Geospatial Assessment of The Potentials of Rooftop Rainwater Harvest at The Federal University of Technology, Akure, Nigeria

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ORIGINAL RESEARCH ARTICLE

Abstract- Recent reports reveal water shortage at the Federal University of Technology, Akure, (FUTA), Nigeria, with possibilities to worsen if adequate measures are not taken. This research focuses on the assessment of the potential of an alternative source of water supply the Roof Top Rainwater Harvest (RTRWH) at FUTA. This study goes beyond the determination of the potential volume of RTRWH by proposing a storage plan for the RTRWH based on geospatial analysis. Data collected for the study are rainfall data covering 19 years (2000-2018), High-Resolution Satellite Image (HRSI), Ground Control Point (GCP), attribute data, Landsat 8 and Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM). The rooftop areas were extracted by processing HRSI using ArcGIS software. The volumes of the RTRWH for each building were computed with the rooftop area, precipitation amount and roof's runoff coefficient of the rooftop material as variables. Suitable locations for siting the storage tanks were proposed based on Multi-Criteria Decision Making (MCDM) and geospatial analysis. Result obtained from the study reveals that the total area of rooftop catchment for all buildings considered is 164,246 m2. The study suggests 9 locations suitable for collecting and storing the harvested RTRW. The potential average daily, average monthly and total annual volumes of RTRWH are approximately 607 m3, 18,473 m3 and 221,681 m3 respectively, and thereby could potentially provide ~ 41% of water demand in addition to the existing water supply sources in FUTA. The RTRWH is therefore recommended as an alternative water source at FUTA.

Keywords- Analytic Hierarchy Process, Geospatial, Rooftop Rainwater Harvest, Water Supply Scheme

1 Introduction

Generally, water is an influential natural resource, if not the most valuable of all. Its importance cannot be overemphasized. Sources of water supply can be classified into groundwater and surface water. Surface water is inadequate to fulfil water demand, groundwater is therefore relied on. Unfortunately, studies have revealed evidence of groundwater depletion and deterioration in quality, which have been linked to rapid population growth, excessive groundwater abstraction, urbanization, climate change and water contamination caused by toxic waste from agricultural practices and Industries (Baby et al., 2019; Ishaku et al., 2012; Shitole et al., 2018; Wu et al., 2018).

Water scarcity is among the most serious challenge that many developing countries face in the 21st century. Sub-Saharan Africa is also challenged with this issue. The acquisition of adequate and potable water sources for human consumption, and industrial and agricultural uses has led to a cause of concern (Olutola, 2019). Despite the abundance of land and water resources accessible in diverse climatic zones, Nigeria cannot satisfy its domestic water needs and only 14% of the population has access to potable water supply services (Federal Ministry of Water Resources, 2020).

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Based on projections, Nigeria is one of the 25 African countries that will experience water scarcity or stress by 2025 (Muritala, 2018). Rainwater Harvesting (RWH) is an effective strategy for dealing with water scarcity (Ammar et al., 2016). It has proven to be incredibly beneficial, because it not only tackles the issue of water shortage but also reduces groundwater extraction, minimizes flooding and improves water resource utilization to maximize water availability (Wu et al., 2018). RWH is not just one part of an integrated plan to maximize water availability, but also the heart of a novel water management paradigm (Huang et al., 2021).

There are two methods of rainwater harvesting: Surface Runoff Harvesting (SRH) and Roof Top Rainwater Harvesting (RTRWH) (Hari et al., 2018). In SRH, the surface runoff due to rain is diverted into ponds, dams, lakes and reservoirs. In the RTRWH method, rainwater falling on rooftops is captured, conveyed and stored either in surface water bodies for direct use or subsurface for groundwater recharge. Capturing rooftop rainwater is a simple and cost-effective approach that promotes sustainable water management. For this study, the Rooftop rainwater harvesting method is considered. This technique was considered suitable because the research area had many buildings with wide roof catchments covering them, mostly of aluminium corrugated sheets which have a high runoff coefficient suitable for harvesting portable water.

The RTRWH refers to the process of harvesting water collection from rooftops (Juliana et al., 2017). Rainwater harvesting comprises the acquisition, storage and prospective uses of rainwater as either the main or as an added source of water. Both domestic and non-domestic applications are possible (Lade and Oloke, 2015). The main purpose of RTRWH is to make water available for prospective uses. Collection and storage of rainwater are relevant in the urban, dry land, hilly and coastal areas.

