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Development of a Rainwater Tank Sizing Calculator for Rainwater Harvesting Application in Southwest Nigeria

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ABSTRACT

Rainwater harvesting (RWH) as a source of potable water supply is gaining prominence in the South-west Nigeria due to increase pressure on conventional sources of freshwater due to population increase and complexity in lifestyle. Reliability of RWH depends on adequate understanding of water demand, quantity of harvestable water, rainfall pattern and storage. The determination of storage capacities varies from one location to the other and from one house to the other within the same location as a result of variations in in rainfall depth, water consumption, roof material and roof size. A tank sizing calculator is needed. This work was designed to produce a tank sizing calculator for rainwater storage in southwest Nigeria. Rainfall data for a duration of 27 years in selected parts of South-west Nigeria (Abeokuta, Akure, Ibadan, Ikeja and Osogbo) for estimation of rainfall depths and distributions were collected from Nigerian Meteorological Agency, Oshodi, Nigeria. Data on household size, water consumption and roofing material were collected from 2500 randomly selected households in the study area using structured questionnaire. The highest rainfall depths of 196, 180 and 65 mm, respectively for Abeokuta, Ibadan and Ikeja occurred in June while 230 and 222 mm for Akure and Osogbo, respectively occurred in September. Average household size was 9 persons with average water consumption of 55±10 and 70±13 $l/h/d$ during the dry and wet season, respectively. About 69% of the houses have galvanised iron sheet, 28% asbestos and 3% other roofing materials. Roof size varied considerably. Galvanised iron sheet roof areas ($C_r = 0.9$) required to harvest rainwater to be stored for 150 days for household size of 7 in Abeokuta, Akure, Ibadan and Ikeja are 35.36, 28.79, 32.67, 25.51 and 30.86 m^2, respectively. The developed tank sizing calculator is capable of determining roof area to be guttered and storage capacity required at any level of satisfaction desired under different conditions of household size, water consumption, roofing material and roof size.

Key words: *Rainwater, Tank Sizing, Household Size, Consumption, Southwest, Nigeria.*

1. INTRODUCTION

Access to clean and hygienic drinkable water having low pathogen and toxic chemicals in reasonable quantities is important to the individuals and the households in order to curb attacks and eventual death from water-borne diseases (DTU, 2005). There is an acute shortage of freshwater supply for potable purposes in homes due to increase in population, complexities in lifestyle and partial or total failure of conventional methods of water supply. Surface water is heavily polluted with wastes from different origins. Over dependence on groundwater has resulted in saline intrusion and land subsidence. Agricultural and industrial activities are increasing with a view to improving standards of living of the ever increasing human population. This puts a direct pressure on the available water supply from different sources. Many of the conventional sources of water are polluted by agricultu;ral, industrial as well as domestic wastes. Water from such sources is non-potable except after adequate treatments. Over the years, governments and various organisations in the developing countries have tried several options to meet the demand for potable water with little success recorded. Integrated Water Resource Management Scheme is an increasingly popular approach aimed at solving problems associated with competing demands on water resources. Rainwater harvesting (RWH) is one of the identified water resources that should be adequately managed for its various potential uses (Coker, 1999; Lucas *et al*., 2005). RWH is the ancient practice of capturing rain runoff from roofs and other surfaces and storing it for later purpose (Despins *et al.*, 2009). Works have been done on the quality of rainwater for domestic use in Nigeria (Akintola and Sangodoyin, 2011; Akintola *et al.*, 2013a; Akintola *et al.*, 2013b, Abegunrin e*t al.*, 2014). However, there is a dearth of information on quantity of rainwater harvestable in southwest Nigeria. This study therefore aimed at estimating the quantity of water harvestable from roofs of different sizes and materials; investigate water demand per household in southwest Nigeria and development of a rainwater harvesting calculator for sizing of storage tanks.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The study was conducted in five states in southwest Nigeria, consisting of Lagos, Ogun, Ondo, Osun, and Oyo states**.** The study area lies between Latitudes 5.5^o and $9.8^o N$ and Longitudes 2.7^o and $6^o E$ of the Greenwich Meridian (Fig. 1). The climate ranges between tropical and humid with average annual rainfall greater than 1000 mm/year with most rainfall occurring in well-defined rainy season of six to seven months (April-October). The rainfall is typically concentrated in high intensity storms with high rates of runoff. The terrain is relatively flat and thickly vegetated with trees. The major perennial rivers, with many tributaries, in the region are

Majidun, Oba, Ofiki, Ogun, Osun, Owena and Oyan among others. The (major) inhabitants of the South-western Nigeria are the Yorubas of different origins (Egbas, Ijebus, Ijesas, Oyos, Ondos, etc). Based on 2006 Population Census, the population of the area is put at 27, 581, 992 habitants with a population growth estimated to be 2.38% (www.thetidenews.com, accessed in May, 2008).

