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Full Length Research Paper

Rainwater harvesting potential in Central Niger Delta

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The three major sources of water are easily accessible in the Central Niger Delta area. The tributaries of the River Niger form a complex network of rivers, streams and lakes; groundwater is available at relatively shallow depths for abstraction; and rainfall lasts for about 9 months and varies from about 3500 to 2000 mm per annum. On relatively sophisticated water supply systems, groundwater is the most exploited but it is characterized with poor quality related to oxides of iron and magnesium. The surface water sources are open to all kinds of activities while rainwater harvesting is relegated to the background. However, the amount of rainfall falling in the Central Niger Delta area is worth exploiting, especially with the prevalent challenges to using other sources. Thus, the potential of harnessing rainwater in the central Niger Delta is explored in this paper using a mass curve analysis with an illustration of its efficacy, flexibility and the sensitivity of the analysis.

Key words: Rainwater harvesting, mass curve, water supply, water demand, Niger Delta.

INTRODUCTION

Rainwater harvesting (RWH) has gained wide popularity and support in recent times since it encourages water conservation and often makes use of simple inexpensive systems which are easy to maintain (GAHC, 2005; DTU, 2007). It is an old technology being giving a new look in the pursuance of domestic water autonomy (Thomas, 1998; Aladenola and Omotaye, 2010). Despite the caution studies have highlighted on the health risks associated with the quality of harvested rainwater (Yaziz, 1989; Simmons et al., 2001; Lye, 2002; Sazakli et al, 2007; Lye, 2009), many communities in low-income countries across the world have continued to informally rely on domestic rainwater harvesting (DRWH). The inadequacies in water supplies common to many rural areas in tropical countries imply that DRWH offers almost the only means of improving household water supplies without waiting decades for an upgrading of community systems (Thomas, 1998). On a brighter perspective, some countries like South Africa have recognised the potential in this technology that her government is committing resources to pursuing DRWH as one alternative to achieving the Millennium Development Goals (Mwenge-Kahinda et al., 2007; Mwenge-Kahinda and Taigbenu, 2011). This is an example that countries sharing similar opportunities need to realise and exploit. Nigeria is one of such countries, as also suggested by Ishaku et al. (2012) in considering RWH as an alternative safe rural water supply in Northeast Nigeria. Thus, DRWH is particularly appropriate in the Central Niger Delta area where there is an abundance of rainfall.

Skinner (1992) identified three reasons to establish the suitability of RWH in an area. They include availability of suitable rainfall pattern; other water sources not being ideal or convenient to exploit; and where the people are already practising some degree of RWH. These points apply in many African communities (Handia, 2003; Mbilinyi et al., 2005; Mwenge-Kahinda et al., 2007) including the Niger Delta area (Efe, 2006). This paper focuses on the investigation of the suitability of rainfall pattern in the Central Niger Delta for RWH vis-á-vis other sources and the development of an analytic graph for estimating storage using the mass curve technique (World Bank, 1985). Thomas (2004) presented how pseudo daily rainfall data could be generated from actual

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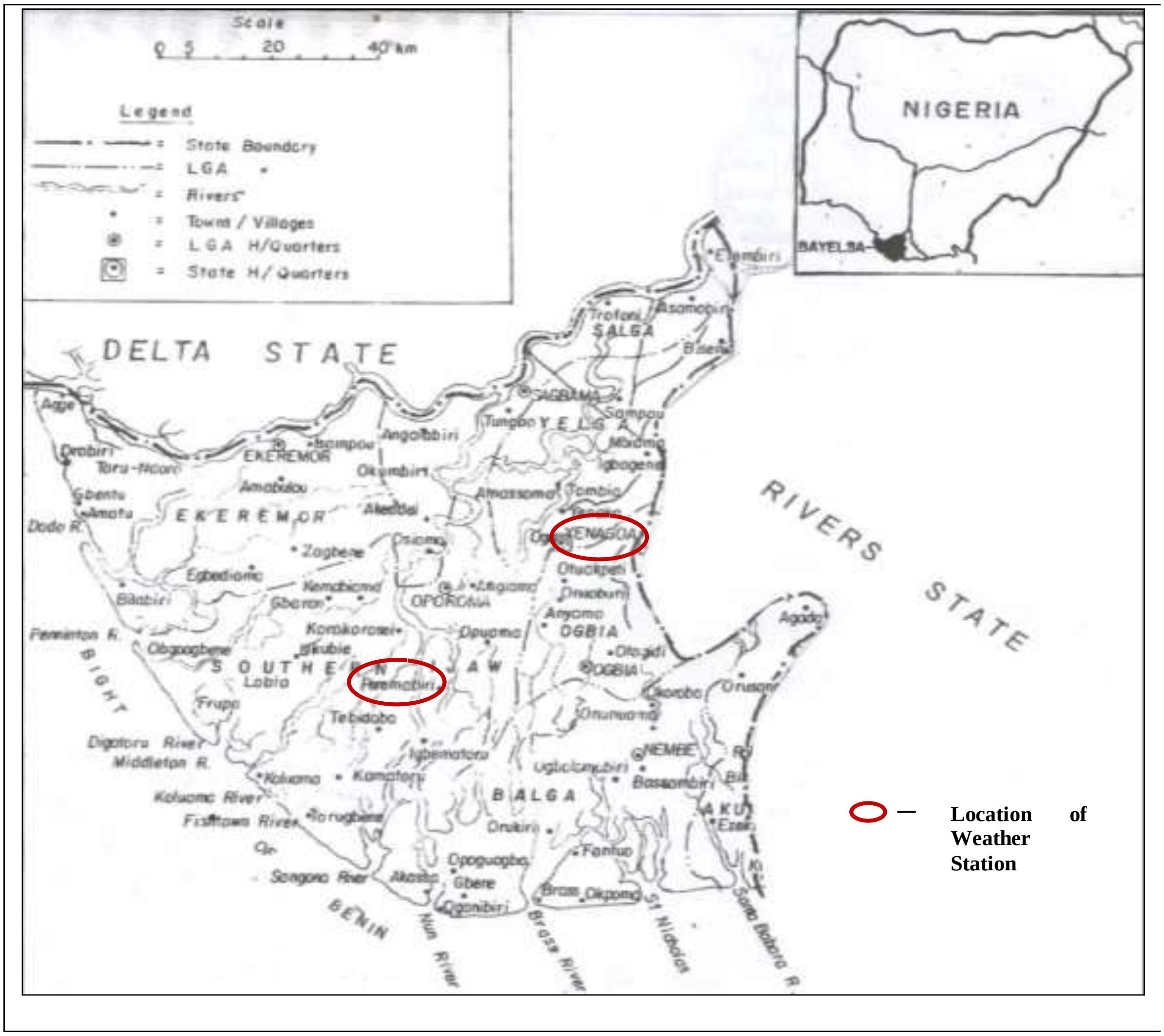