The RTRWH can support the water supply in most areas through water savings (Ojwang et al., 2017). For this research, the storage and volume of RTRWH are considered. Several studies have been conducted to assess and analyse the capacities of RTRWH. For example, Abdullahi et al. (2014) investigated the influence of RWH in Coventry University buildings and the possible impact on the surrounding urban environment of the city centre, it was stated that “the rainwater that can potentially be harvested from the buildings amounts to about 25% of the University's total annual water consumption”. Also, Hari et al. (2018) made use of GIS techniques in assessing the overall potential of RTRW. Similarly, Baby et al. (2019) employed the GIS approach to evaluate the entire area of catchment available for RTRWH in Wollert and to calculate the volume of water, that could be harvested for replenishing groundwater reserves. Furthermore, the potential for water-saving by adopting rainwater sources in “Smt Dhairya Prabhadevi Sojatia” (SDPS) Women’s College in Indore city in Madhya Pradesh, India, was evaluated by Shitole et al. (2018). The findings from the study reveal that the application of the rainwater harvest project on the campus will be the best approach to fight the scenario of water shortage.

A study carried out in the same study area adopted for this study, on evaluations of recent and future potable water requirements and supply at the Federal University of Technology, Akure (FUTA) (Akeju et al., 2021), has shown water shortage exists in FUTA and the situation would worsen as the years go by if adequate measures are not put in place. The study has shown that FUTA depends mainly on underground water. Throughout the dry season, FUTA experiences severe water scarcity, due to a massive drop in the level of underground water in the area. Also, the safety of the extracted groundwater is under contention, due to a vast portion of the campus being used as research farms, which are cultivated using agrochemicals. Studies reveal that a large number of agrochemicals used in farming end up contaminating groundwater resources, since the water-soluble agrochemicals percolate rapidly through the soil, allowing them to linger in groundwater for decades (Namdev et al., 2011; Srivastav, 2020; Yadav et al., 2015).

Also, the energy cost expended in the extraction of groundwater remains a major issue. The costs of extracting groundwater include both capital and running costs. To use groundwater, users must first get groundwater to the land surface. This necessitates significant capital investments (e.g., well and borehole construction, pumps) and operating cash flows (e.g., power expenses) (Turner et al., 2019). Pumping groundwater may also induce land subsidence and enable contaminants into drinking water sources (Gleeson and Richter, 2018; MacDonald et al., 2016; Zhu et al., 2015). The challenge is not just how much water is physically accessible; we also need to determine how much is economically and sustainably exploitable, since this will most likely define future global groundwater depletion. Hence, there is need to consider an alternative water source for the University Campus.

Considering some of the recent research reviewed, RTRWH has shown an effective alternative water supply scheme, however, there is a need to determine the possible quantity of the RTRW which can be harnessed. Beyond the determination of the possible volumes of RTRWH, a storage and management plan must be considered. The study aims to assess the potential of RTRWH, at the main campus of FUTA. This can be achieved by the determination of the potential volumes of RTRWH and the development of the storage plan for RTRWH based on geospatial analysis.

2 Materials and Method

2.1 Study Area

The research area is the main campus (Obanla and Obakekere) of FUTA, Ondo State, Nigeria, located between latitudes 7°17'0''N and 7°19'0''N and longitudes 5°07'02''E and 5°09'05''E. The area covers about 577 hectares of land, having ~ 60% of the land area developed. The area covers all building footprints on the campus. Fig. 1 is a satellite image of FUTA indicating the study area.

Akure is located within the tropical rain forest (Fasinmirin et al., 2018) and experiences a warm humid tropical climate, with two distinct seasons, the rainy and dry seasons. The rainy season spans a period of seven months (April - October) and the dry season spans a period of five months (November - March) (Olujumoke et al., 2016). Akure and its surrounding areas, experience frequent rainfall, with a mean annual of ~ 1500 mm with rainfall occurring virtually all the months of the year, with heavy downpours during the rainy season and light downpours during the dry season.

According to the 2019 record, FUTA has a population of 28,419 comprising 9.16% staff and 90.84% students, and a consistent growth rate of ~ 2.65% with the population projected to be 33,247 by 2025 (Akeju et al., 2021). The major water source in FUTA is subsurface water, and the commonest are hand-dug wells and boreholes (Simon-Oke et al., 2020). In FUTA, there exist 25 boreholes, 6 are non-functional and the 19 functional boreholes provide an average daily supply of ~ 1,198 m3 stored in the existing total capacity of ~1359 m3 (FUTA Directorate of Works, 2017). In FUTA, the mean daily water demand estimated in 2019 stands at ~ 1,475 m3 projected to ~ 1,724 m3 by 2025 (Akeju et al., 2021).