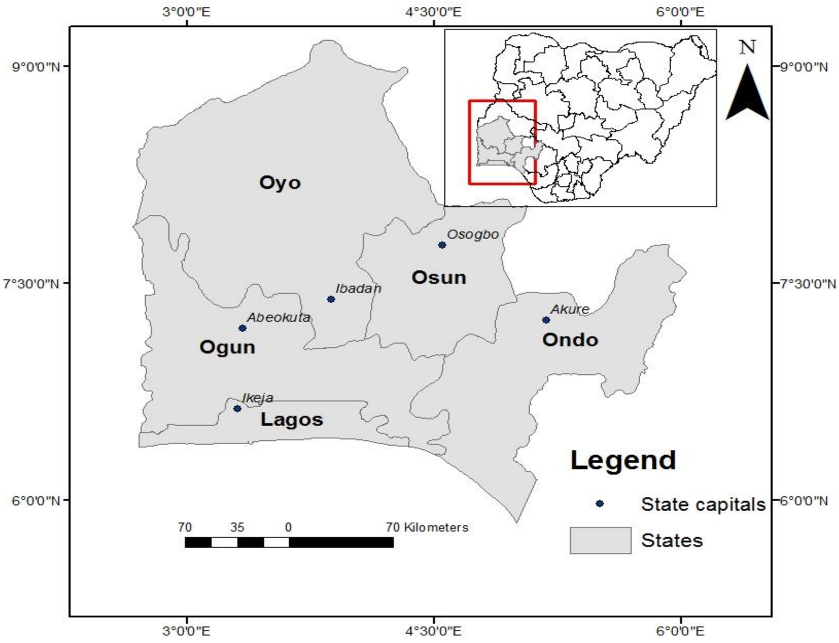

Fig.: Map of southwest Nigeria

2.2. Data Collection

The rainfall data of the study area (Abeokuta, Akure, Ibadan, Lagos, and Osogbo) were collected from the National Meteorological Centre, Oshodi, Lagos. Several researchers (Genton and Furrer, 1998; DTU, 1999; Ngigi, 1999; Smith *et al*, 1999; Waweru, 1999; Ferdausi and Bolkland, 2000; Lau, *et al*, 2005 and Walker, 2007) have collected such secondary data for analyses in different parts of the world. A survey of water supply and demand situation in the study area was conducted using questionnaire and oral interview in some instances. These methods had earlier been used by Adekalu *et al.* (2002) and Ferdausi and Bolkland (2000). The sizes of the households were also investigated as this will affect water demand situation. Shaaban *et al.* (2002) carried out similar survey in Malaysia while working on the household water demand. Acceptability of rainwater as a source of potable water supply was investigated. The questionnaires were distributed to randomly selected households within the study area. In each town, a target of 500 respondents was set.

2.3. Rainfall Data Analysis

The monthly rainfall data of the study area were analysed for pattern using Microsoft Office Excel spreadsheet (2007 version) for easy handling. The pattern of rainfall for the study area was plotted.

2.4. Computation of Storage Capacity

The determination of storage tank size was based on the household size, guttering efficiency, per capita water consumption, roof type, rainfall pattern, level of satisfaction required and the length of dry spell. This was based on the basic rainwater harvesting equation (Thomas and Martinson, 2007).

$$Q_{th} = A_r \times C_r \times R_a \qquad (1)$$

Where

Q_{th} = quantity of harvestable water from the roof (m^3)

A_r = roof plan area (m^2)

C_r = runoff coefficient (ratio)

R_a = average annual rainfall (m)

Q_{th} is the theoretical quantity of water that is expected to be delivered to the storage tank. However, it is not always all the water that is received in the gutter that is delivered to the storage tank. Thus, the guttering efficiency, the ability of the gutter to intercept and convey water from roof to the storage tank, was incorporated, according to Abegunrin and

Sangodoyin (2011), the actual quantity of water delivered to the storage tank is given as:

$$Q_s = A_r \times C_r \times R_a \times E_g \tag{2}$$

Where

Q_s = quantity of water delivered to the storage tank (m^3)

E_g = guttering efficiency ($0 < E_g \leq 1$)

The storage capacity, C_d, desired by the user, is given, according to Abegunrin (2014), as

$$C_d = s \times Q_s \tag{3}$$

where

s = the level of satisfaction desired by the user ($0 < s \geq 1$)
Rainwater harvesting is based on the average rainfall, which means that there could be good rainy years when the water harvested may be greater than the designed capacity of the storage tank. Thus, there is the need to use a factor of safety to cater for any upsurge in the inflow of water. An overflow device should be installed as well. Also, water demand may increase above the design capacity. To make provision for such increase, the level of the satisfaction could be raised, particularly where rainwater is the sole water supply source for the house. However, in household where rainwater is used for some purposes, the percentage contribution by rainwater to the household water demand would be determined and the storage size should be determined proportionately to minimize cost. Abegunrin (2014) device a relationship between C and Q_s as:

$$C_d < Q_s\,;\ C_d = Q_s \text{ or } C_d > Q_s \tag{4}$$

subject to

$$0 < s \geq 1$$

To further reduce the cost of rainwater harvesting, the quantity of water needed was related to the roof area, such that there may not be need to install gutter for the whole roof area.
Due to the wide variation in water demand, level of satisfaction, household size, roof area, roof material, guttering efficiency and level of income, a tank sizing calculator was developed with a Graphical User Interface in MATLAB environment (Fig.2) to combine all the inputs into rainwater storage sizing.

