years (2000-2016) rainfall data for Girei in the tropical district was collected from the Geography Department of MAUTECH, Yola and analyzed.

Two basic sources of data collection used in this study, included the primary and secondary sources. The primary sources of data comprise of information collected from the people by means of administered questionnaires and oral interviews, where necessary. In this case, the people where consulted in the evenings because at such time, they would willingly provide answers to the questionnaires. In view of the fact that some of these people are illiterates, each of the questionnaires was interpreted to each person in the language he/she understood.

The secondary source of data included all relevant information concerning the study area that is in printed form. These include rainfall data, location map of the area and roof

catchment design. Table 1 provided the calculation for the sufficient storage capacity to carry a household through extended period of low rainfall.

Table 1: Reservoir Design Storage Capacity Ranges



### 3.1 Reservoir Design

From reservoir design storage capacity shown in Table 1. Annual water needed for a family of six is 45,000 gallons estimated as 11,250 gallons required. The volume of the reservoir computed as 11.25 m<sup>3</sup>. The reservoir area was estimated to be 7.5 m<sup>2</sup>. Reservoir length was estimated as 5.48 m. the reservoir depth was computed as 1.7 m. therefore, the Dimension = Length x Width x Depth = 5.5 x 1.4 x 1.7 = 13.09 m<sup>3</sup>.

### 4.0 Results

If the motive power to drive the fluid through the pipe is available free, for instance when the pressure is let down from one vessel to another or if there is sufficient head for gravity flow, the smallest pipe diameter that gives the required flow rate would normally be used. However, if the fluid has to be pumped through the pipe, the size should be selected to give the least annual operating cost. Standard typical pipe velocities and allowable pressure drops were used to estimate pipe sizes [13, 14, 15].

The height of the building (from the gutter to the ground) = 3 m = 3000 mm, while gutters and downpipe slopes towards the inflow, was calculated for the gutters using a 0.3% slope as the minimum requirement at 3 mm per meter.

A gutter length of 7.0 mm was added to the slope down pipe of 57 mm. Adding 15 mm for the distance from the gable wall to the reservoir inflow, resulting in 75 mm for the imprecise workmanship, measuring gutter etc. we arrived at a total of 100 mm.

Deducting from the height (3000-100 = 2900 mm) gives the gap between the reservoir and the ground level as 600 mm. The total height from the roof was computed as 2.30 m. Since the water falls due to gravity, the diameter of pipe required is 0.15 m. The reservoir was placed at 1.5 m from the building. Thus, the total height calculated plus length from the

T-connector to the elbow-connector is 3,050 mm. Table 2 shows the dimensions of rain water conveyance system.

Table 2: Dimensions of rain water conveyance system

S/No	Dimensions	Measurements
1	Volume of Reservoir	11.25 m <sup>2</sup>
2	Area of Reservoir	7.5 m <sup>2</sup>
3	Depth Considered	1.7 m
4	Width of Reservoir	1.4 m
5	Length of Reservoir	5.5 m
6	Gutter Length	3.5 m
7	Diameter of Pipe	0.15 m
8	Total Length of Pipe	3.05 m
9	Reservoir Placement away from the building	1.5 m