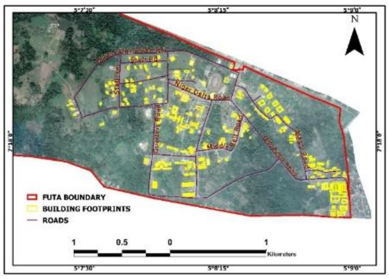

Fig. 1: Satellite imagery of the study area highlighting the building footprints

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Table 1. Details of data sets used and their sources

Data type	Sources	Description
Rainfall data 2000-2018 (19 years)	Centre for Space Research and Applications (CESRA) FUTA	Monthly rainfall data.
HRSI	Google Earth Satellite Imagery	1-m Resolution Google Satellite Image 2020.
Ground Control Points (GCP)	GPS Survey (South DGPS)	Easting and Northing Coordinates of 10 GCPs well widespread over the study area.
SRTM	United States Geological Survey (USGS)website(https://earthexplorer.usgs.gov/)	Raster digital elevation model (DEM) with global coverage, data for year 2020.
Landsat 8 Satellite Imagery	United States Geological Survey (USGS) website (https://earthexplorer.usgs.gov/)	30m resolution 11 bands multispectral image collected with both OLI/TIRS, 2020.
Non- Spatial / Attribute Data	Reconnaissance Survey, Fieldwork (with Hand Held GPS etrex 10)	Building and road identification, Utilities (toilets and water facilities etc.), important places.

2.2 Data Acquisition

The major datasets used for this study include nineteen (19) years of precipitation data, High-Resolution Satellite Image (HRSI), Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM), Landsat 8 and other non-spatial / attribute data. Table 1 provides details of the datasets used and their respective sources.

2.3 Estimation of Volume of RTRWH

The estimated volume of harvested Rooftop Rain Water (RTRW) was calculated, using the formula specified in equation (1) (Hari, 2019).

$$S = R \times A \times I \quad (1)$$

Where S is the volume of harvested RTRW (m3), R is the mean rainfall (m), A is the roof's catchment area (m2) and I coefficient of runoff. In estimating the average rainfall used in the computation on equation 1, 19 years of rainfall data (2000 – 2018) for the research area was used. The sum of the annual rainfall in the study area is represented by a chart in Fig. 2. Since the computation of RTRWH volumes was computed on monthly basis (January, February, … December), the mean rainfall applied in the computation of the volume of harvested RTRW in equation 1, was determined on the monthly scale. The mean monthly rainfall trend was derived by taking 19 years' average amount of rainfall per month represented in Fig. 3.

In the estimation of the rooftop catchment area, remotely sensed HRSI (Google Earth) was adopted for the geospatial analysis using ArcGIS 10.7 software. Georeferencing was performed on the HRSI based on 10 precisely determined evenly spread Ground Control Points (GCPs) and 6 Independent Check Points (ICPs) collected within the research area. These were considered necessary, to transform the HRSI from the image coordinate system to the ground coordinate system and assessment of the map accuracy, to enable the correct representation of the roof catchment area on the HRSI. The coordinates of the GCPs and ICPs were measured using a south differential Global Positioning System (GPS) receiver, with observations made in static mode. Based on the assessment of the resulting map accuracy using the ICPs, a linear accuracy of approximately 1/6800 resulted which conforms to a third-order mapping accuracy (1/5000), as specified by the Surveying Council of Nigeria (SURCON, 2003). The rooftops along with other map features such as roads, parks, and other important map elements identified in the research area were digitized as polygon features from the georeferenced HRSI using the editor tool in ArcMap. The digitized building polygons are shown on the map depicting the research area in Fig. 1. The estimates of the areas of each digitized rooftop polygon feature were computed using the "calculate geometry tool" of ArcGIS. The estimates of the areas of each digitized rooftop polygon feature were applied as an input in equation 1. Furthermore, non-spatial attributes recorded in each building polygon related to the study are building names, the number of floors, uses and rooftop materials.