Figure 1. Political map of Bayelsa State (Alagoa, 1999).

monthly rainfall data to aid RWH design for areas such as the tropics where rainfall records could be unavailable; however this paper is based on actual data that have been collected over decades by the Niger Delta Basin Development Authority (NDBDA), Nigeria and overcomes some degree of uncertainty associated with the random generation of rainfall data.

This paper is presented in five sections: introduction, method, results, discussion and conclusion. The introduction gives an overview of the paper, the study area and its characteristics; the estimation of rainwater supply potential and how the tool for estimating minimum storage was developed are presented under method. The results show case-illustrations of the developed tool and the output from the application of sensitivity analysis with related comments presented in the discussion section. The discussion also extends to cover other aspects required for implementing RWH programmes in the Niger Delta. This is followed by conclusion.

Climate of Central Niger Delta and rainfall pattern

The central Niger Delta is partly occupied by Bayelsa State (Figure 1) where this study is focused. Bayelsa State is geographically located within Latitude 04° 15' North, 05° 23' South and longitude 05° 22' West and 06° 45' East and shares boundaries with Delta State on the North, Rivers State on the East and the Atlantic Ocean on the West and South (BYSG, 2010). Mangrove swamp is predominant over Rain forest vegetation types found in the area and rainfall has been noted to occur all year round with a mean annual rainfall of about 3500 mm/year around the coastal areas (Akpokodje, 1987). This rainfall is directly caused by the equatorial maritime air mass that blows from the Atlantic Ocean bounding the southern part of Nigeria (Nissen-Peterson, 1982).

In order to ascertain the potential for rainwater harvesting for any area, reliable rainfall records for a period of at least 10 years are required (Gould and