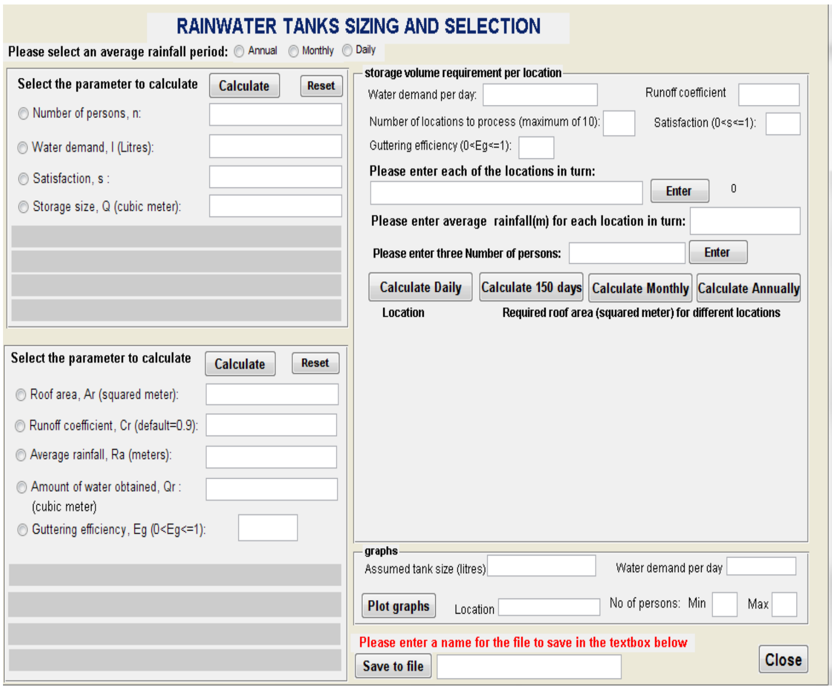

Fig. 2: The rainwater tank sizing calculator

3. RESULTS AND DISCUSSIONS

3.1. Rainfall pattern of southwest Nigeria

The mean monthly rainfall pattern of the study area within a study period of 1981 – 2007 is presented in Fig. 1. Abeokuta, Ibadan and Ikeja had similar pattern while that of Akure and Osogbo were similar. Although, there was slight variation in the pattern of distribution, the five towns have a bimodal pattern, with peaks in June and September of each year. In Abeokuta, Ibadan and Ikeja, the highest rainfall depths of 196, 180 and 365 mm, respectively occurred in the month of June, while in Akure and Osogbo the highest depths of 230 and 222 mm respectively, occurred in September. All the five towns experienced the phenomena of ‘august break’. The slight variation in the rainfall pattern may not have any significant implication on rainwater harvesting because the critical period of dryness span through the months of November to March in each town.

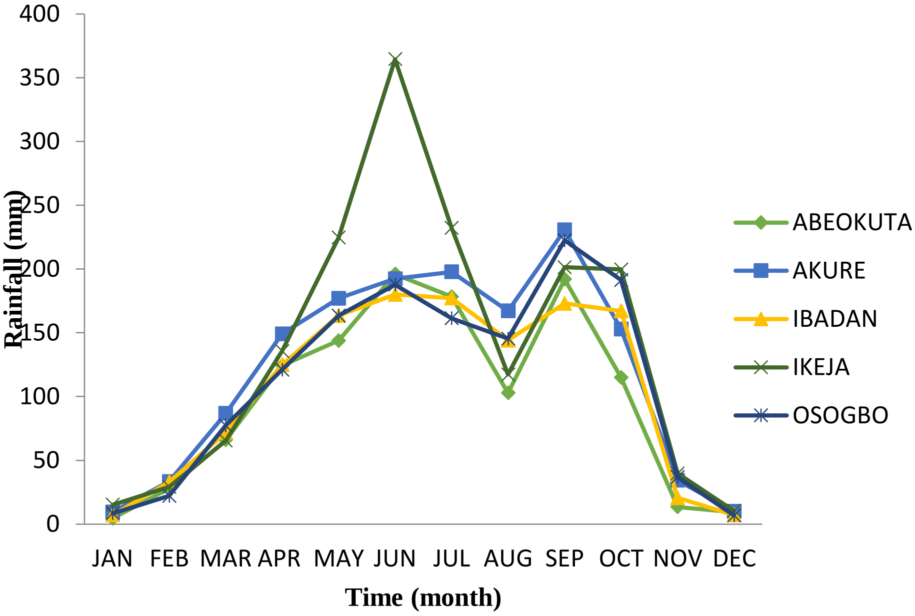

Fig. 3: Mean monthly rainfalls of five towns in southwest Nigeria

3.2. Household size in southwest Nigeria

Household size is one of the important parameters in the design of rainwater harvesting system. Household size is related to the total water demand, storage volume and catchment area required.