The coefficient of runoff adopted for rooftop surface materials is described as the ratio between volumes of water that runs off and that of the total volume of rain that falls on the rooftop (Hari et al., 2018). The surface coefficient of runoff varies for different roof surfaces, the coefficient of runoff adopted in the computation depended on the roof material. Table 2 presents the surface coefficient of runoff for different roof types. The rooftop materials for each building were derived from the attribute data of the building polygons. However, most of the buildings over 90% comprised of galvanized iron sheets. This information was applied in computing the runoff coefficient for each building polygon and applied in equation 1 for computing the volume of harvested RTRW.

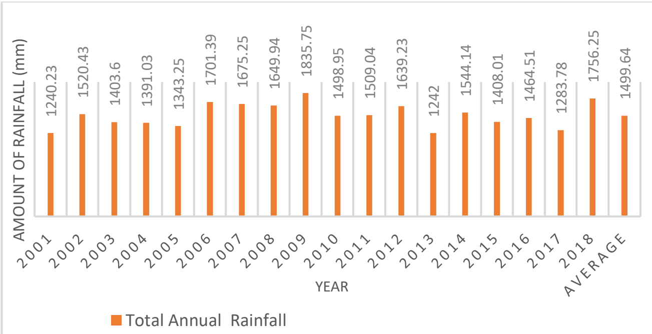

Fig. 2: Annual monthly average and total annual rainfall chart for the study area (2000 - 2018). Source: (*Centre for Space Research and Applications*, 2019)

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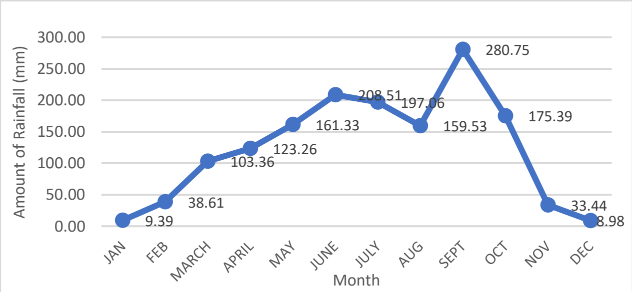

Fig. 3: Monthly rainfall trend 19 years average (2000-2018) for the study area Source: (Centre for Space Research and Applications, 2019)

Table 2. Runoff coefficient of various roof types

S/N	Surface Type	Runoff coefficient
1	Galvanized iron sheet	0.90
2	Asbestos sheet	0.80
3	Tiled roof	0.75
4	Concrete roof	0.70

Source: Adapted from Anchan & Prasad (2021).

2.4 Geospatial Analysis for Locating Suitable RTRWH Storage Sites

Suitable storage sites for RTRWH with their associated building clusters (catchments) were located based on geospatial techniques in combination with Multi-Criteria Decision Making (MCDM). The MCDM used is the Analytic Hierarchy Process (AHP), this is because of the reliability and flexibility of the technique. The geospatial assessment was done based on criteria adapted from standards recommended by expert studies (Ammar et al., 2016; Jha et al., 2014) and data availability. Criteria considered are land cover, slope, relative elevation, proximity to catchment areas and major road crossing.

A land cover map was prepared using a Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) satellite imagery data. Maximum Likelihood Classifier on ArcMap was used for the supervised classification. Training samples were acquired during the field survey to create spectral signatures for the supervised classification. The land cover map was classified into five main classes – forest, light vegetation, bare land, built-up and impervious surface (such as rock outcrop and roads) and the extent of each class was estimated. The land cover map of the study area is represented in Fig. 4a. The proximity to buildings map was prepared based on the building features extracted from the HRSI. The proximity to building maps within the research area was obtained by using the Euclidean distance function in ArcGIS, considering the farthest distance of 1000m. The proximity to the building map is represented in Fig. 4b. The elevation and slope maps were prepared from SRTM digital elevation data with a 30m resolution. The SRTM data was first converted to a Digital Elevation Model (DEM) map and then elevations and slope maps were generated in ArcGIS represented on Figs. 4c and 4d respectively.

Suitability indices for slope, land cover and proximity to building criteria, adopted for locating areas suitable for siting RTRW storage tanks are provided in Table 3. These were the major criteria considered in locating areas suitable to determine the weight factor of the criteria, a pairwise comparison matrix is designed based on Saaty's AHP comparison scale adapted from Bozdag et al. (2016) presented in Table 4. The vector of weights is then calculated based on Saaty's eigenvector method. Then, eigenvector (a) is normalised using equation 2 and the weights (w) are computed using equation 3. Table 5 is the outputs of the computations from equations 1 and 2 showing the normalised eigenvector elements (normalized pairwise comparison matrix) and the weights.

$$a_{ij} = \frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \quad (2)$$

$$w_{ij} = \frac{\sum_{j=1}^{n} a_{ij}}{n}, \quad (3)$$

where $i, j = 1, 2, 3 \ldots n$.

