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CASE STUDY

Surface runoff estimation in an upper watershed using geo-spatial based soil conservation service-curve number method

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ABSTRACT

Runoff assessment and estimation are crucial for watershed management as it provides information that is needed to expedite the course of watershed planning and development. The most commonly used model due to its simplicity and versatility in runoff estimation is the soil conservation service curve number developed by the United States Department of Agriculture. The study estimates the surface runoff of Upper Benue watershed using a geospatial based soil conservation service curve number model. Datasets utilized for this purpose are; Rainfall, land use, digital elevation model and FAO-Soil. The soil and land use data were intersected to create the curve number grid and database. The curve number grid combined with the mean annual rainfall data from 1990 – 2017 was used to estimate runoff. The result revealed that 61.5% of rainfall was direct runoff while tree/plant cover and soil retained 38.5% of the rainfall. The average curve number for the normal condition was calculated to be 80.1 while the dry and wet season was 59.6, and 93.2 respectively. The average runoff volume for 27 years was estimated to be 69,887.43mm3. A correlation coefficient of 0.79 was found for the relationship between rainfall and runoff. The research highlights the importance of geospatial technique when integrated with soil conservation service curve number to estimate runoff conditions in Upper Benue Watershed.

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INTRODUCTION

One major element of the hydrological cycle is precipitation (Rainfall); the principal cause of runoff (Mishra *et al.*, 2013). Li *et al.,* (2004) defined runoff as "the flow of water that comes from excess water from rain, meltwater, or other sources that flow over the Earth's surface". It is an important part of the water cycle, which has direct effects on lives because it supplies water resources for agricultural and non-agricultural use. The occurrence, as well as quantity of runoff, are reliant on the attributes of precipitation events like amount, length, spread and watershed characteristics like morphology, area differentiation(slope), size, geology, land use land cover, shape, and climatic situation (Tailor *et al.*, 2016). Catchment runoff is the main issue because of its influence on the environment, agriculture, and inundation potential (Zhang *et al.*, 2013). The quality of water and surface runoff are prone to deterioration due to rapid urbanization (Khan *et al.*, 2011). Sharma and Singh (2014), identified different ways of estimating runoff namely; the Rational method, Soil Conservation Service- Curve Number (SCS-CN) method, Cook's method and Unit hydrograph method. Soulis and Valiantzas (2012) noted that the SCS-CN method is an easy method for determining the volume of runoff in a rainfall situation and it entails the use of formula, tables, and curves (Shadeed and Almasri, 2010). SCS-CN is the most widely used method for predicting flood in a watershed that is poorly gauged especially when used with soils and land use. The method exposes catchment that is highly vulnerable to flood and those exposed to the process of runoff generation (Sharma and Singh, 2014). Fenglei *et al.*, (2013) noted that the attributes of land cover and conditions of the soil influence the value of CN and when the CN is high, the rainfall-runoff volume will be high. The traditional method of surface runoff estimation is important, however, it is costly, arduous and demanding. Advancement in computational capacity, geospatial technique, and geodata availability have made it possible for the SCS-CN model to be integrated with GIS (Gupta and Panigrahy, 2008). GIS and Remote Sensing enhance quantitative evaluation of the watershed as input into the model to estimate runoff (Assefa *et al.*, 2002). GIS and Remote Sensing makes the SCS-CN more efficient in aiding watershed management (Gajbhiye, 2015). Some studies have adopted this method. Sharma and Singh, (2014), in their study used the SCS-CN Method incorporated with geospatial tools and data to assess the risk and vulnerability of lower Tapi Basin Tributary to flood. Costache *et al.* (2014), did a study in Sarˇaţel River basin, Romania using Geospatial tool to estimate runoff depth. Shadeed and Almasri (2010) demonstrated how indispensable the SCS-CN method is when used with GIS for calculating runoff volumes in West Bank catchments Palestine. Shammout *et al.* (2018) applied the CN to the restoration of the Zarqa River Basin. Matomela, *et al.* (2019) used the SCS-CN model coupled with GIS to estimate rainfall-runoff of Bojiang lake watershed for watershed management. The upper Benue watershed is one of the eight hydrological watersheds in Nigeria. There seems to be little or dearth of information about the surface runoff of the upper Benue watershed. Watershed management is imperative as it aims at assessing natural resources in a watershed especially water, land, and soil. It also provides insight as to how these resources are utilized, what is affecting them and how they can be used and protected. The current study aims to estimate surface runoff in upper Benue watershed using the geospatial based SCS-CN method for assessing flood vulnerability. To achieve the aim of this study, the following objectives were taken into consideration; 1) to delineate sub-watershed; 2) to determine Curve Number, and 3) to determine the initial abstraction and potential water retention. This study has carried out in upper Benue watershed, northern Nigeria in 2019.

MATERIALS AND METHODS

Study area

The study area is the upper Benue watershed which lies between latitude 6°29'N to 11°46'N and longitude 8°55'E to 13°30'E and occupies an extent of 154,328 Km^2 (Fig. 1). The upper Benue watershed is bounded to the north by Lake Chad watershed, to the east and south by the Republic of Cameroon, and the west by Lower Benue and upper Niger watershed. The height of the watershed ranges from 600 – 1700 meters above sea level. The study area is drained by River Benue and its tributaries. The River Benue is the principal river that flows into Nigeria from the east of the northern part of the hills of the Cameroon Republic and flows south-west to meet with River Niger. The upper Benue watershed has two seasons: the wet season, which starts from April to October, and the dry season, which starts from November to March. The average annual rainfall is about 700 to 1200mm and an average annual temperature range from 24°C to 27°C (Ishaku *et al.*, 2015).