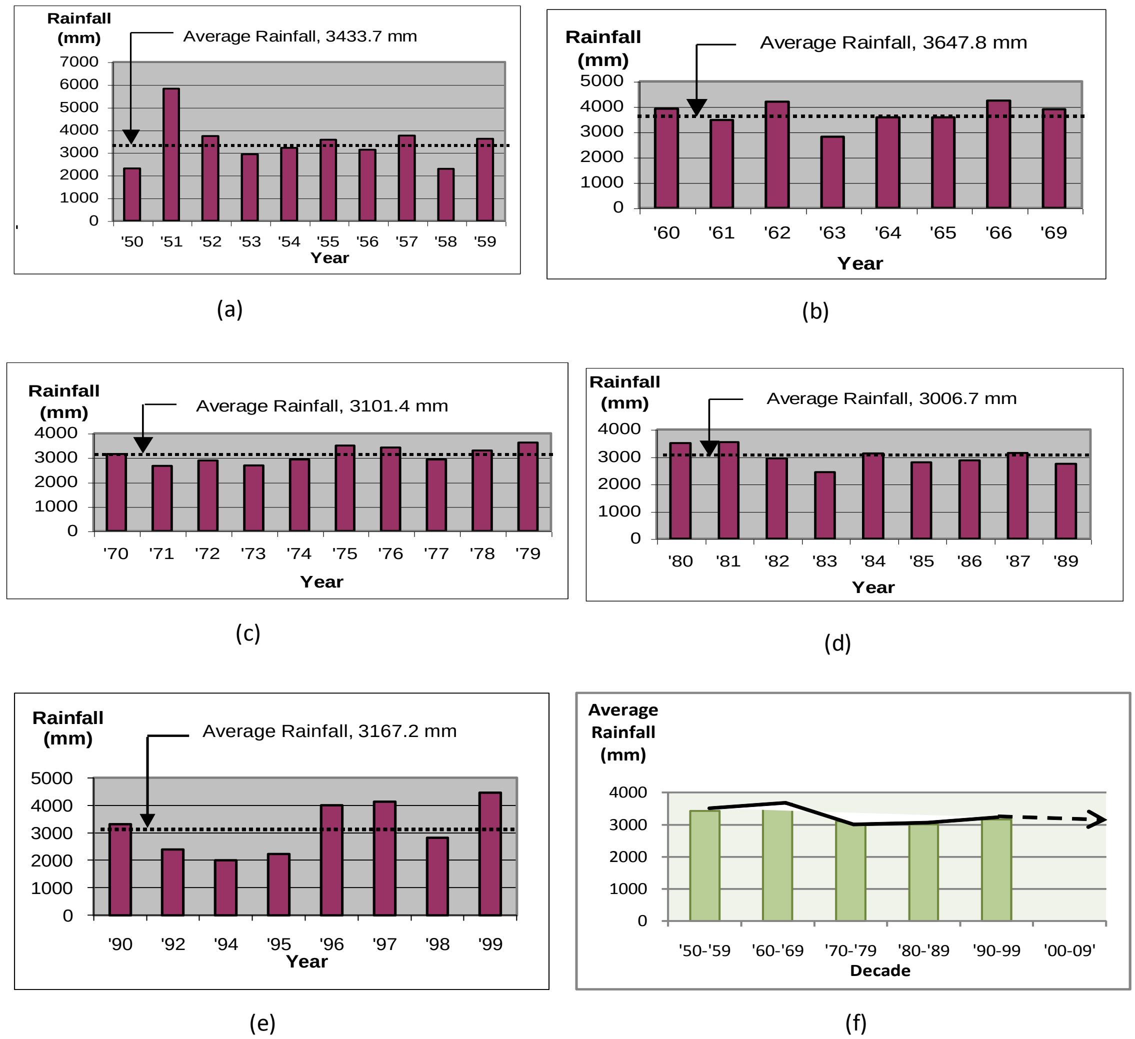


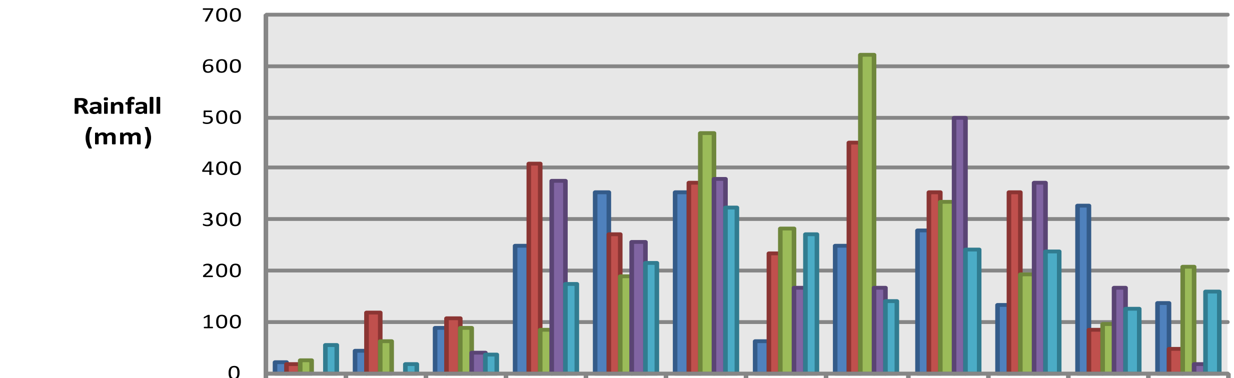
Figure 2. Variation of annual and average rainfall in Bayelsa State (Peremabiri and Yenagoa stations). (a) 1950-1959 (b) 1960-1969 (c) 1970-1979 (d) 1980-1989 (e) 1990-1999 (f) summary of decades.

Nissen-Peterson, 1999 as in Latham and Schiller, 1984). This may even need to be for 20 to 30 years in drought-prone areas for clarity in rainfall trends and reliability (Gould and Nissen-Peterson, 1999). In this paper, rainfall records were sourced for 5 decades (1950 to 1999) but from two different whether stations manned by the Niger Delta Basin Development Authority (NDBDA, 2001), Port Harcourt, Rivers State (NDBDA, 2001). The data for 4 decades (1950 to 89) are from the Peremabiri Station (Figure 2(a) to (d)) and 1 decade (1990 to 1999) is from Yenagoa Station (Figure 2(e)). These rainfall records have been combined in the analysis of the rainfall pattern. Figure 2(a) to (d) shows that the variation of average rainfall over the 5 decades is more than 3000 mm. Rainfall record for 2000 to 2009 decade has not been included in the figure; however this does not affect the analysis expressed in this paper since the summary of Average Annual Rainfall over the decades shows a relatively consistent trend as seen from Figure 2(f). Also, the method requires the periods (year) with the worst rainfall events for which the available data suffices.

The reliability of at least 3000 mm of annual rainfall means that RWH has good potential in this part of the Niger Delta. This is even more evident when the years of least annual rainfall are examined for the 5 decades (Figure 3). It rained almost every month of the year except in January and February of 1983. However, from March to November the rainfall is relatively regular in all the years shown in Figure 3. Rainfall is very low for a period of about 3 months, December to March, which characterise the critical months of the dry season in this region.

METHODS

The research method entailed collection of recorded rainfall data of the study area and field visit to verify local RWH practices. Aspects relating to estimating the RWH potential were carried out based on



AR = Annual Rainfall	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1958, AR = 2296.4 mm	22.1	41.6	87.2	248.4	355	355	63.1	250.3	278.3	132	325.7	137.7
1963, AR = 2815.9 mm	18.3	116.4	105.1	409	270.7	370.1	233.7	451.3	351.8	354.9	86.1	48.5
1971, AR = 2661.0 mm	24.2	62.9	89.5	84.3	190.3	468.1	283.4	623.7	335.8	193.7	96.6	208.5
1983, AR = 2438.7 mm	0	0	39	377.5	256.3	378.5	166.3	165.8	499	372.6	168.1	15.6
1994, AR = 1994.1 mm	52.7	17.8	35.6	173.1	216.3	324.6	269.3	141.3	242.1	236.4	126.6	158.3

Figure 3. Average monthly rainfall driest years of each decade (Peremabiri and Yenagoa stations).

conventional water demand and supply principles using the mass curve analysis (World Bank, 1985). This method is based on volumetric simulations of estimated rainwater demand and supply (Palla et al., 2011) over periods of worst rainfall. Results from the mass curve were further examined by the application of sensitivity analysis to look at possible scenarios and their implications in the study area. The sub-sections briefly describe the background of the method, state the key assumptions and also discuss the procedures adopted in assessing the RWH potential of the study area.

Background for method

The important preliminary aspects in rainwater harvesting are being able to compare the potential supply against estimated demand; and also to work out the minimum storage that is required for individuals, households or groups. Once these aspects have been established to be adequate the design process could then be extended to detailed analysis.

Rainwater supply potential and demand estimation

There are three possible scenarios when considering annual rainfall for RWH design (Skinner, 1992). First, it is possible to have a year with long dry period (months) but with high overall annual rainfall and secondly, a year with the lowest overall annual rainfall but with short dry period (months). The third possibility is a single year having relatively longest dry period and also the lowest annual rainfall. For the three situations, the one that will require the highest minimum storage during the dry season is the third scenario which is given priority in selection of the years used in developing the mass curve. Considering the rainfall pattern across the five decades, 1983 is the year of least rainfall and longest dry months (December-February) which corresponds with the third scenario. Thus for a corrugated galvanized steel sheet roof with a runoff coefficient of 0.8 (Gould and Nissen-Peterson, 1999), the average annual rainfall (3007 mm) guarantees a supply of about 2.4 m^3/m^2/year (3007 × 0.8/1000) or 6.59 L/m^2/day. This means that typical roof areas have good potential as surfaces for harvesting rainwater.