The average household sizes of the five towns in southwest Nigeria are presented in Fig. 2. In Abeokuta, the household size ranged from 5 to 11 persons per house. About 88% of the population had household between 7 and 11 persons. The average household size was about 10 persons. In Akure, the household size ranged from 6 to 11 persons per house. About 89% of the population had household size between 7 to 11 persons. The average household size was found to be about 8 persons. In Ibadan, the household size also ranged between 7 and 11 persons per house, however with about 77% of the population having household size of 8 to 11 persons while the average household size was about 9 persons. The household size in Ikeja was lower, ranging from 6 to 9 persons per house while the average household size was found to be about 8 persons. The household size in Osogbo ranged between 6 and 11 persons per house, with an average of 9 persons per house.

3.3. Water Consumption

Water consumption varies from one locality to the other probably due to the variation in availability and ease of getting water. The results of the average water consumptions in South-western Nigeria are presented in Table 1 with the mean, standard deviation and the coefficient of variation (CoV). Per capita water consumption ($l/h/d$) varies with seasons. Generally, consumption reduced in the dry season.

During the rainy season, water consumption in Abeokuta ranged from 40 to 50 $l/h/d$, with an average consumption of 45.3 $l/h/d$. However during the dry season, the consumption

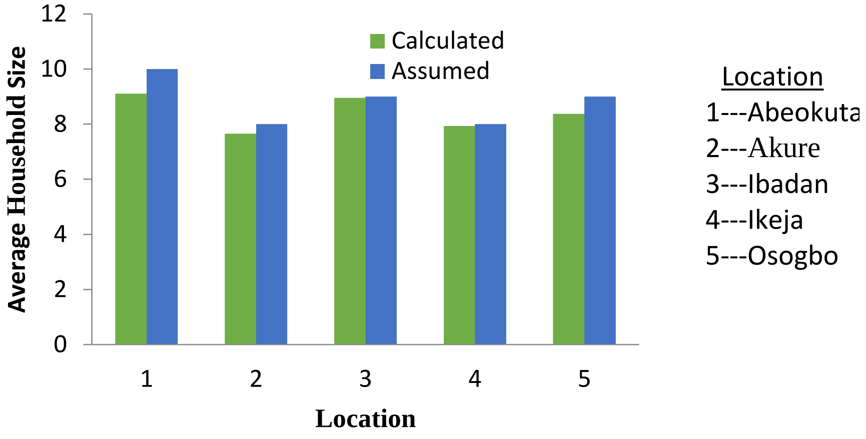

Fig. 4: Average Household Size in South-western Nigeria

ranged between 30 and 50 $l/h/d$, with an average consumption of 38.6 $l/h/d$. Consumptions in other towns seem to be a bit higher than at Abeokuta. In Akure, water consumption during the rainy season ranged between 50 and 120 $l/h/d$, with an average consumption about of 81.0 $l/h/d$. During the dry season, the consumption was a bit lower, ranging from 40 to 100 $l/h/d$, with an average of 64.9 $l/h/d$. In Ibadan, the consumption varied from 60 to 100 $l/h/d$ during the rainy season, with an average of 82 $l/h/d$. The consumption dropped to about 62.8 $l/h/d$ during the dry season with the actual consumption ranging between 50 and 80 $l/h/d$. Ikeja had an average consumption of 69.3 $l/h/d$, with a range of 45 to 100 $l/h/d$ during the rainy season. During the dry season, the average consumption dropped to 56.7 $l/h/d$, with a range of 30 to 80 $l/h/d$. Osogbo had an average daily water consumption of 71.0 $l/h/d$ during the rainy season. The actual consumption varied from 45 to 100 $l/h/d$. The consumption reduced to 49.5 $l/h/d$ in the dry season, with a range between 30 and 70 $l/h/d$.

The above results indicated that residents of the study area adjust their consumption to the available water. This could be attributed to many factors such as energy input, time and even cost that is required to get the usual quantity especially during the rainy season. Although some residents increased their water consumption during the dry season due to the nature of their work.

Table 1: Average Water Consumption per Person per Day in South-western Nigeria

	Average Water Consumption ($l/h/d$)	
Location	Rainy Season	Dry Season
Abeokuta	45.30	38.55
Akure	80.95	64.93
Ibadan	82.00	62.75
Ikeja	69.30	56.74
Osogbo	70.99	49.58
Mean	*69.71*	*54.51*
Std. Dev	*13.23*	*9.60*
CoV	*0.19*	*0.18*

which influenced body physiology and water consumption, the general trend is a decrease in water consumption during the dry season.