Land use land cover (LULC)

A high-resolution land cover map of Africa that has been developed at 20m base on one year of Sentinel-2 A satellite observation from December 2015 to December 2018 was used to extract LULC. The Copernicus Sentinel-2 mission is a constellation of two polar-orbiting satellites placed in the same sun-synchronous orbit, phased at 180° to each other. It has a wide swath width (290 km) and temporal resolution (10 days at the equator with one satellite, and 5 days with 2 satellites under cloud-free conditions which result in 2-3 days at mid-latitudes) that will support monitoring of Earth's surface changes including water management, land use, and land cover mapping, natural hazard management, etc The land cover map of Africa from which the upper Benue watershed was extracted was downloaded from European Space Agency Land Cover Climate Change Initiative Research Data Package (CRDP). A reference system, known as World Geodetic System 84(WGS84) is used to project the LULC map. The data has 8 generic classes: tree cover areas (forest), shrub cover areas, grassland, cropland, bare areas, built-up areas, open water, and vegetation aquatic.

Soil texture

The FAO soil data of the upper Benue watershed of 30 arc-second was downloaded from the Harmonized World Soil Database version 1.1,2009 (HWSD)/FAO-UNESCO. The HWSD is a 30 arc-second raster database with over 16,000 different soil mapping units that combine existing regional and national updates of soil information worldwide with the information contained within the 1:5,000,000 scale FAO-UNESCO Soil Map of the World Based on the data, eight soil types were identified; Loam, sandy clay loam, Clay, silt loam, silt, sandy loam, silty clay, and Silt loam.

Rainfall data

Average Annual rainfall (1990-2017) and data from the meteorological stations of the study area was obtained from the Nigerian Meteorological Agency (NIMET). The rainfall data are yearly average, which was analyzed. The rainfall data are entered as input for the SCS-CN model to estimate runoff and

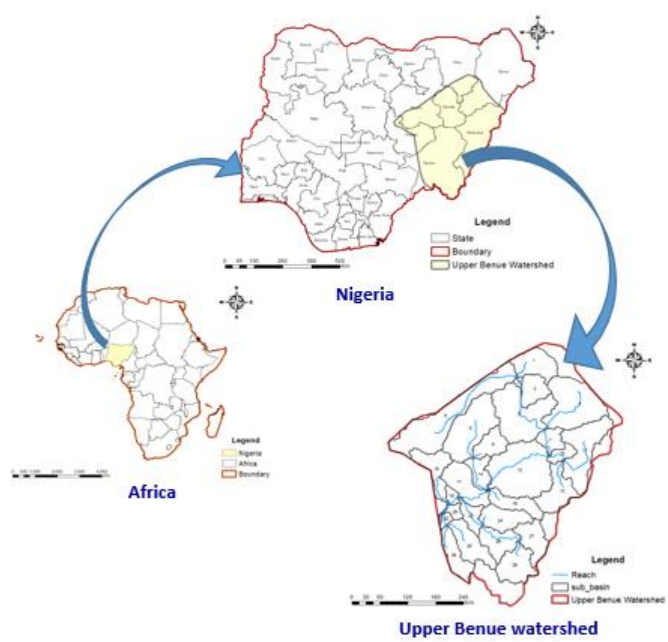

Fig. 1: Geographic location of the study area in the upper Benue Watershed in Nigeria

discharge of the catchment. Rainfall is a factor that influences surface runoff generation, i.e when rainfall is high there is a concomitant increase in the runoff but that can be governed by the surface conditions like LULC, soil texture that can directly or indirectly alter runoff. Higher rainfall does not necessarily mean higher runoff conditions (Sutradhar, 2018). Fig. 2 is the map showing the average annual rainfall from 1990-2017. It shows that the southern part of the watershed has higher rainfall while it is low in the northern part.

Digital elevation model

Information on the elevation and streams of the watershed was obtained using the digital elevation model (DEM) based on Shuttle Radar Topographic Mission (SRTM) of 30m resolution of the year 1999 was downloaded from the United States Geological Survey (USGS, 1999). The stream network of the study area was created using DEM by utilizing the ArcGIS 10.5 hydrology tool.

Method of data preparation

Delineation of watershed and sub-watershed

In delineating the watershed, DEM was imported in the Soil and Water Assessment Tool (SWAT). Using the "Burn-in" function, the stream network was overlaid onto the DEM to outline the boundary of watershed and sub-watershed of the area. Burn-in is an algorithm that was first put forward by Maidment of the University of Texas, US. This technique used the stream network dataset to superimpose onto the DEM to define the location of the stream network. Burn-in helps to process the DEM by filling sinks and calculating the flow direction and flow accumulation grids for hydrographic segmentation and sub-watershed boundary delineation (Luo *et al.*, 2011)

Hydrological soil group

The boundary shapefile of the upper Benue watershed was overlaid on the soil data to specifically clip the boundary of the watershed from the data. The soil data were then grouped into different Hydrological Soil Group (HSG) based on their water transmitting soil layer (Hong and Adler,2008; NEH-4,2004) Fig 3a and 3b. Base on soil characteristics, the HSG falls under the following; A, B, C, and D