In the estimation of household rainwater demand, users-behaviour and climate change are uncertain; however the past is used as a template for the future (Thomas, 2004). The usual methodological approach entails estimating the acceptable water demand for individuals and summing them up for a household according to its occupancy. The acceptable water demand is a function of several factors such as needs for drinking, cooking, washing, bathing, gardening etc. For RWH, considerations also extend to whether other sources will also be used since it is often difficult to make domestic RWH the definitive answer to household water problems (DTU, 2007). This is especially important for design purposes because it could help to reduce the volume of tank that may be required for storage since only water for potable purposes and cooking then needs to be stored for use in the dry periods. Many rural communities in Bayelsa are located by the banks of the Niger Delta tributaries and have often combined surface water sources with rainwater to meet their water needs (Egborge, 1980; Tamuno et al., 2009). The mass curve used in this paper has therefore been developed assuming that non-potable needs are satisfied by surface water sources.

The basic level of service when source of water is within 1 km (or 30 min total collection time) outside the home is about 20 litres per person per day (WHO, 2003). This is about the minimum consumption level at which water demand starts to be satisfied and covers drinking, cooking, bathing and washing needs (Nissen-Peterson, 1999). In the Central Niger Delta, a 3-month (dry season) storage for 20 L consumption level will be 1.83 L/person (3 months × 30.5 days × 20 L). However, this consumption level is halved to take advantage of the existing water use pattern and also to target a manageable size of tank for household storage. A supply level of 10 L/cap/day might just be more than enough to meet demand for potable purposes such as drinking and cooking. Another important issue is the number of persons living in a household. The mass curve is independent of this figure once it has been developed.

Minimum rainwater storage for households

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 values of these variables are not always available so approximations are usually used with attempts to ensure maximum reliability. However, results from a highly accurate hydrological estimation of minimum storage volume might not be the final answer in determining the required tank capacity. Affordability by the users and ease of construction of the tank may eventually be the deciding factors (Pacey and Cullis, 1986). The various methods, including the mass curve analysis and dimensionless constant, for estimating minimum tank storage volume have been discussed in World Bank (1985). The mass curve analysis and dimensionless constant is a detailed analysis with a graphical output as the end-result. The advantage with this method is that the resulting graph has a high degree of flexibility in its application within a specific local rainfall pattern.

Implementation of method

The mass curve principle and dimensionless graph make up the core rainwater harvesting simulation method used in this research. The implementation of this method, based on some key assumptions, is laid out in the subsections.

The mass curve principle and dimensionless graph

The mass curve and dimensionless graph entails using the principle of mass curve to predict the cumulative supply which is compared against cumulative demand over a 12-month period to obtain the minimum storage required graphically or by using tables. It requires at least 10 years rainfall data, runoff coefficient, and catchment area. A further plot of scaled-down demand levels (as percentages of supply) against the corresponding storage volume (as a percentage of supply) gives a graph from which the dimensionless constant can be obtained. The calculation in this method may be based on some particular design parameters but the resultant graph can work for all demands, for any roof area and with any runoff co-efficient. This quality makes the graph especially valuable for field analysis where different roof sizes and types, and demand levels are inherent. However, the limitation of the tool is that the graph can only be used in a particular locality because of the uniqueness of rainfall pattern used to generate it.

The assumptions in the method include:

1. Demand is constant for every month: Demand actually varies. Abundant water from rainfall will be available for use during the rainy season so usage may increase, as the tank will always be refilled. However, it is important to ensure that the tank is always full, towards the end of the rainy season
2. Rainfall pattern in the future will be similar to the one used in the calculation: Future yearly rainfall figures are unpredictable, but the use of data for at least 10 years increases the degree of reliability.
3. Demand is constant from year to year: This analysis is based on no growth in demand over the years. The maximum expected family size could be used in calculating the total demand. This, of course, may vary from household to household. The analysis allows for this variation as different figures can be used in the field.
4. Evaporation from the roof is covered by the coefficient of runoff for the roof material: Evaporation is a loss that can be allowed for in the runoff coefficient. Evaporation from tanks may also be considered in specifying the final tank capacity.

Development of the dimensionless graph

The underlying calculations comprising the simulations that give rise to the dimensionless graph are based on the conventional rainwater supply equation (Equation 1) and cumulative mass balance equations considered for the worst period of rainfall.

$$S_M = R_M \times C_R \times H_{RA} \tag{1}$$

Where, S_M = Monthly rainwater supply; R_M = Monthly rainfall; C_R = Coefficient of run-off; H_{RA} = Roof area of house. Equation 1 is further modified based on annual rainfall data to yield average annual supply values as given in Equation 2.

$$S_{AM} = R_A \times C_R \times H_{RA}/m \tag{2}$$

Where, S_{AM} = Average monthly rainwater supply; R_A = Annual rainfall; m = Number of months in the year (12). The method further assumes that demand must always be less than supply. As such average annual supply values need to be scaled-down based on percentages to obtain corresponding demand figures (Equation 3).

$$D_{AM} = S_{AM} \times p \tag{3}$$

Where, D_{AM} = Average monthly rainwater demand; p = Percentage for scaling-down average monthly supply. The cumulative values of average annual supply and average annual demand are then compared for each month to estimate the monthly storage as given in Equation 4.

$$V_i = \sum_{i=1}^{n} S_{AM} - \sum_{i=1}^{n} D_{AM} \tag{4}$$

Where, V_i = Volume of storage required for month, i.

The maximum ($V_{i,max}$) and minimum ($V_{i,min}$) values of storage required will respectively occur at the beginning and end of all the dry season included in the simulation period (years). The maximum of the differences between the pairs of required storages ($V_{i,max}$ and $V_{i,min}$) is the actual volume of tank required for the particular scaled-down demand case.