The consistency ratio (CR) was computed to test for consistency in the normalized weights and was found to be 0.06 which was less than 0.10 and so, rating is consistent.

Additional criteria considered are relative elevations and major road crossings. The relative elevation between the rooftop elevations and collection points were considered because water will flow naturally from high to low point. To achieve this, all rooftops elevation were determined by adding the ground elevations to the building heights. The approximate height of the building was determined by multiplying the Number of building floors attribute, by the standard 3m per floor. The rooftop elevations were recorded as a field in the attribute table and assessed to ensure that within each cluster allocated to a collection point, all rooftops elevation exceeded the elevation of the proposed collection point. In the case of major road crossing considerations, the need for RTRWH facilities to cross major roads was minimized. These added criteria deal mainly with fine-tuning the categorization of the rooftop catchments into clusters associated with the potential RTRW storage points since the main criterion for this categorization is proximity to building.

The cluster catchment area is obtained as the sum of the areas of the building polygons at each cluster, while the potential total annual RTRWH volume is obtained by summing the monthly volumes. The mean daily and mean monthly values are obtained by dividing the total annual RTRWH volume by 365 days and 12 months of the year respectively at each cluster.

The workflow of the methodology adopted in this study is represented in Fig. 5. This comprises steps in the research presented in a logical sequence.

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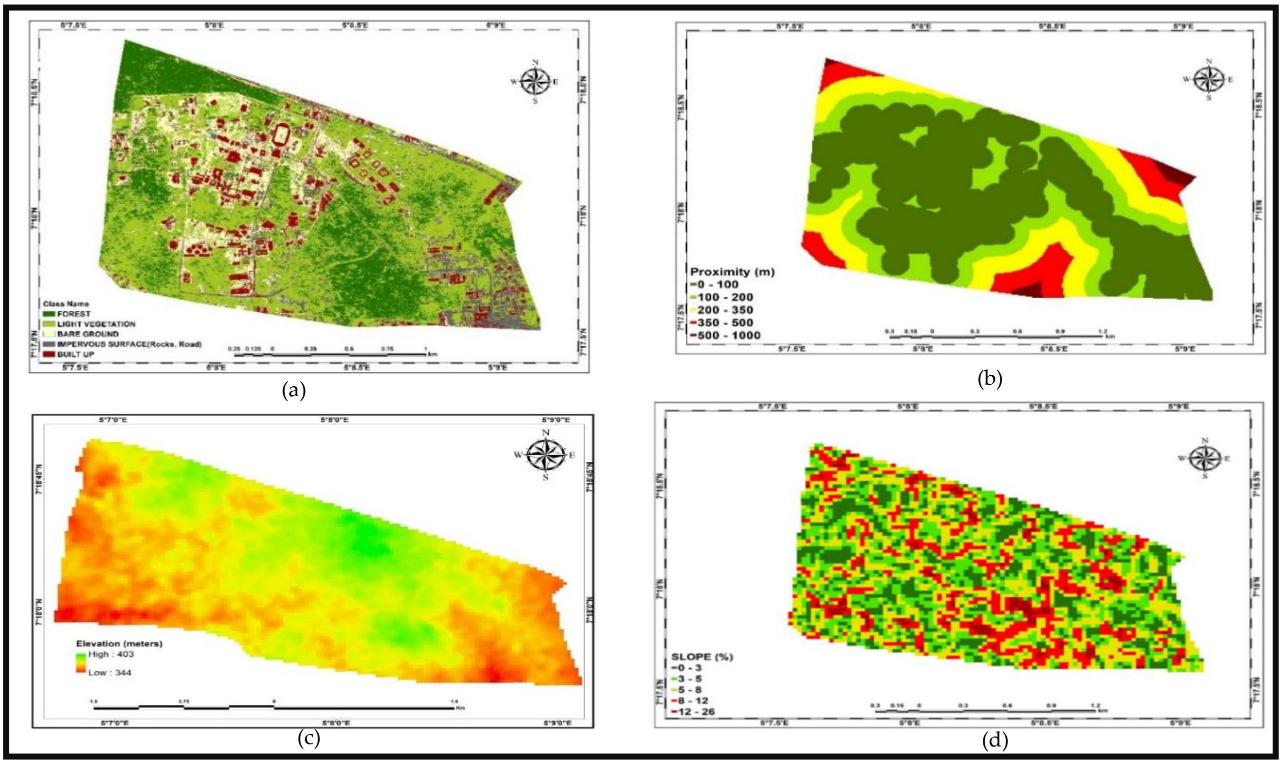