The standard deviation was quite high, particularly during the rainy season. This is due to the variation in the water consumption in the different locations. However, the CoV in each case is low. This indicated that the mean value can be the true representation of the daily water consumption for southwest Nigeria.

Table 2 shows how water from various sources is used in southwest Nigeria. The highest rainwater use is at Abeokuta with about 87.4% of the population using rainwater for one purpose or the other. Osogbo had the least rainwater utilization, with about 62.4% of the population using it. It was observed however that people use water from more than one source. This may be attributed to factors such as nearness to water source, cost per unit of water from the source, quality and energy input required among others. This is in consonance with the findings of Adekalu *et al.* (2001) that the choice of a source for a particular purpose depends on whether it meets their demand in terms of quality and quantity.

Table 2: Percentage of People Using Water from different Sources in southwest Nigeria

	Location				
Source (%)	Abeokuta	Akure	Ibadan	Ikeja	Osogbo
Pipe borne	92.8	59.4	52.0	100,0	67.6
Well	59.0	85.0	65.2	60.4	100.0
Borehole	71.0	61.8	13.0	32.4	48.0
Vendor	31.0	23.2	18.0	39.6	35.0
Rain	87.4	76.2	83.0	75.0	62.4
Storage Tank	93.8	55.6	52.0	100.0	55.0

3.4. Rainwater Storage

In southwest Nigeria, rainwater of varying quantity is stored. Individual household collects rainwater mostly in drums and PVC tanks, sometimes to save water to be used for few days. Table 3 shows the percentage of people that store rainwater in southwest Nigeria. Almost every house in Ibadan indicated that rainwater is stored.

Table 3: Percentage of People Storing Rainwater in Southwest Nigeria

Place	Store Rainwater (%)
Abeokuta	87.8
Akure	79.4
Ibadan	100.0
Ikeja	89.0
Osogbo	77.4

3.5. Roofing Materials

Different materials are used for roofing in southwest Nigeria. These include Galvanized Iron Sheets (GIS), asbestos, long span aluminium sheet, PVC roofing and tiles. However, the two most common ones are the GIS and asbestos roofing sheets. Figure 3 shows the results of the investigation on the roofing materials in southwest Nigeria. The result indicated that about 96.5 % of the population use either GIS or asbestos as the roofing materials. These roofing materials are suitable for rainwater harvesting for domestic use (Campbell, 1993). However, according to Ferdausi and Bolkland (2000), other roofing materials could also be used with some modifications. It should be noted that long span aluminium sheet behaves like the GIS roofing sheets with a runoff coefficient C_r of 0.9 (DTU, 2003).

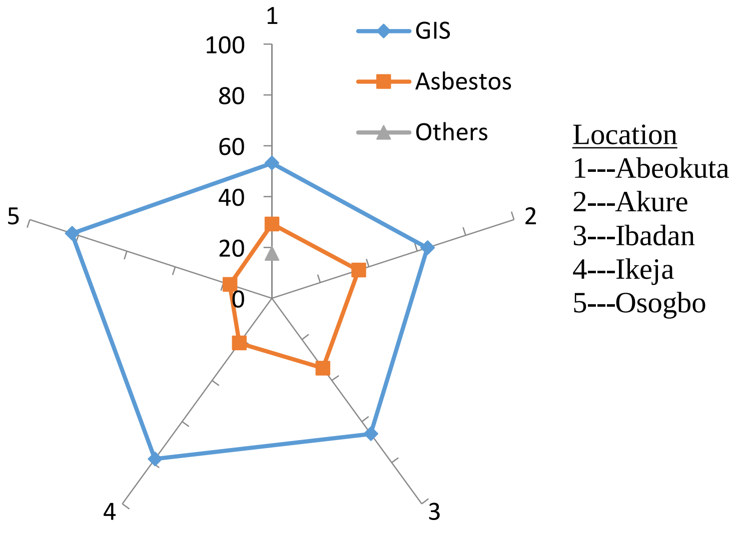

Figure 5: Different roofing materials in southwest Nigeria

3.6. Roofing Size

There is no data on roofing size in southwest Nigeria and the existing roof area cannot be easily measured. However, in a field survey conducted, the average roof areas obtained in five towns in southwest Nigeria as presented in Fig. 4, which ranged between 60 and 70 m^2.

These figures will not be applicable to all houses in the region but provides an idea of catchment size in the study area which can then be used for the computation of rainwater catch from roofs.