Table 1 show the values used in plotting the dimensionless graph. These values were obtained from the mass curve analysis performed for various scaled-down demand, D_{AM} in the order of 90, 70, 50, 30 and 10%, as p, of the average annual supply, S_{AM}. As mentioned earlier the assumption is that the annual demand must be less than the average annual supply. Further, a typical mass curve analysis for the scaled-down demand, D_{AM}, of 90% is given in Table 2, which is a Microsoft Excel spreadsheet of the rainfall simulations. The corresponding minimum storage required is the maximum value (20,712 L) of all the values in Column 8 of

Table 1. Minimum storage as percentage of average annual supply

Annual demand (as % of average annual supply)	Storage required (litres)	Storage required (as % of average annual supply)
10	1804	2.5
30	6280	8.7
50	11091	15.4
70	15902	22.0
90	20712	28.7

Table 2. Minimum storage for annual demand equals 90% of average annual supply.

Month	Monthly rainfall (mm)	Monthly supply (mm)	Cumulative supply (litres)	Monthly demand (litres)	Amount stored (litres)	Total amount stored (litres)	Level	Required tank volume (litres)
Apr, 1980	308	7390	7390	5412	1978	1978		
May	396	9514	16903	5412	4102	6079		
Jun	438	10510	27413	5412	5098	11177		
Jul	342	8196	35609	5412	2784	13961		
Aug	361	8654	44263	5412	3242	17203		
Sep	395	9485	53748	5412	4073	21276		
Oct	613	14712	68460	5412	9300	30576		
Nov	486	11657	80117	5412	6245	36820	(max.)	
Dec	1	24	80141	5412	-5388	31432		
Jan, 1981	63	1507	81648	5412	-3905	27527		14419
Feb	71	1699	83347	5412	-3713	23815		
Mar	167	3998	87346	5412	-1414	22401	(min.)	
Apr	294	7054	94399	5412	1642	24042		
May	261	6262	100661	5412	850	24892		
Jun	625	14988	115649	5412	9576	34468		
Jul	492	11803	127452	5412	6391	40859		
Aug	46	1092	128544	5412	-4320	36539		
Sep	401	9626	138170	5412	4214	40753		
Oct	383	9185	147355	5412	3773	44526		
Nov	333	7980	155335	5412	2568	47094	(max.)	
Dec	0	0	155335	5412	-5412	41682		
Jan, 1982	0	0	155335	5412	-5412	36270		20712
Feb	0	0	155335	5412	-5412	30858		(MAX.)
Mar	39	936	156271	5412	-4476	26382	(min.)	
Apr	378	9060	165331	5412	3648	30030		
May	256	6151	171482	5412	739	30769		
Jun	379	9084	180566	5412	3672	34441		
Jul	166	3991	184558	5412	-1421	33020		
Aug	166	3979	188537	5412	-1433	31587		
Sep	499	11976	200513	5412	6564	38151		
Oct	373	8942	209455	5412	3530	41681	(max.)	
Nov	168	4034	213490	5412	-1378	40304		
Dec	15.6	374	213864	5412	-5038	35266		
Jan, 1983	0	0	213864	5412	-5412	29854		19632
Feb	46	1109	214973	5412	-4303	25551		
Mar	157	3766	218738	5412	-1646	23904		
Apr	148	3557	222295	5412	-1855	22049	(min.)	

Parameters used for calculations and sample calculations. Annual rainfall (1983) = 3007 mm. Coefficient of runoff = 0.8 Area of roof = 30 m^2. Monthly supply (first row) = 308 x 0.8 x 30 = 7390 L. Average Monthly supply = 3007 x 0.8 x 30 /12 = 6014 L. Monthly demand (Average) = 90% x 6013 = 5412 L.

Table 2. The other values of minimum storage for the rest of the scaled-down demands were obtained through similar analysis. The resulting dimensionless graph is shown in Figure 4(a) used in demonstrating the efficacy of the tool.

RESULTS

Here output of the mass curve analysis and an illustration of how it can be applied to various rainwater demand and supply cases possible in the field is presented. In order to examine impacts of possible variations in annual rainfall, available roof areas and number of person living in a household; the outcome of a sensitivity analysis is also presented here.

A case-illustration of method efficacy

The efficacy of the dimensionless graph earlier discussed is further illustrated in Figure 4(b). For an annual demand of 21.90 m^3 for 6 persons in a household (that is 10 L/cap/day), based on the mean annual rainfall of 3007 mm (1983), the volume of minimum storage (tank) that will be required in the Central Niger Delta area will be 6.60 m^3. This is obtained by: calculating the annual demand and annual supply; calculating what percentage the demand is of the supply; reading-off the corresponding value from the dimensionless graph; and then multiplying this value by the annual supply to give the volume of storage required. Thus a corresponding volume of tank can be calculated for any level of demand estimated in the field and any family size as illustrated in Figure 4(c) and (d).

Sensitivity of the developed mass curve tool

A sensitivity analysis was carried out based on the worst annual rainfall, 3007 mm for 1983. This was examined for roof areas ranging from 16 to 324 m^2; and households occupied by 1, 3, 6 and 9 Persons/household (Pers/hld) corresponding to rainwater demand levels of 3.65, 10.95, 21.90 and 32.85 m^3 respectively. Figure 5 shows how the roof area varies with the required volume of tank to store rainwater through the year. To account for possible fluctuations in the annual rainfall, Figures 6 and 7 were generated for 10% decrease and increase, respectively, of the annual rainfall of 1983. The trends of the respective curves compare relatively well and are next discussed.