Fig. 4: Thematic layers considered in siting RTRWH storage facilities (a) Land cover map, (b) Proximity to buildings, (c), Elevation and (d) Slope map

Table 3. Suitability indices for thematic layers (criteria) considered in siting RTRWH facilities

Thematic layer/criteria	Classification	Suitability
Slope (%)	< 3	Very high
	≥ 3 < 5	High
	≥ 5 < 8	Moderate
	≥ 8 < 12	Low
	≥ 12 < 25	Very low
Land cover	Bare land	Very high
	Light Vegetation	High
	Forest	Moderate
	Impervious Surface	Low
	Built-up	Very low
Proximity to Buildings (m)	< 100	Very high
	≥ 100 < 200	High
	≥ 200 < 350	Moderate
	≥ 350 < 500	Low
	≥ 500 < 1000	Very low

Source: adapted from Bozdag et al., (2016)

Table 4. Pairwise comparison matrix

Criteria	Slope	Land cover	Proximity to Buildings
Slope	1	3	7
Land cover	1/3	1	5
Proximity to Buildings	1/5	1/5	1
TOTAL	1.476	4.2	13

Source: Adapted from Bozdag et al. (2016)

Table 5. Normalised Pairwise comparison matrix and weight factors

Criteria	Slope **(a)**	Land Cover **(b)**	Proximity to Buildings **(c)**	Weight **(a+b+c)/3**
Slope	0.6774	0.7143	0.5385	0.6434 (64.34%)
Land Cover	0.2258	0.2381	0.3846	0.2828 (28.28%)
Proximity to Buildings	0.0968	0.0476	0.0769	0.0738 (7.38%)
TOTAL	**1**	**1**	**1**	**1**

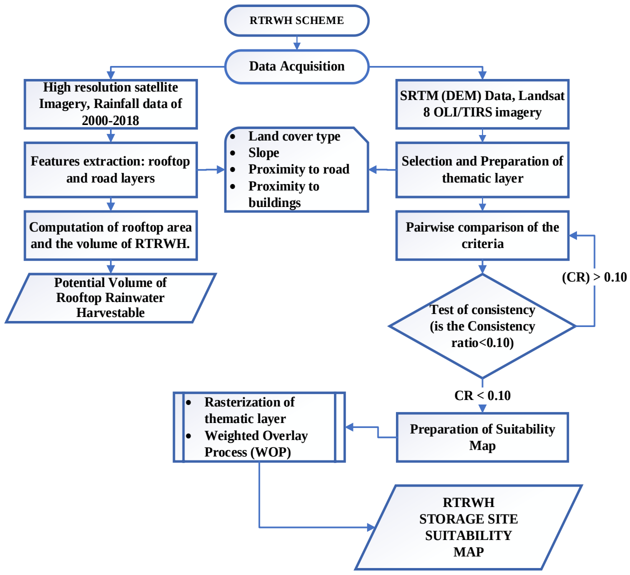

Fig. 5: Workflow of methodology

3 Results and Discussion

3.1 Results on Suitable RTRWH Storage Sites

Results obtained from the study were presented in this section. The study area is categorized into 4 classes: most-suitable, moderately-suitable, least-suitable, and unsuitable for siting the proposed RTRWH storage tanks. Fig. 6a is a map showing the spatial representations of suitability classes, while Fig. 6b is a pie chart showing the percentage land coverage of each suitability class. For this study, the most and moderately suitable areas were adopted for siting the proposed RTRWH storage tanks. Fig. 7 is a map showing the proposed locations for harvested RTRW proposed storage tanks. From this map, 9 locations were identified as suitable for siting the proposed RTRWH storage tanks. Building clusters were also identified as catchments for each proposed RTRWH storage tank location. On this map, a 200 m buffer can also be seen from Table 3 representing very high and high suitability indices considering the proximity to buildings.