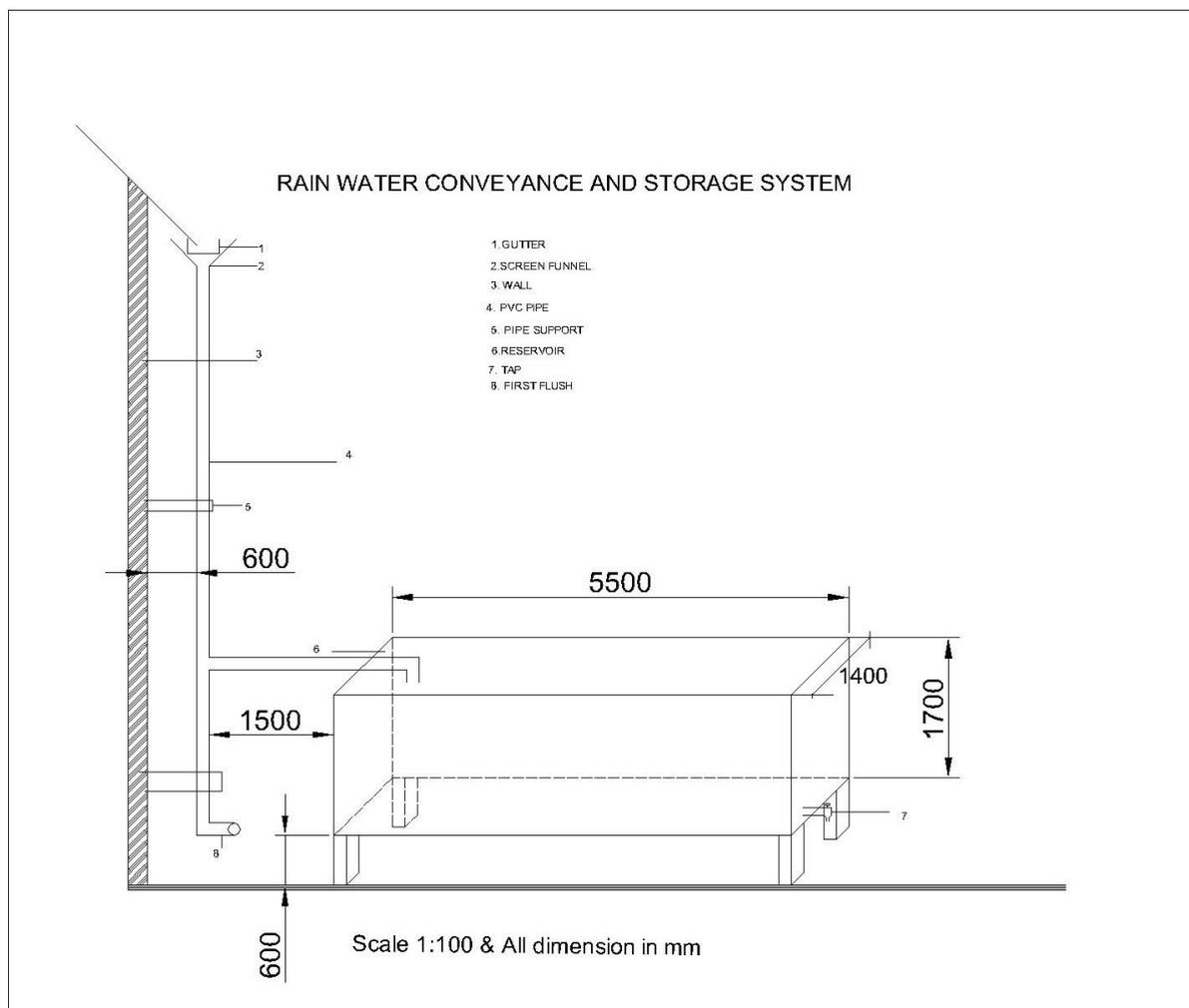


Figure 3: Sketch of rain water conveyance and storage system

Table 3 shows the cost of constructing the rainwater conveyance and storage system for the households.

Table 3: Cost of constructing the rainwater conveyance and storage system

S/No	Material Description	Quantity	Unit cost (₦)	Total cost (₦)
1	Metal sheet 4mm thickness	2.5m	30,000	75,000
2	Angle iron for support 3mm thickness	2.4m	2,500	6,000
3	PVC pipe 0.15mm diameter	3.1m	12,000	37,200
4	Screen	1 yard	1,500	1,500
5	Funnel (fabricated)	1m	1,200	1,200
6	pipe support belt	3 pieces	1,000	3,000
Total				123,900

## 5.0 Discussion

Previous studies by [8], tried the prospects and possibilities of harvesting rainwater in Adamawa. However, this research sought to design a rainwater conveyance and harvesting storage system for rural house hold supply during low trough and no rainfall, with a view to ascertain and the reality of previous studies.

The total annual rain for the period of sixteen years between the high peak of rainfall (May, June, July, August, and September), has been calculated to be 17.1 mm (Department of geography, MAUTECH). However, this has been a reasonable prospect for much quantity of rainwater to be harvested during rainy season [16, 17].

During this design, use was made of simple, available, and low cost storage facilities were suggested adoption by the rural households, for storing the rain water harvested [18]. These rainwater conveyance and storage systems comprise of a gutter, screen funnel, first flush and a PVC pipe that conveys clean water to the painted steel reservoir in order to minimize corrosion. Similar researches were design by [19, 20] on rainwater harvesting in Cambridge London and their results are consistent with the present study. Adoption of this simple design can enable the local dwellers to construct and installed the system for storing rain water during low trough and non-rainy days. The cost of constructing the storage system is approximately one hundred and twenty four thousand naira only; this amount is affordable for the family six.