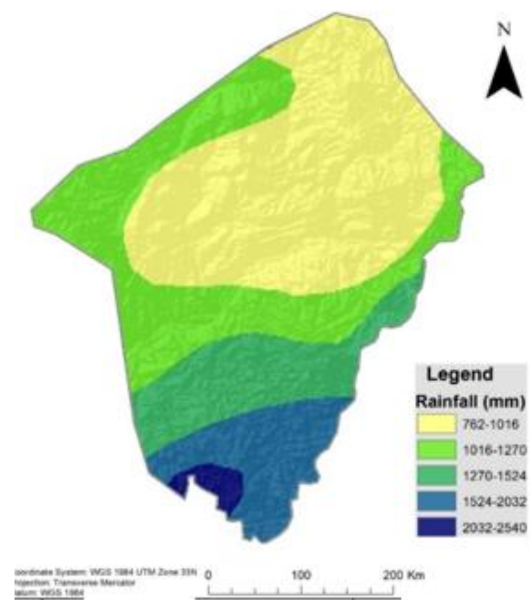

Fig. 2: Average annual rainfall map of upper Benue watershed from 1990-2017

Table 1: Hydrological soil group characteristics and coverage area of the watershed

HSG	Soil texture	Descriptions	Area (Km^2)	%
A	Sand, loamy sand or sandy loam	The propensity for runoff and infiltration rate is low when it is wet thoroughly. The transmission of water is free for these soils.	171	0.11
B	Silt loam or loam	Infiltration is moderately low for these soils and hence the potential for runoff is averagely low. Water is transmitted through the soils unhindered.	42775.4	27.88
C	Sandy clay loam	Infiltration is moderately high and when thoroughly wet, the potential for runoff is moderately high. However, the transmission of water is obstructed	2836.2	1.84
D	Clay loam, silty clay loam, sandy clay, silty clay or Clay	These groups of soils have the highest runoff potential and water transmission through these soils highly is impeded.	107633.2	70.15

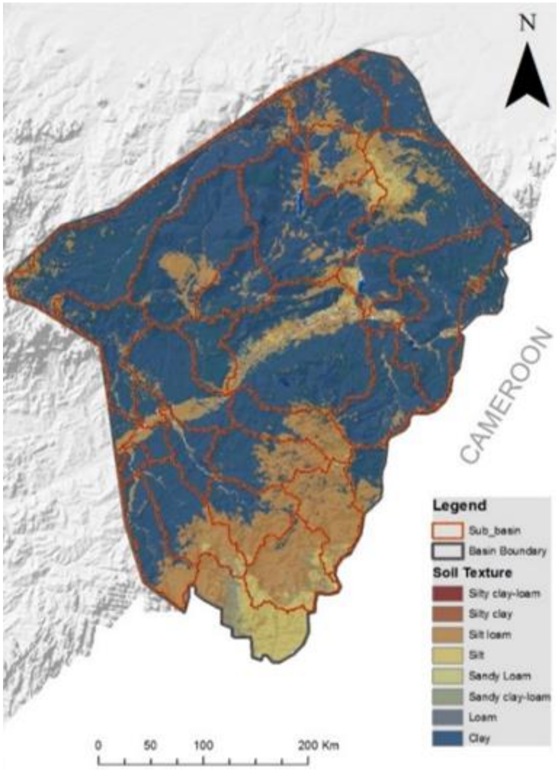

Fig. 3a: Soil map of upper Benue watershed

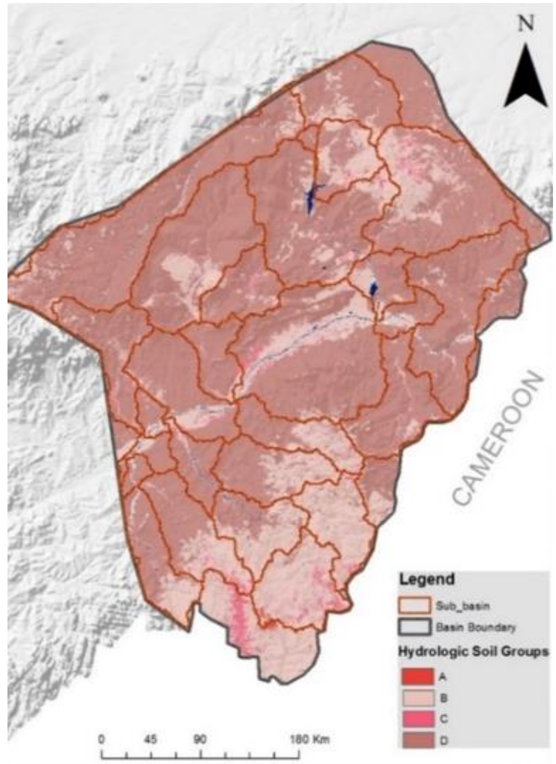

Fig. 3b: HSG map of upper Benue Watershed

(Chow, 1964; Adham *et al.*, 2014). The predominant HSG in the watershed is D that makes up 70.15% of the watershed and soil group A is the least covering 0.11% of the area (Table 1).