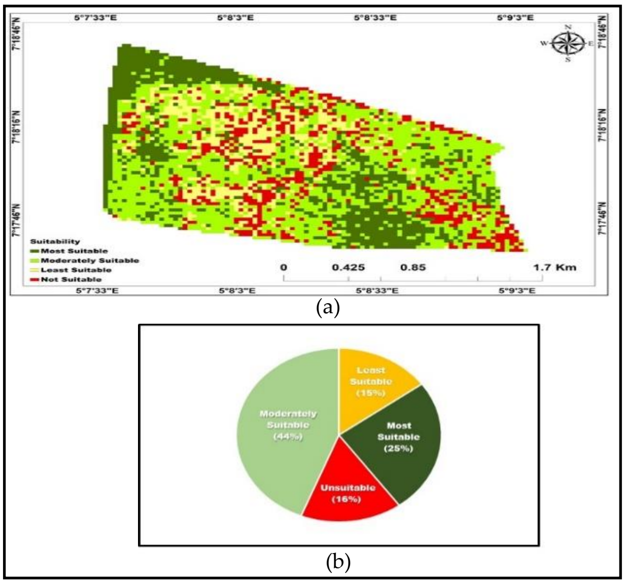

Fig. 6: (a) Suitability Map for siting RTRW storage tanks; (b) Spatial extent of each suitability class

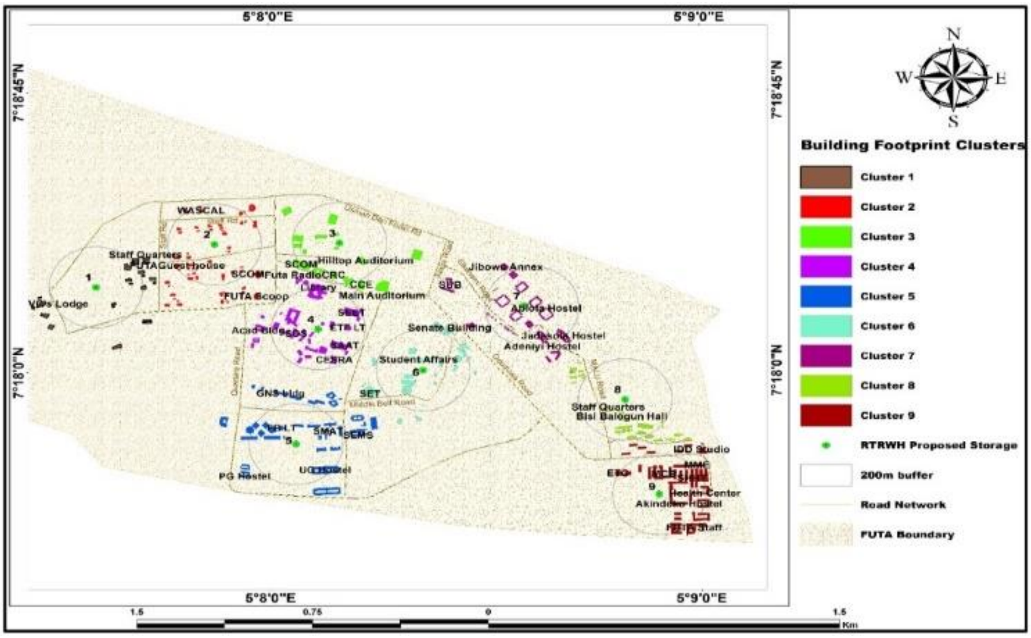

Fig. 7: RTRWH map of FUTA showing suitable storage locations and associated building clusters

3.2 Results on Volume of RTRWH

The chart in Fig. 8. represents the monthly chart of the potential volumes of RTRWH that can be obtained from building clusters in Fig. 7. While the catchment areas and potential RTRWH volumes for building clusters are presented in Table 6.

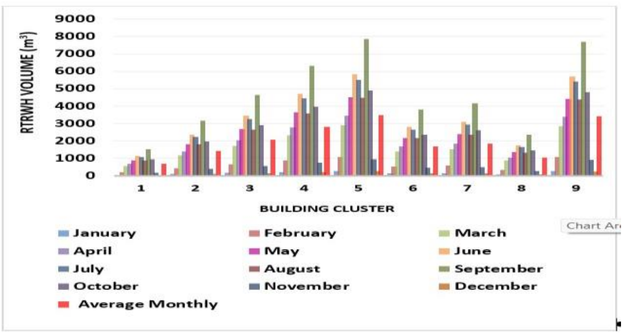

Fig. 8: The monthly chart for the potential volume of RTRWH from building clusters at FUTA