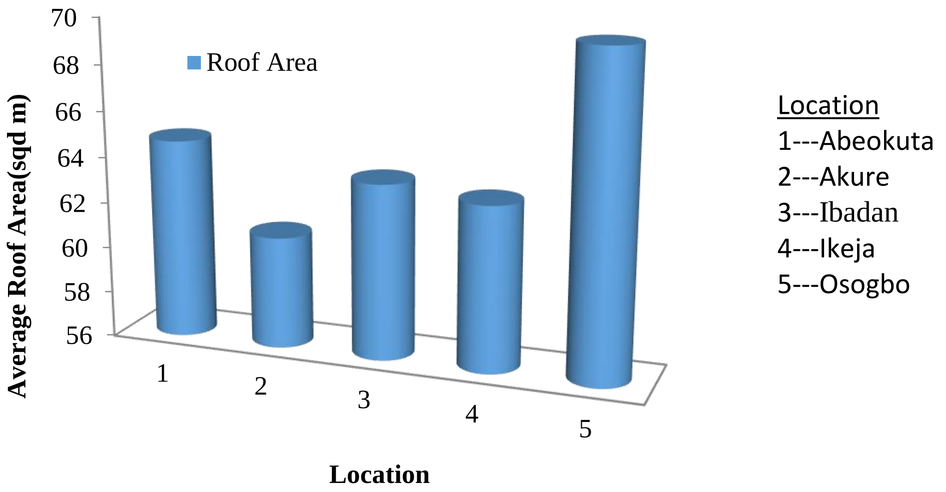

Figure 6: Average roof area in different locations of southwest Nigeria

3.7. Output of the Calculator

Typical output from the calculator on GIS roof on daily, monthly, 150-day and annual areas to be guttered to meet 80% of water requirements of 5, 6 and 7 persons per house at a per capita water demand of 40 l per day and a guttering efficiency of 90% are presented in Table 4. The variation in the roof areas in different location is due to the variation in the rainfall depth. Abeokuta with the least rainfall depth has the largest daily roof area of 0.168 m^2 while Ikeja with the highest rainfall depth has the smallest of 0.121 m^2 to be guttered.

Table 4: Daily, monthly, 150-daily and annual roof area (m^2) required at different locations in southwest Nigeria with per Capita Water Demand of 40 l; Runoff Coefficient of 0.9; Guttering Efficiency of 90% and 80% level of satisfaction

	Daily Roof Area			Monthly Roof Area			150-Day Roof Area			Annual Roof Area		
	---No. of person---											
Location	5	6	7	5	6	7	5	6	7	5	6	7
Abeokuta	0.17	0.20	0.24	5.13	6.15	7.18	25.26	30.31	35.36	61.51	73.81	86.11
Akure	0.14	0.16	0.19	4.17	5.01	5.84	20.56	24.67	28.79	50.07	60.08	70.10
Ibadan	0.16	0.19	0.22	4.74	5.68	6.63	23.33	28.00	32.66	56.81	68.17	79.55
Ikeja	0.12	0.15	0.17	3.70	4.44	5.18	18.22	21.87	25.51	44.37	53.25	62.12
Osogbo	0.15	0.18	0.21	4.47	5.37	6.26	22.05	26.46	30.86	53.68	64.42	75.15

Figures 5 to 8 present the results of level of satisfaction required against the storage size (m^3) for the daily, monthly, 150-day and annual storage capacity at 69 l per capita water demand per day; 0.9 runoff coefficient and 90% guttering efficiency. With the graphs, the storage size for a given level of satisfaction and number of persons could be determined. On the other hand, a user may fix the storage size he/she could afford due to economic reasons. The level of satisfaction to be derived from the storage size could be obtained from the curves and similar ones that could be generated by the programme. Once the level of satisfaction is determined, the user may then search for the remaining amount of water from other sources. Rahman and Yusuf (2000) in their study on rainwater harvesting reliability concept and Maribyrnong City Council (undated) have provided similar curves for Barisal, Bangladesh and Maribyrnong City in Australia, respectively. The curves however, apart from being limited to the range of values on them, did not consider the guttering efficiency.

The programme can accept any other condition and produce similar tables and curves. Thus, the programme becomes very useful in tank sizing and in determining the level of satisfaction.

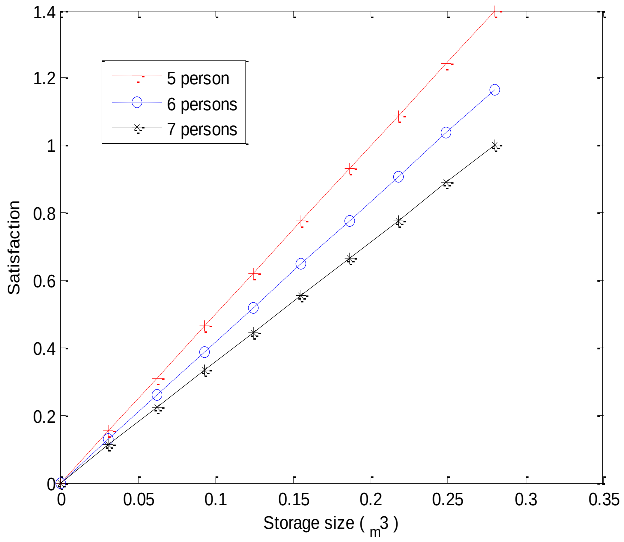

Figure 7: Daily Satisfaction Desired against Storage Size Required at per Capita Water Demand of 40 *l* per day; 0.9 Runoff Coefficient and 90% Guttering Efficiency