Creating curve number (CN) grid

CN ranges from 0 (no rain ever becomes runoff) to 100 (all rain is always runoff). In creating the CN grid, ArcGIS 10.5 intersection tool was used to combine LULC and Soil texture map to create a new polygon and database in which a new attribute table (area) was added (geodatabase). CN was assigned to each polygon based on the characteristics of the LULC and soil texture by using the SCS-CN table (Chow *et al.*, 1988; NEH-4, (2004)) as seen in Table 2. The output from the intersection was then combined with average annual rainfall from 1990 to 2017. Weighted CN was calculated using the field calculator from the database by using CNs of diverse sub-areas that align with the LULC and soils. Weighted CN was calculated using Eq. 1 (Ramana, 2014; Askar, 2014).

$$CN_W = \sum CN_i * A_i / A \quad (1)$$

Where:

CN_w = Weighted Curve Number

CN_i = Curve Number from one to any number say N;

A_i = Area with CN_i

Antecedent moisture condition (AMC) refers to the quantity of water existing in the soil at a given time (Chow *et al*, 1988). The *CNII* can be adapted to other AMC using Eqs. 2 and 3.

$$\text{AMC I} \quad CN(I) = \frac{4.2CN(II)}{10 - 0.058CN(II)} \quad (2)$$

$$\text{AMC III} \quad CN(III) = \frac{23CN(II)}{10 + 0.13CN(II)} \quad (3)$$

Runoff Measurement

The runoff CN model is based on the influence of LULC and soil conditions. The general equation is shown in Eq. 4 (Slack and Welch, 1980).

$$Q = \frac{(1 - I_a)^2}{(P - I_a) + S} \quad (4)$$

Water losses before surface runoff begins are termed as an initial abstraction. Water held in surface depressions, infiltration and retained by vegetation are included in initial abstraction using Eq. 5 (Shadeed and Almasri, 2010).

$$I_a = 0.2S \quad (5)$$

The equation for runoff is given in Eq. 6.

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad (6)$$

Potential infiltration is given in Eq. 7

$$S = (25400 / CN) - 254 \quad (7)$$

Where Q = runoff in depth (mm), P = rainfall (mm), S = potential maximum retention (mm) after runoff begins, I_a = initial abstraction (mm), CN= Curve Number.

RESULTS AND DISCUSSION

Subwatershed delineation

Boundaries of sub-watershed were created using the Burn-in function in SWAT. Fig. 4 shows the upper Benue watershed is divided into 29 sub-watersheds each with Identification Number. Each sub-watershed has an outlet and a reach. The largest sub-watershed is number 6 covering an area of 14446.43 sqkm and the smallest subwatershed is number 15 that covers an area of 6.78 sqkm. The upper Benue watershed covers an area of 154,328km^2. One of the factors that influence runoff is the size of the watershed. The larger the physical size of the watershed, the lower the runoff per unit area and the travel time for runoff increases thereby allowing for more infiltration and losses. Conversely, the smaller the catchment, the higher the runoff and the shorter the distance travel time (Anwar, 2011). As a consequence, the smaller sub-watershed like 2, 15, 19, 20, 21, and 22 are prone to flash flood.

Table 2: Curve numbers for land use categories (NEH-4, 2004)

Land use	A	B	C	D
Forest	30	55	70	77
Grassland	43	65	76	82
Cropland	67	77	83	87
water bodies	100	100	100	100
Built-up area	77	85	90	92
Bare surface/rock	39	61	74	80
Shrubs	39	61	74	80
Wetland	100	100	100	100

Analysis of land use land cover and curve number

The upper Benue watershed is constituted by eight LULC classes; built-up, grassland, tree cover areas, cropland, open water, shrubs, floodplain and bare surface as shown in Table 3. Cropland occupies 42.52% of the watershed; Tree cover (forest) covers 31.23% and shrub make up 15.48%. Grassland and built-up make up 9.9% and 0.73% respectively while open water accounts for 0.17% floodplain and bare surface occupy 0.13% and 0.2% of the watershed as shown in Fig. 5. Each of the LULC has a significant influence on the surface runoff of the watershed, for example, tree cover and other vegetation types mitigate the impact of a raindrop on the soil and reduce the speed of water flowing over the surface of land thereby allowing water to infiltrate into the soil and slowing down erosion process. However, runoff is excessive with cropland, urban space, and bare surface. The SCS-CN was used to estimate

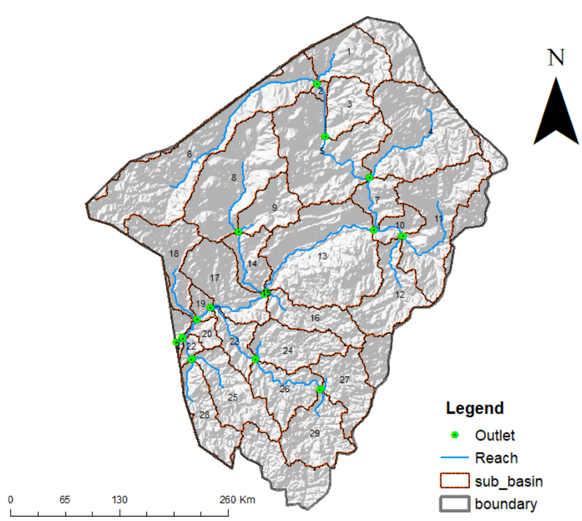

Fig. 4: Sub-watershed of upper Benue Watershed

runoff of the watershed by using LULC and soil as model input to determine surface runoff potential from a given rainfall value. The potential for flooding depends on the CN and CN depend on the LULC and soil properties of the watershed. The AMC II was considered as base CN for the watersheds, which is essentially an average moisture condition. Fig. 6 is the distribution pattern of CN in the watershed. The CN pixel values varied from 35 to 96 among the sub-watershed 1 to 29. The low and moderate CN value is found in the south particularly sub-watershed 4, 15, 16, 21, 25, and 29. Low CN value indicates areas of the watershed with high water infiltration, and dense forest leading to low runoff. The higher CN values are cluster majorly in the north in sub-watershed 5, 2, 1, 6, 7, 9, 18 and 23. The high CN value indicates areas of the watershed with low water infiltration, low vegetation, impervious surface (concrete, asphalt and other artificial features), cropland and waterbody leading high surface runoff (Zeng *et al.*, 2017).