DISCUSSION

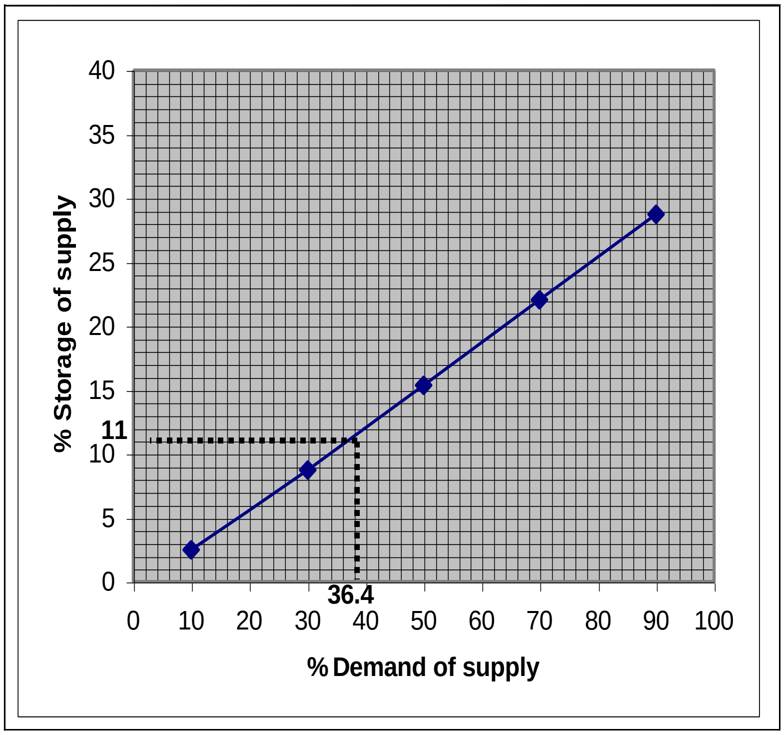
The results presented demonstrate the benefits of the mass curve analysis and graphically shows the implications associated with the sensitivity aspect of the developed tool. These and other soft issues associated with RWH implementation in the Niger Delta have been examined here.

Use-case illustration and sensitivity implications

As earlier mentioned, the resulting graph from the mass curve analysis could be used to estimate the volume (size) of tank required by any household, within the study area of the Niger Delta, to store rainwater for potable use throughout the year. The advantage with such illustrations is that households become aware of the capacity of tank they require and the roof area that could comfortably provide the respective harvest. This can enhance planning and implementation of RWH projects with respect to estimation of materials and reduction of costs. Thus, the (roof) area required by a particular household for a comfortable harvest could turn out to be a fraction of the entire roof area of an occupied building. On another hand, a roof area dedicated to the purpose of RWH can be built with guidance from the result obtained from the mass curve tool.

Since variations usually abound in the field, the sensitivity analysis examines ±10% fluctuation in annual rainfall over a range of 16 to 324 m^2 roof area available for rainwater supply to 1 to 9 persons/household. It is of interest to note that the tool does not work on a direct proportional interpolation with respect to number of persons per household and the respective volume of storage (capacity of tank) required. For example considering the annual rainfall of 3007 mm (Figure 5), for a roof area of 36 m^2 the capacity of tank (3.07 m^2) for 3 Persons/household is more than three times the capacity (0.87 m^2) required for 1 person. Furthermore, beyond certain values of roof area, it will become impossible to obtain values for the volume of storage, as the percentage of the ratio of demand to supply drops beyond what can be read off the dimensionless graph. This is most critical for the case of 1person/household as seen in Figure 5 to 7. The implication for such cases is that, the household may be able to use rainwater all through the year without any significant storage. However, this may not be practicable so a provision must still be made for minimum storage, guided by the closest tank size for a particular number of persons/household obtained from the dimensionless graph.

Generally, the larger the available roof area dedicated to RWH – the less is the minimum capacity of tank required for rainwater storage. The sensitivity results show a remarkable effect on the required storage when the Annual Rainfall changes. Thus, a reduction in the annual rainfall does not significantly affect the required tank capacity as does the increase. The overflow from the tank when it is full during the rainy season compensates for the reduction in annual rainfall and by extension the rainwater supply. However, the supply increases and likely spreads over a longer period (months)



(a)

Roof area = 25 m^2, runoff coefficient = 0.8, mean annual rainfall. = 3007 mm

Annual demand = 21.90 m^3

(10 l/cap/d, for 6 persons.)

Annual supply = 3007 x 25 x 0.8/1000

= 60.14 m^3

Demand as % of supply = 21.9/60.1 x 100

= 36 %

From the graph,

% storage of supply = 11%

Therefore, volume of tank =

11% x 60.1 = 6.60 m^3

(b)

Roof area = 35 m^2, runoff coefficient = 0.8, mean annual rainfall = 3007 mm

Annual demand = 21.90 m^3

(10 l/cap/d, for 6 persons.)

Annual supply = 3007 x 35 x 0.8/1000

= 84.20 m^3

Demand as % of supply = 21.90/84.20 x 100

= 27 %

From the graph,

% storage of supply = 8%

Therefore, volume of tank =

8% x 84.19 = 6.72 m^3

(c)

Roof area = 25 m^2, runoff coefficient = 0.8, mean annual rainfall = 3007 mm

Annual demand = 29.20 m^3

(10 l/cap/d, for 8 persons.)