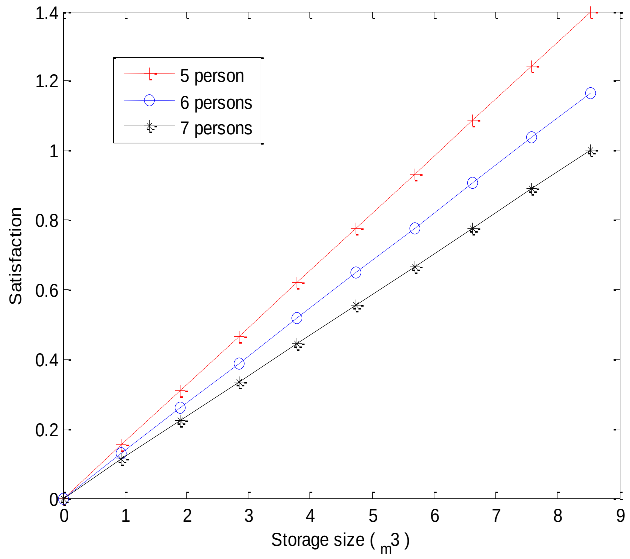

Figure 8: Monthly Satisfaction Desired against Storage Size Required at per Capita Water Demand of 40 *l* per day; 0.9 Runoff Coefficient and 90% Guttering Efficiency

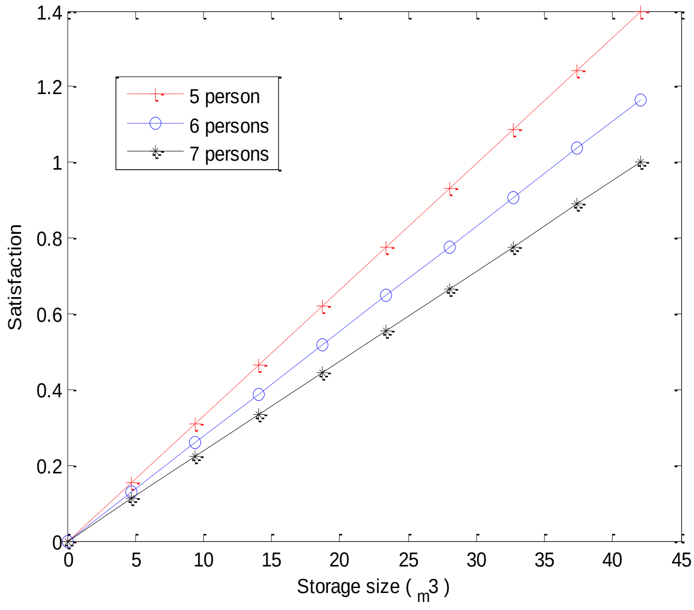

Figure 9: 150- Day Satisfaction Desired against Storage Size Required at perCapita Water Demand of 40 *l* per day; 0.9 Runoff Coefficient and 90% Guttering Efficiency

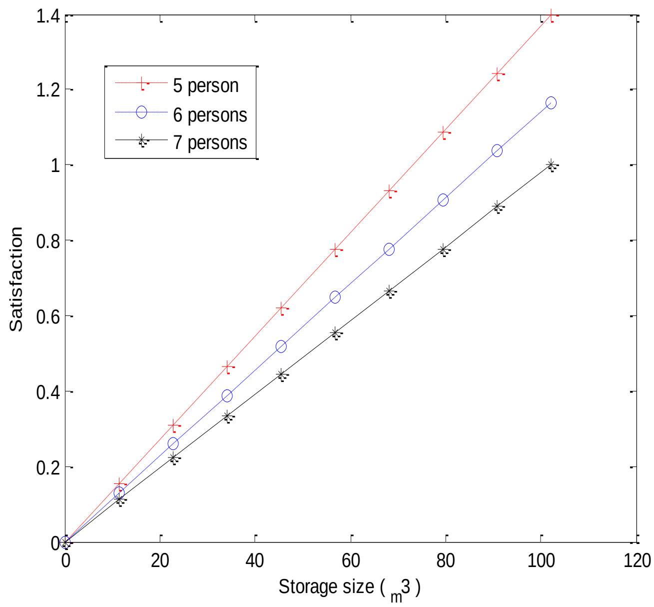

Figure 10: Annual Satisfaction Desired against Storage Size Required at per Capita Water Demand of 40 *l* per day; 0.9 Runoff Coefficient and 90% Guttering Efficiency

4. CONCLUSIONS

The quantity of harvestable water varies with rainfall depth, roof size and roofing materials. Water consumption in southwest Nigeria varies with location, season and household.

The developed tank sizing calculator is capable of determining roof area to be guttered and storage capacity required at any desirable level of satisfaction under different conditions of rainfall depth, household size, water consumption, guttering efficiency, roofing material and roof size.