Table 3: LULC distribution

LULC	Area (sqkm)	Area (%)
Tree cover	47738.5	31.23
Bare surface	297.33	0.2
Built-up	575.76	0.73
Cropland	65030.72	42.52
Grassland	15130.08	9.9
Open water	262.19	0.17
shrubs	23671.9	15.48
Floodplain	194.77	0.13

Table 4 shows the spread of LULC, HSG, CN and weighted CN of the watershed. The different LULC, soil type, CN and HSG are vital to influencing surface runoff. Finding from the study revealed that predominant HSG is the D type, which makes up 63.89% of the upper Benue watershed. Matomela, *et al.* (2019) in their study also observed that about 60.79% of the Bojiang Lake watershed is covered by soils that belong to HSG D. Therefore, it indicates that the watershed is dominated by soils with low infiltration rate and high runoff potential. The weighted CN for the upper Benue watershed is 80.1

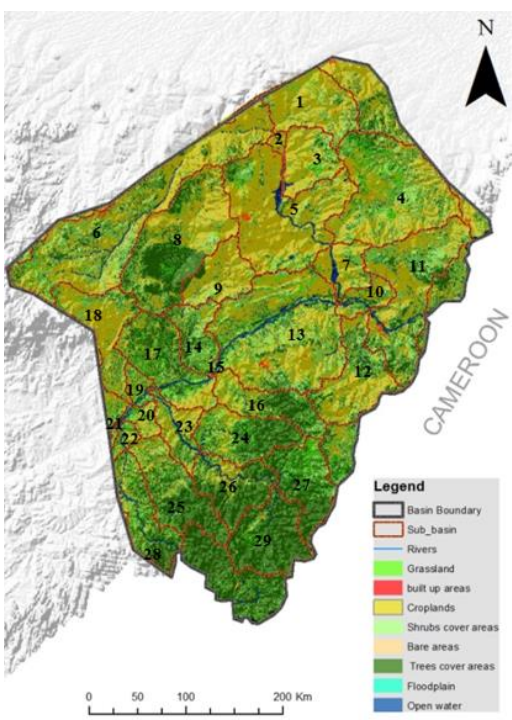

Fig. 5: Land use land cover of upper Benue watershed

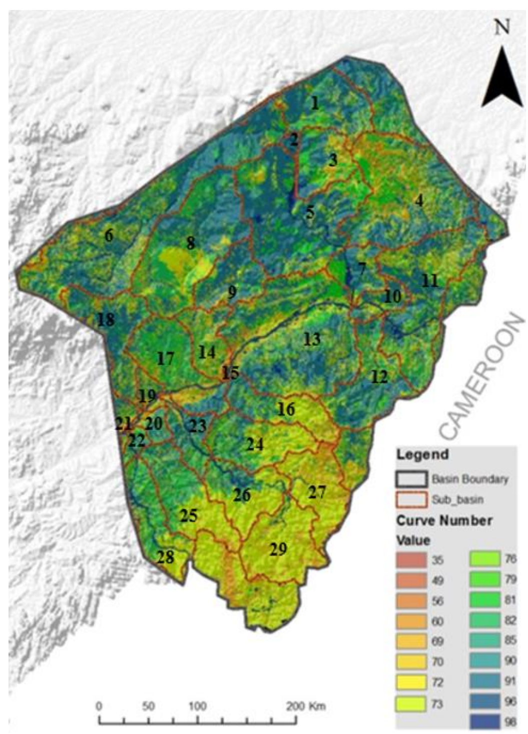

Fig. 6 : Curve Number of upper Benue watershed

Table 4: Land use/ land cover categories and CN for each HSG

LULC	Area	Area (%)	HSG	CN	CN*A	CNW
Tree cover	147.5	0.10	A	43	6342.5	
	24310.8	15.91	B	65	1580202	
	1732.5	1.13	C	76	131670	
	21547.7	14.10	D	82	1766911	
Bare surface	0.00527	0.01	A	76	0.40052	
	56.3	0.04	B	85	4785.5	
	3.005	0.00	C	76	228.38	
	238.02	0.16	D	90	21421.8	
Built-up	0.828	0.00	A	98	81.144	
	68.39	0.04	B	98	6702.22	
	1.64	0.00	C	98	160.72	
	504.91	0.33	D	98	49481.18	
Cropland	5.04	0.00	A	72	362.88	
	7797.57	5.10	B	81	631603.2	
	463.46	0.30	C	88	40784.48	
	56764.65	37.15	D	91	5165583	AMC I = 59.6 AMC II = 80.1 AMC III = 93.2
Grassland	12.78	0.01	A	49	626.22	
	5933.2	3.88	B	69	409390.8	
	349.33	0.23	C	79	27597.07	
	8834.77	5.78	D	85	750955.5	
Open water	0.52	0.00	A	98	50.96	
	223.91	0.15	B	98	21943.18	
	4.19	0.00	C	98	410.62	
	33.57	0.02	D	98	3289.86	
Shrubs	3.35	0.00	A	35	117.25	
	4168.9	2.73	B	56	233458.4	
	226.87	0.15	C	70	15880.9	
	19272.78	12.61	D	75	1445459	
Floodplain	0.14	0.00	A	43	6.02	
	101.07	0.07	B	58	5862.06	
	4	0.00	C	71	284	
	89.56	0.06	D	78	6985.68	
Total	154,328.6983	100.00				

indicating high flooding potentials while the dry and wet conditions are 59.6 and 93.2 respectively. Similarly, Sharma and Singh, (2014) observed a weighted CN of 86.07 for Wareli watershed. These weighted CNs are important to modeling runoff at the watershed outlets (Shammout *et al.*, 2018).