Annual supply = 3007 x 25 x 0.8/1000

= 60.14 m^3

Demand as % of supply = 29.20/60.14 x 100

= 49 %

From the graph,

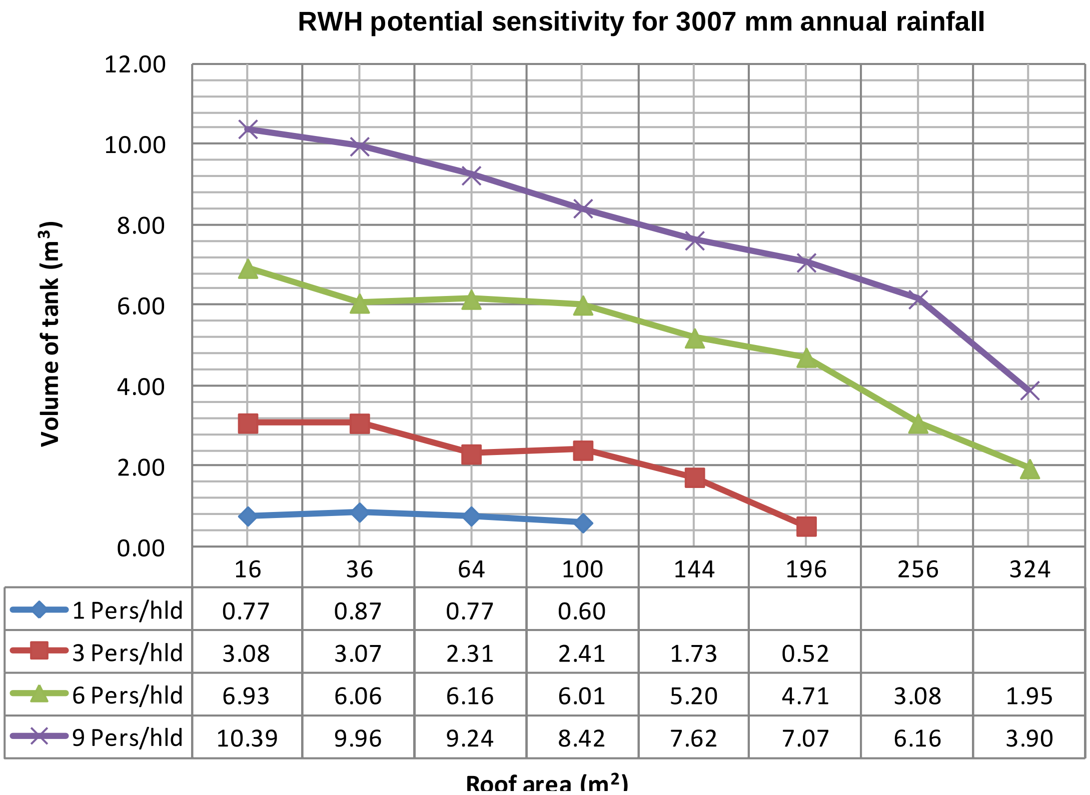
% storage of supply = 15%

Therefore, volume of tank =

15% x 60.13 = 9.02 m^3

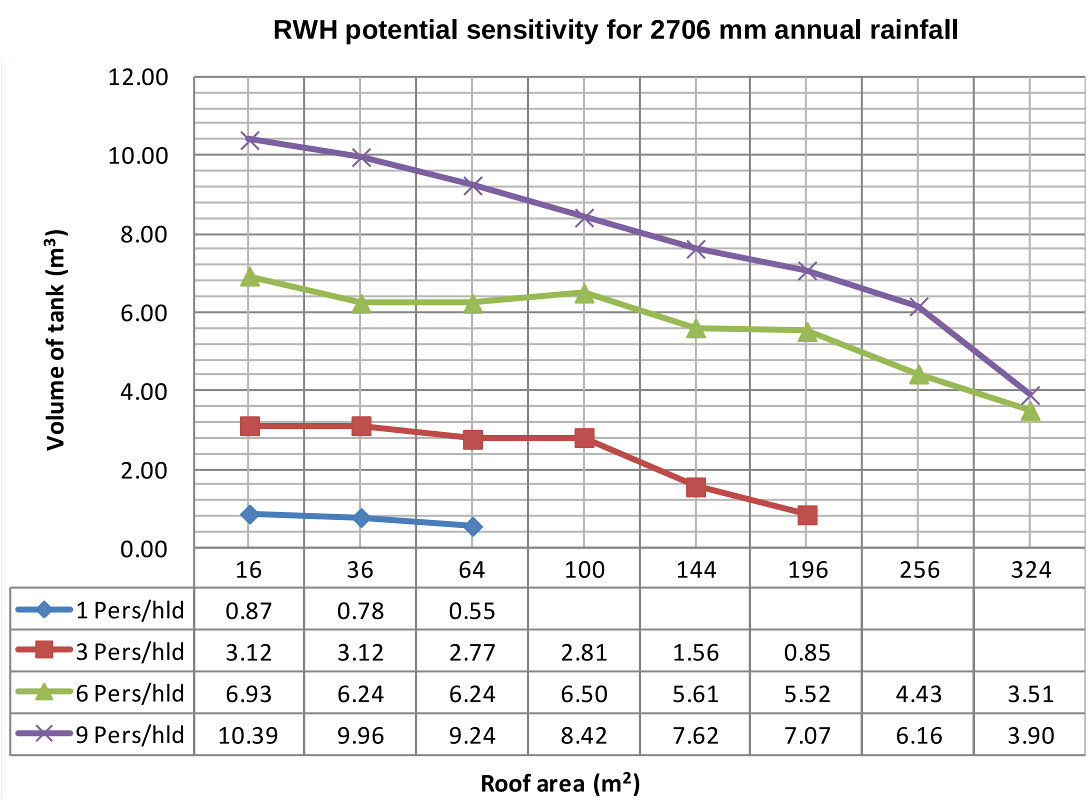
(d)

Figure 4. Finding the minimum volume of storage from the dimensionless graph. (a) dimensionless graph (b) calculation of volume of tank (c) volume of tank for variation of roof size (d) tank volume for variation of family size.



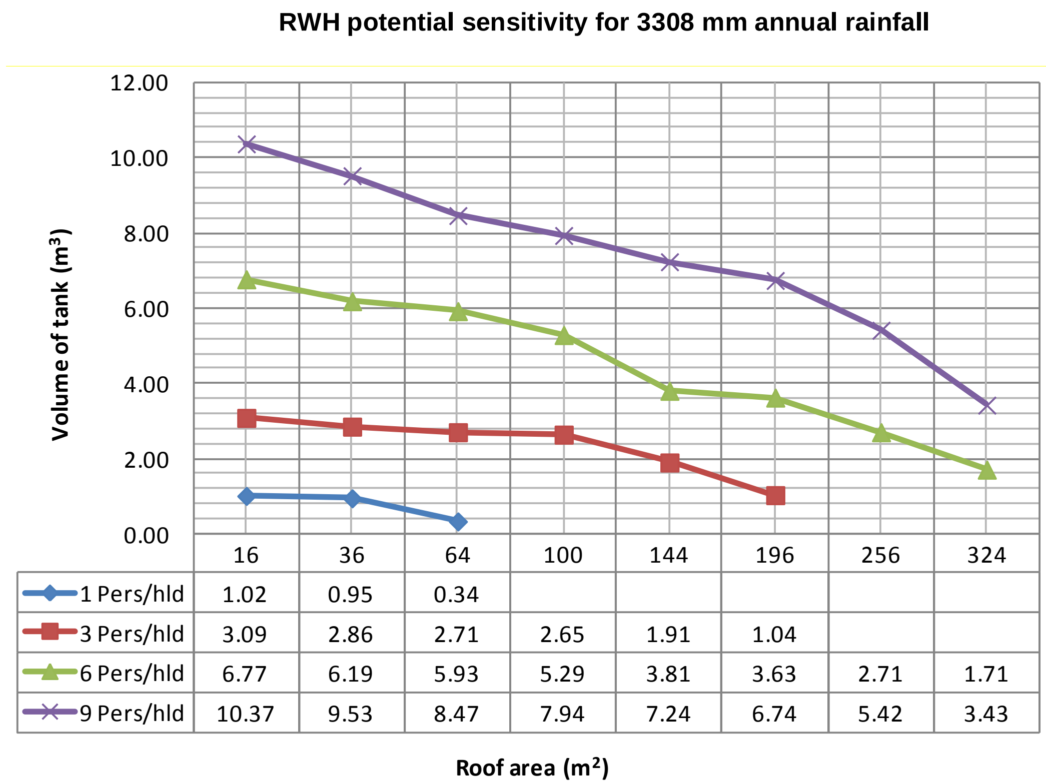
	16	36	64	100	144	196	256	324
1 Pers/hld	0.77	0.87	0.77	0.60				
3 Pers/hld	3.08	3.07	2.31	2.41	1.73	0.52		
6 Pers/hld	6.93	6.06	6.16	6.01	5.20	4.71	3.08	1.95
9 Pers/hld	10.39	9.96	9.24	8.42	7.62	7.07	6.16	3.90