## 6.0 Conclusion

Water as we know is a resource vital to human existence. Although, some communities may not have any hope of being served by more centralized water supply schemes in the foreseeable future, improvement in the design, organization and overall implementation of rainwater harvesting schemes holds out great hope for rural dwellers. The result of this study showed that, rainwater harvesting has been in practice for years, but the method of collection and the amount of water collected which was not technologically justifiable. The success rate will be high if the result of this research is implemented by the community. The design of 11.25 m<sup>3</sup> of reservoir for the family of six for rural dwellers is relatively cheap due to the choice of storage material which is readily available and can be installed and maintained by the local personnel. The cost of constructing the storage system is approximately one hundred and twenty four thousand naira only; this amount is affordable for the family six people. This is more preferable and offers greater hope than construction using expensive materials and blocks, reinforce concrete with low technical know-how personnel.

## References

1. United Nations (2015). End Poverty 2015 - Millennium Development Goals - make it happen. [www.un.or./millenniumgoals], (accessed 20/08/2010).
2. Barnes, D. A. (2009). Assessment of Rainwater Harvesting in Northern Ghana [Unpublished Master's thesis]. Massachusetts Institute of Technology.
3. Pandey, D.N. Gupta, A.K. and Anderson, D.M. (2003). Rainwater harvesting as an Adaptation to Climate Change. *Current Science*, vol. 86, no. 1, pp. 46 – 59.
4. Ziadat, A.H. (2005). Impacts of storage tanks on drainage water quality in Al-karak Province-Jordan Mu'tah University, Karak-Jordan, *journal of applied sciences*, 5(4).
5. Jawas, M. Al-Ghazali, M.R. and Kharshid, M.S.H. (1988). The effect of domestic storage tanks on the quality of drinking waters. *Environmental Monitor and Assessment*, vol. 11, pp. 79 – 87.
6. Gould, J. and Nissen-Petersen, E. (1999). *Rainwater Catchment Systems for Domestic Supply. Design, construction and implementation.* Intermediate Technology Publications, London.
7. Kahinda, J. and Mwenge (2008). Developing suitability maps for rainwater harvesting in South Africa. *Physics and Chemistry of the Earth*, vol. 33, pp. 788 – 799.
8. Tanko, J.A. and Ankidawa, B.A. (2008). The prospect of rain-harvesting for supplementing municipal water supply in Adamawa State and environs. *Global Journal of Engineering and Technology*, vol. 1, no. 2, pp. 225 – 227.
9. Adebayo, A.A. (1999). Climate: Sunshine, Temperature, Evaporation and Relative Humidity. In *Adamawa State in Maps*, Edited by Adebayo and Tukur, Paraclete Publisher, Yola, Nigeria, pp. 20 – 26.
10. Ankidawa, B.A., Tanko, J.A. and Umar, A.S. (2015). Climatic variability and River Benue discharges in Yola and Garoua, West Africa. *Journal of Environment, Ecology, Family and Urban Studies*, vol. 5, no. 1, pp. 1 – 14.
11. Umar, A.S. and Ankidawa, B.A. (2016). Climate variability and Basin Management: A threat to and from wetlands of Komadugu, Yobe Basin, North Eastern, Nigeria. *Asian Journal of Engineering and Technology*, vol. 4, no. 2, pp. 25 – 36.
12. Midwest Plan Service, Iowa state University (1968). *Private water system*, pp. 1 – 15.
13. Sinnott, R.K. (1999). *Chemical engineering design 3rd edition*, vol. 6, pp. 1 – 217.
14. Lundgren, A. and Akerberg, H. (2006). Rainwater Harvesting. in pre-urban areas of Accra; status and prospects (master's thesis) Royal Institute of Technology Stockholm, Sweden, pp. 27 – 35.
15. Thomas, T.H. and Martinson, D.B. (2007). *Roof water Harvesting: A Handbook for Practitioners.* Delft, the Netherlands, IRC International Water and Sanitation Centre. Technical Paper Series; no. 49. 160p.
16. Pudyastuti, P.S. (2006). Rooftop rainwater harvesting collection, a small scale water supply for domestic water use. *Dinamika Teknik Sipil*, vol. 6, no. 1, pp. 46 – 51.
17. Thomas, T. (1998). Domestic water supply using rainwater harvesting. *Building Research and Information*, vol. 26, no. 2, pp. 94 – 101.

18. Patrick, E. (1997). Assessing Water Harvesting Suitability. Food and Agriculture Organisation (FAO) Corporate Document Repository, Water Report, 16.
19. Pacey, A. and Cullis, A. (1986). Rainwater Harvesting-The collection of rainfall and runoff in rural areas. Intermediate Technology Publications London.
20. Cresti, D. (2007). Analysis and design of household water catchment systems for rural Rwanda [Master's thesis]. MIT University, Cambridge, MA, pp. 41 – 52.