Initial abstraction and potential retention

The initial abstraction (I_a) comprises mainly of "water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration" (Saheed and Almasri, 2010). The initial abstraction ranged from 1.036mm to 94.34mm. The I_a is high in the south particularly in sub-watershed 27, 29, and some parts of 24, 25, 26, and 16. The high I_a can be attributed to rainfall interception by forest coverage. It is also high along the main river channel due to rainfall intercepted by surface storage or depression. It is however low in most areas in the north especially in sub-watershed 1, 2, 5, 9, and 23 as shown in Fig. 7. The potential retention of the upper Benue watershed varies from 52 to 471mm

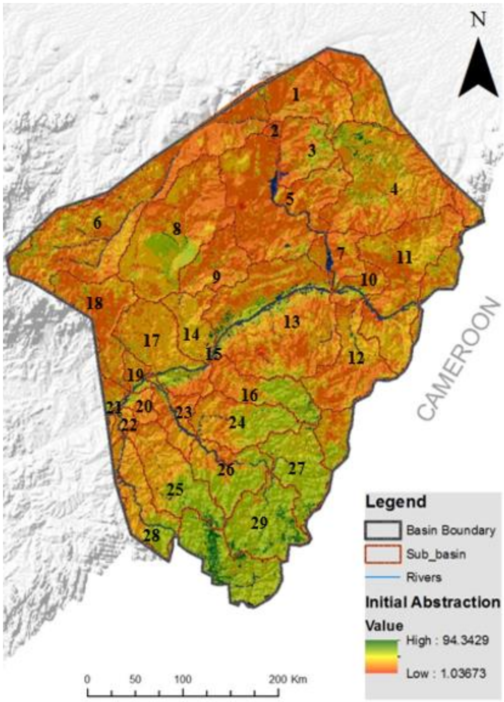

Fig. 7: Initial Abstraction of upper Benue watershed

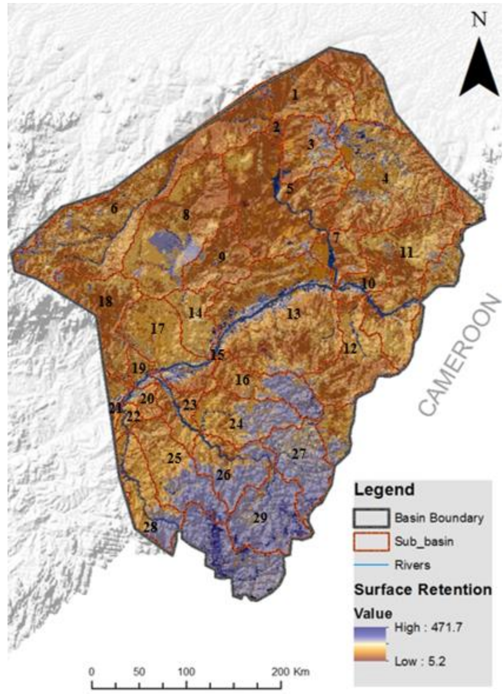

Fig. 8: Potential retention of upper Benue watershed

(Fig. 8). The built-up and cropland have poor water interception occurring mostly in sub-watershed 1, 2, 5, 9, and 23 of the study area and contrariwise, low water retention due to the predominate clay soil texture. Low retention capacity means that the area has a high potential for runoff and the built-up areas are most vulnerable. However, water interception is high for forest area especially in the southern and in the main river channel of the watershed and on the other hand, the sandy and silty clay soil texture of the areas allow for high water retention. Areas with high water retention could be suggested for growing a particular crop that thrives well in this condition.

Surface runoff

The HSG, Land cover, and precipitation were used as input for equation 6 of SCS-CN to estimate the potential runoff of the watershed. The result from the runoff depth is shown in Fig. 9 where the values range from 35 to 623mm based on the characteristics of the different surfaces. The built-up areas, cropland, bare surfaces, and open water surface have the highest runoff value located majorly