REFERENCES

Abegunrin TP and Sangodoyin AY (2011): Gutter Projection, Roof and Gutter Slopes Effect on Rainwater Harvesting. *International Journal of Engineering*. 5(4): 181-188.

Abegunrin TP, Sangodoyin A Y, Odeniyi J, Onofua OE (2014): Roof age Effect on the Quality of Harvested Rainwater and its Health Implication in a Selected Location, Southwest Nigeria. *International Journal of water Resources and Environmental Engineering.* 6(10): 261-266.

Akintola OA, Sangodoyin AY (2011): The Suitability of Domestic Roof-Harvested Rainwater as a Source of Irrigation Water for Homestead Gardening. *Centrepoint Journal*. 17(1): 61-69.

Akintola OA, Sangodoyin AY, Agunbiade FO (2013a): Evaluation of Environmental Effects on Domestic Roof-Harvested Rainwater in Southern Part of Nigeria Using Impact Indices. *Water Practice and Technology.* 8(2): 244-255.

Akintola OA, Sangodoyin AY, Adebayo OS (2013b): Microbiological Quality of Domestic Roof-Harvested Rainwater Rainwater in Selected Locations in Nigeria. *Journal of Biol. Chem. Research.* 30(2): 849-860.

Campbell D (1993): ‘Asbestos Roofing and Safety.’ *Raindrop.* First Series, February pp 7-12.

Coker A (1999): Potentials of Rainwater in a South-Western Nigeria Community. In Hans Hartung (ed.). *The Rainwater Harvesting CD (2002).* Margraf Publishers, Weikersheim, Germany.

Despins C, Farhbakhsh K, Leidi C (2009): Assessment of Rainwater Quality from rainwater Harvesting Systems in Ontario, Canada. *Journal of Water Supply: Research and Technology-AQUA.* 58(2): 117-134.

DTU (2005): Current Technology for Storing Rainwater. Development Technology Unit, University of Warwick. (www.eng.warwick.ac.uk/DTU/rainwaterharvesting/index.html).Pp 31. Accessed July 2008.

Ferdausi SA, Bolkland MW (2000): Rainwater Harvesting for application in Rural Bangladesh. Water, Sanitation and Hygiene: Challenges of the Millennium. 26th WEDC Conference. Dhaka, Bangladesh. pp 16-19.

Genton MG Furrer R (1998): Analysis of Rainfall Data by Simple Good Sense: Is Spatial Statistics Worth the Trouble? *Journal of Geographic Information and Decision Analysis*. 45(2):11-17.

Lau TL, Majid TA, Choong KK, Zakaria NA, Ghani AA (2005): Study on a High Rise Building Incorporated with Rainwater Harvesting Storage Tanks towards Building a Sustainable Urban Environment in Malaysia. *World Sustainable Building Conference.* Tokyo.

Lucas EB, Ogedengbe K, Abegunrin TP (2005): Guttering System Design for Rainwater Harvesting Applicable for Ibadan Metropolis, Nigeria. *LAUTECH Journal of Engineering and Technology.* 3(2): 93-98.

Maribyrnong City Council (undated): Rainwater Tank Sizing and Selection. www.maribyrnong.vic.gov.au (accessed January, 2010).

Ngigi SN (1999): Optimization of Rainwater Catchment Systems Design Parameters in the Arid and Semiarid Lands of Kenya. In Hans Hartung (ed.) *The Rainwater Harvesting CD (2002) Margraf Publishers.* Weikersheim, Germany.

Rahman MM, Yusuf FMS (2000): Rainwater Harvesting and Reliability Concept. *Proceedings of the 8th American Society of Civil Engineers Special Conference on Probabilistic Mechanics and Structural Reliability.*

Shaaban AJ, Kardi J, Awang S (2002): Rainwater Harvesting and Utilisation for a Double Storey Terrace House at Taman Wangsa Melawati, Kuala Lumpur. *Workshop of Rainwater Harvesting as a Tool for Sustainable Water Supply and Storm water Management, Construction Development Board (CIDB).* Kuala Lumpur, Malaysia.

Smith H, Heitz LF, Fok YS (1999): Development of Rooftop Rainwater Catchment System Design Criteria for Pohnpei State, Federal States of Micronesia. In Hans Hartung (ed.) *The Rainwater Harvesting CD (2002) Margraf Publishers.* Weikersheim, Germany.

Walker BF (2007): Rainfall Data Analysis at Newport and the Relationship to Land Sliding in Pittwater. *Journal of Australian Geomechanics.* 42(1): 1858 – 1872.

Waweru DW (1999): Influence of Rainfall amount and Distribution on Rainwater Catchment System Design. In: Hans Hartung (ed.) *The Rainwater Harvesting CD (2002) Margraf Publishers.* Weikersheim, Germany.

The Tide News. www.thetidenews.com. Accessed in May, 2008.