Table 6. Catchment area, and potential RTRWH volumes for building clusters

Building Clusters	Sum of Roof's Catchment Area (m²)	Average Daily RTRWH Volume (m³)	Average Monthly RTRWH Volume (m³)	Annual RTRWH Volume (m³)
1	6042.1561	22.3425	679.5854	8155.0246
2	12555.1486	46.4261	1412.1276	16945.5315
3	18407.4590	68.0666	2070.3603	24844.3237
4	25018.5307	92.5129	2813.9339	33767.2068
5	31078.1642	114.9201	3495.4850	41945.8204
6	14995.8326	55.4512	1686.6411	20239.6929
7	16471.6329	60.9084	1852.6302	22231.5627
8	9265.5410	34.2619	1042.1323	12505.5880
9	30411.5489	112.4551	3420.5081	41046.0978
TOTAL	**164246.0140**	**607.3448**	**18473.4040**	**221680.8483**

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3.3 Discussion

From the suitability map in Fig. 6a and the pie chart showing the percentage coverages in Fig. 6b, approximately 25% and 44% of the study area were found to be most and moderately suitable respectively representing mostly bare land and light vegetation cover. This was determined based on standards recommended by expert studies (Ammar et al., 2016; Jha et al., 2014).

Considering the RTRWH map of FUTA in Fig. 7, evaluations of the proximity to buildings based on a 200 m buffer, reveal that majority of the building footprints fell within these buffer zones, which implies cost savings in the installation and maintenance of the RTRWH facilities. The monthly chart of RTRWH volumes in Fig. 8 shows that the harvested RTRW volumes are proportional to the monthly rainfall trend derived from 19 years averages (Fig. 3), with maximum and minimum monthly rainfall values of 8.98 mm in December and 280.75 mm in September respectively. From Fig. 8, 9 locations were identified to serve as storage for RTRWH along with their associated building clusters. Building clusters 5 and 9 comprising mainly of student hostels have the highest catchment area, with an average monthly RTRWH volume of 3495.5 m3 and 3420.5m3 respectively and cumulatively constitute 37.4% of the total catchment area for the RTRWH in the study area.

While building clusters 1 and 8 comprised mainly of the staff residential quarters have the lowest catchment area, with mean monthly RTRWH volume of 679.6 m3 and 1042.1 m3 respectively and cumulatively constitute 9.3% of the total catchment area for the RTRWH in the research study area. This may be attributed to the spatial distribution patterns of the building clusters. The student's hostels and their surrounding areas are densely populated with building footprints, while the staff residential areas have sparsely distributed building footprints as seen in Fig. 7. Considering the catchment areas, and potential RTRWH volumes in Table 6. The total rooftop catchment area for all buildings considered in this study is 164,246 m2, having the potential of harvesting average daily, average monthly and a total annual volume of approximately 607 m3, 18473 m3 and 221681 m3 respectively. Considering the average daily water demand estimated in 2019 as ~ 1,475 m3 (Akeju et al., 2021), and the average daily potential RTRWH volume of ~ 607 m3, implies that the RTRWH has the potential of providing ~ 41% of the water demand, in FUTA. The RTRWH in the research area have proven to exhibit a better potential compared to buildings at Coventry University (Abdullahi et al., 2014), with a potential of providing 25% of the University's total water demand

4 Conclusion and Recommendation

The study which was aimed at assessing the potential of RTRWH, at FUTA, Nigeria, was achieved by determination of the potential amount of RTRWH and developing the storage plan for the RTRW based on geospatial analysis. The study reveals that the total area of rooftop catchment for all buildings considered is 164,246 m2. The study suggests 9 locations suitable for collecting and storing the harvested RTRW, located based on geospatial assessment and the MCDM approach. The potential average daily, average monthly and total annual volumes of RTRWH are approximately 607 m3, 18,473 m3 and 221,681 m3 respectively. These estimated volumes would aid to inform the decision on the capacity of the storage facility to be installed at the respective proposed storage sites. The study reveals that the RTRWH holds the potential to provide approximately 41% of water demand in addition to the existing water supply sources in FUTA. The identified building clusters in the study would aid in developing an efficient reticulation system for independently managing the RTRWH. The possibility for a future increase in RTRWH volumes exists with an increase in the rooftops by additional building construction within the FUTA. This study could also serve as a flood and erosion control measure, since the surface runoff displaced from impervious roof surfaces constituting ~ 5% of the developed part of FUTA landmass, would be well managed. The RTRWH is therefore recommended for an improved water supply scheme within FUTA. Further studies are recommended in the aspect of assessing the quality of harvested RTRW as well as the quality of the intervening atmosphere, to determine the safety of the harvested rainwater.

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