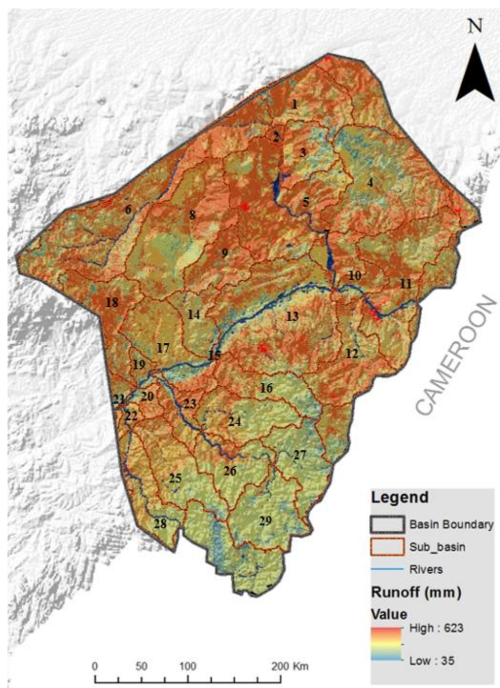

Fig. 9: Surface runoff of upper Benue watershed

Table 5: mean annual rainfall, runoff, and volume

Year	Rainfall (P) (mm)	Runoff (Q) (mm)	Volume (mm^3)
1990	730	455	70,219.24
1991	698	407	62,811.496
1992	777	493	76,083.704
1993	542	267	41,205.576
1994	700	430	66,361.04
1995	798	495	76,392.36
1996	802	545	84,108.76
1997	757	454	70,064.912
1998	696	416	64,200.448
1999	729	442	68,212.976
2000	805	623	96,146.344
2001	777	467	72,071.176
2002	795	565	87,195.32
2003	441	158	24,383.824
2004	765	464	71,608.192
2005	695	397	61,268.216
2006	726	460	70,990.88
2007	755	486	75,003.408
2008	753	469	72,379.832
2009	807	621	95,837.688
2010	673	412	63,583.136
2011	698	435	66,669.696
2012	591	289	44,600.792
2013	572	342	52,780.176
2014	776	452	69,452.976
2015	807	543	83,800.104
2016	611	331	51,082.568
2017	594	319	49,230.632
Average	735.93	452.85	69,887.4348

in the north where the dominant HSG is clay soil especially in sub-watersheds 1, 2, 5, 9, 18, 20 and 23. The sub-watershed with high runoff potential would make a good site for potential water harvesting. The lowest runoff values are dominated by sandy and silty clay soil and large coverage of trees especially in the south and some area in the north mostly in sub-watershed 15, 4, 17 and 21. The calculated weighted CN for AMC-II is 80.1, which indicates the vulnerability of the watershed to flood especially in areas with high surface runoff. Flooding has over the years hit three states and several towns within the watershed. Analysis of the surface runoff condition of the study underscores the need for attention to be given to vulnerable areas especially built-up areas as lives and properties are at risk.

Table 5 shows the mean yearly precipitation and the calculated average yearly runoff of the watershed from 1990-2017. The mean annual rainfall for the watershed is calculated to be 735.93mm out of which 452.85mm representing 61.5% was runoff while 38.5% of the rainfall was retained in surface depression (like lakes, ponds, etc) intercepted by vegetation, and infiltrated by soils. Taher (2014) in his study had an average annual runoff depth for Wadi Zaher AlGhayel watershed of 212mm and estimated total volume of water runoff of 75.80 mm^3, which is 76% of the total annual rainfall. Cropland covers the largest