Figure 5. Sensitivity chart for 3007 mm Annual Rainfall (AR) of 1983.



	16	36	64	100	144	196	256	324
1 Pers/hld	0.87	0.78	0.55					
3 Pers/hld	3.12	3.12	2.77	2.81	1.56	0.85		
6 Pers/hld	6.93	6.24	6.24	6.50	5.61	5.52	4.43	3.51
9 Pers/hld	10.39	9.96	9.24	8.42	7.62	7.07	6.16	3.90

Figure 6. Sensitivity chart for 2706 mm AR (10% reduction of 1983 AR).



	16	36	64	100	144	196	256	324
1 Pers/hld	1.02	0.95	0.34					
3 Pers/hld	3.09	2.86	2.71	2.65	1.91	1.04		
6 Pers/hld	6.77	6.19	5.93	5.29	3.81	3.63	2.71	1.71
9 Pers/hld	10.37	9.53	8.47	7.94	7.24	6.74	5.42	3.43

Figure 7. Sensitivity chart for 3308 mm AR (10% increase of 1983 AR).

of the year when there is an increase in annual rainfall. As such the mass curve tool is robust enough to balance off possible fluctuations in annual rainfall figures.

Other aspects of RWH implementation in the Central Niger Delta

A high annual rainfall figure, as in the Central Niger Delta, is often an indication of the potential for RWH in an area; however a key aspect of DRWH design is the detailed analysis of the rainfall pattern in respect to dry periods and required storage. This paper presents a tool, adapted to the Central Niger Delta rainfall pattern, which could be used in the field to easily obtain the volume of RW storage required for any level of household demand. There are quite a number of issues, besides specification of adequate storage, imbedded in the implementation of RWH programmes. Social aspects related to the acceptance of RWH as a recognised formal water supply means, cost implications of systems and the sustainable management of projects are essential areas that need attention.

Informal collection of rainwater is wide-spread in the Central Niger Delta (Efe, 2006) but some form of sensitization will be required to tune the mindset of people to accepting RWH as a source of drinking water rather than looking forward to a more sophisticated supply systems. One of the ways forward is a situation where existing local government structures enact RWH policies and anchor related programmes which can help gather good momentum and deal with associated costs issues. Communities in South Africa are already benefiting from such government involvement in pursuing the Millennium Development Goals (Mwenge-Kahinda et al., 2007). The track record of Community Based Organisations (CBOs) and Non-Governmental Organisations (NGOs) in aiding such water supply programmes is worth mentioning (Handia et al., 2003). These organisations remain a store-house from where expertise and knowledge could be tapped for successful and sustainable programme implementation. Thus, some of the areas identified for further work to corroborate the favourable rainfall pattern in the Central Niger Delta for the implementation of a sustainable RWH programme include:

1. Win the Local and State government attention to RWH technology aimed at considering rainwater as a formal water supply source in the water policies of the state.
2. RWH sensitization to canvass a wide societal acceptability of the technology as a formal supply option
3. Investigate management options of RWH programmes, including aspects of selecting appropriate type and size

of tanks; cost and economic issues; ensuring good rainwater quality; and rainwater related health and hygiene practices.

4. The development of appropriate RWH guidelines for the Central Niger Delta area to serve as a general technical guide in developing the technology in this area.

Conclusion

RWH is truly an old technology that has often been relegated to the background. This is due to a number of reasons including; stigmas rising from societal perception, lack of government support and desire for more sophisticated water supply schemes. However, it is becoming increasingly obvious that investment in RWH could bring water more easily to people in both urban and rural areas alike at a much less cost and also contribute to conservation of nature's resources. Among the key aspects of RWH programme, the suitability of rainfall pattern stands as a main determining factor on the possible level of scale. Hence, this has been targeted as a theme to demonstrate the potential of RWH endowed in the Niger Delta area. Storage that could last a minimum of the 3 months critical dry periods in the Central Niger Delta is what is needed to be able use rainwater all year round. If surface water sources are used to meet non-portable purposes; with some level of discipline in water use pattern, the size of tank for rainwater storage can be reduced to a more affordable size. For such sizes of tanks, water is likely to overflow during the rainy season. This water can actually be utilised by the family. They can easily collect overflowing water by putting a drum under the overflow or increasing the amount of water taken from the tank but monitoring the level so the tank will still be full at the start of the dry season. Such water would be very conveniently available and would reduce their need to carry water from other sources in the rainy season.

Thus, this paper has shown that in the Central Niger Delta, development of RWH system is worth consideration owing to the large volume of water that naturally falls from the sky. The dimensionless graph developed from analysis serves as a ready tool for easy application in the field. Like many other water supply programmes, RWH also requires planning, management, finance, and safe health/hygiene practices. These are some areas where support is required from government, non-governmental agencies, the academia and even the society. Such support will help to stir up new innovations and technologies that will drive RWH to greater heights and general acceptability by both the poor and the rich of the society, and the world at large.

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