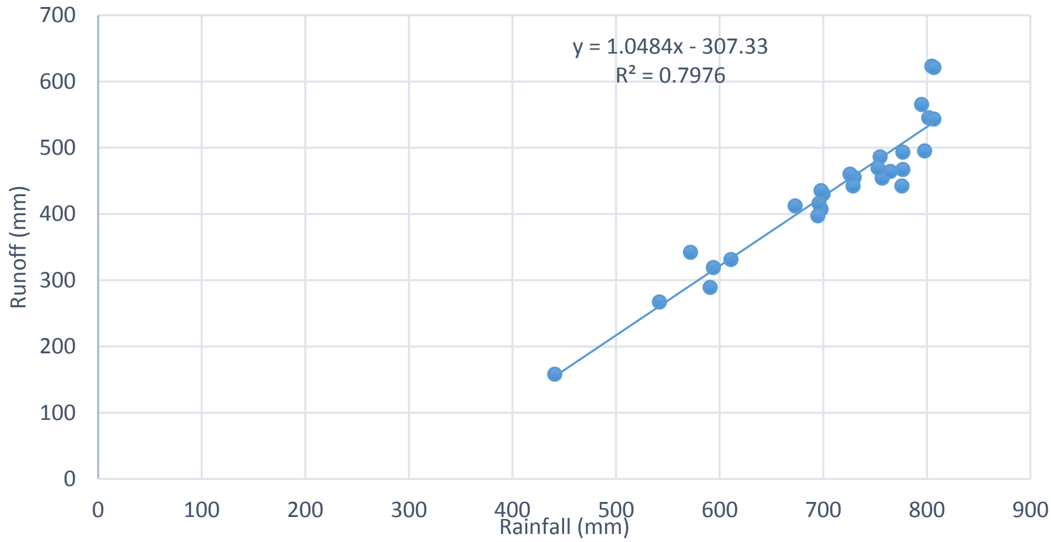

Fig. 10: Rainfall-runoff relationship for the upper Benue Watershed

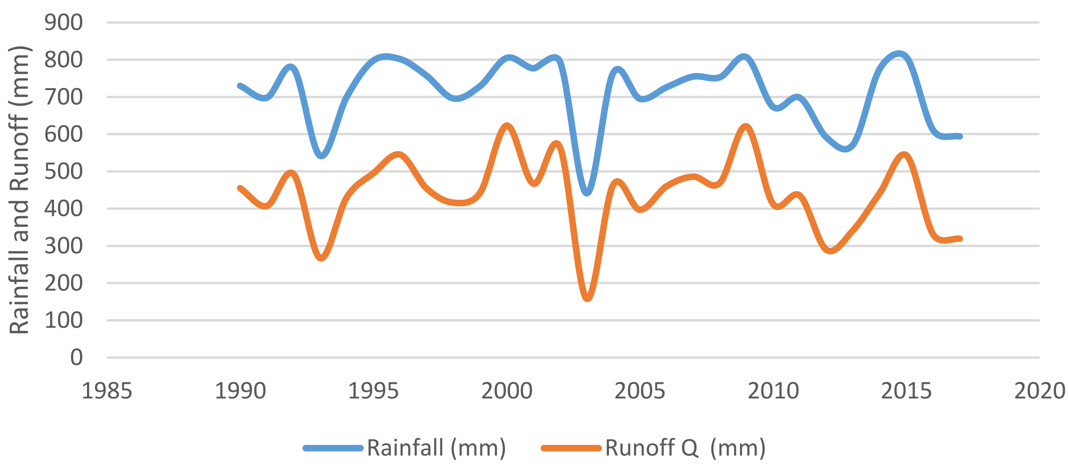

Fig. 11: Rainfall-runoff graph of upper Benue watershed

portion of the LULC of the watershed accounting for most of the runoff. Built-up, bare surface and open water contribute a substantial amount to runoff. A large proportion of the cropland, bare surface and built-up areas is underlined by clay soil, which has high runoff potential but low water infiltration rate. The urbanized areas in the watershed will require drainage systems to carry runoff directly to streams and more runoff directed to streams may result in flooding. Runoff from croplands carries nutrients into lakes, ponds, and stream, which can affect the water quality. A significant portion of rainfall in dense vegetation areas and other vegetation cover are retained (infiltrate) into the soil as groundwater. Flooding is less significant in these parts of the watershed because runoff during rainfall is absorbed into the ground thereby lessening the amount of runoff into a stream. Increase surface runoff overtime causes erosion that could lead to a situation where sediments and nutrients enter drinking water.

The average runoff volume of the watershed from 1990-2017 is estimated at 69,887.43mm^3. Within this period, runoff volume for the year 2000 was maximum at 96.146.344 mm^3 and the minimum was 24.383.824 mm^3. Runoff volume of this sort needs to be utilized for developing the watershed.

Fig. 10 show the connection between rainfall and runoff for 27 years with a coefficient of 0.79 indicating a strong correlation between rainfall and runoff. Fig. 11 shows changes in rainfall-runoff patterns from 1990 to 2017. It shows that in 2003 and 2012 runoff fell below average. It can be observed that in 2000 and 2009, runoff reached its peak.

CONCLUSION

The study highlights the viability of the geospatial based SCS-CN method to estimate runoff for precipitation events, especially in an ungauged watershed. This is useful for the management and vulnerability assessment of the watershed. Delineation of the sub-watershed was carried out using a medium resolution digital elevation model in the SWAT environment. Out of 29 sub-watershed delineated, sub-watershed 2, 15, 19, 20, 21, and 22 were observed as the most susceptible to flash flood due to their small size because of runoff per unit area increases if the size of the watershed is small. Soil and LULC were used as input for the SCS-CN model for creating CN of the watershed and as well as estimating runoff. The result of the weighted CN is 80.1 indicating that the watershed has a high potential for flooding. The areas susceptible to flooding are majorly in the Northern part of the upper Benue watershed where grassland, urban spaces, and cropland occupy these areas. The result also revealed that average annual rainfall for 27 years in the watershed was estimated to be 735.93mm out of which 452.85mm representing 61.5% was direct runoff while 38.5% of the rainfall was intercepted mainly in the forested areas where it is absorbed into the soil and stored as groundwater. Thus, areas with 61.5% of direct runoff should have a drainage system to direct the enormous runoff to the stream especially in urban areas. Indeed, the study demonstrates that the SCS-CN is a simple, versatile and cost-effective method for facilitating runoff estimation from a watershed that is poorly gauged. Validation of the performance of the SCS-CN model was not carried out due to a lack of observed runoff measurements of the watershed. The result of this study can be applied in areas of flood mitigation in urban areas, agriculture, and locating ideal spots for water harvesting.

AUTHOR CONTRIBUTIONS

C. Odiji organized all the data, processed, interpreted and participated in preparing manuscript. D. Oje provided the Land use Land cover and Rainfall data and also participated in processing of the data. M. Ekwe assisted in the literature review and data analysis. O. Aderoju assisted in providing internet for downloading related journals and was involve manuscript preparation. J. Osagie Imhanfidon for providing digital elevation model data.

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CONFLICT OF INTEREST

The authors declare that there is no conflicting interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been fully observed by the authors.

ABBREVIATION

%	Percentage
A_i	Area with CN
AMC	Antecedent moisture condition
CNi	Curve Number from one to any number say N;
CN_w	Weighted Curve Number
CRDP	Climate Change Initiative Research Data Package
DEM	Digital Elevation Model
E	Eastings
FAO	Food and Agricultural Organization
HSG	Hydrological Soil Group
HWSD	Harmonized World Soil Database
Km^2	Kilometer Square

Ia	Initial Abstraction
LULC	Land Use Land Cover
Mm	Milimeter
N	Northings
NASRDA	National Space Research and Development Agency
NIMET	Nigerian Meteorological
P	Rainfall
Q	Runoff in depth
R^2	Correlation Coefficient
S	Potential maximum retention
SCS-CN	Soil Conservation Service- Curve Number
SQKM	Square Kilometer
SRTM	Shuttle Radar Topographic Mission
SWAT	Soil and Water Assessment Tool
UNESCO	United Nations Educational, Scientific and Cultural Organization
USGS	United State Geological Survey
WGS	World Geodetic System

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