Global Research in Environment and Sustainability – ISSN 3033-3644
March 2024, Vol. 2, No. 3, pp. 01-15.

Estimation of Runoff Using CN Method and Arc GIS for Irrigation Water Accessibility at Kulumsa Watershed, Arsi Zone of Ethiopia

Samuel Lindi, Mehiret Hone, Bakasho Eticha and Kebede Nanesa

1. Ethiopian Institute of Agricultural Research/Kulumsa Agricultural Research Center, Ethiopia

Abstract:
Rainfall and runoff are essential components in water resources assessment. Rainfall serves various purposes, including agriculture, hydropower, industries, climate, and the environment, being the primary source of runoff. Rainfall-runoff models estimate surface runoff from watersheds. This study aimed to locate potential water harvesting sites and estimate runoff for irrigation at the Kulumsa Agricultural Research Center. The Curve Number (CN) model predicted runoff based on empirical equations for ungauged Kulumsa watersheds. Rainfall, land use/land cover, and soil data were used for runoff estimation. Landsat 8 imagery from the USGS aided land use/land cover preparation and underwent accuracy assessment. Data on land use and soil types were inputted into a GIS to determine the composite curve number, resulting in a watershed CN of 85, with AMC I dry and AMC III wet seasons having values of 71 and 93, respectively. The Kulumsa watershed has 4.66 km² and receives an average annual rainfall of 821mm. The estimated average annual surface runoff depth was 78.9mm, with a computed volume of approximately 3,673,024m³ generated during the same period. This runoff volume represents 9.61% of the total annual rainfall, signifying the portion that contributed to runoff instead of infiltrating the soil. This study demonstrates the practicality and efficiency of using empirical models integrated with GIS for water resource management. Findings not only highlight potential water harvesting and irrigation but also provide insights for policymakers and water resource managers. Moreover, it presents a scalable framework applicable to diverse areas, contributing to enhanced water management practices and bolstering agricultural sustainability in Ethiopia.

Keywords: Runoff Volume, Irrigation, Water Resource, SCS CN, Kulumsa Watershed

INTRODUCTION

Runoff is a significant hydrologic component in the water resources assessment (Ibrahim et al., 2021). Most water resource applications rely on runoff as an essential hydrologic variable (Shadeed and Almasri, 2010). Runoff is the flow of precipitated water through a channel in the catchment area after all surface and subsurface losses have been met. River basin features such as length, width, area, shape, drainage design, soil type, vegetation cover, land usage, and hydrological conditions affect the rainfall-runoff procedure considerably (Caletka et al., 2020). After evaporation, the term runoff is percolation by dirt, rocks, and excess water flowing over the surface through the stream channel. It is one of the complex characteristics of nature that affects, on the one hand, flora and fauna and, on the other, determines the rate of weathering and erosion (Xiaojun et al., 2021).

Moreover, irregular and insufficient precipitation, floods, soil attrition by high rainfall amount, and high surface runoff rate are also wide spread. Rainfall is essentially required to meet various requirements, including agriculture, hydropower, industries, climate, and environmental systems, and is the primary source of runoff (Ogden et al., 2017; Meraj et al., 2021; Rizeei et al., 2018). The water supplies for recharging groundwater in the watershed are critical for rainfall and runoff (Sateeshkumar et al., 2017). Management of water resources involves a system strategy that includes all hydrological components and the ties, relationships, interactions, consequences, and implications between these components (Al-Ghobari and Dewidar, 2021). Estimation processes or reliable methods are essential to control flood, soil erosion, and proper water resource utilization in these areas. For the study of watersheds or river basins, primary hydrological data such as peak runoff rate and annual surface water capacity were also assessed, and these are essential criteria for successful watershed management (Meshram et al., 2017).

In terms of spatial domains, runoff models can be classified as lumped, distributed and semi-distributed. The lumped models, assume that each sub-watershed within the watershed can be adequately represented by a weighted average representation of hydrologic parameters. A distributed basin model (or grid-based model) approach allows for a hydrologic analysis of watershed to a grid-cell level of detail. Some salient rainfall-runoff models that are widely in practice include SCS-CN (NEH 1985), CASC2D (Downer et al 2002; Marsik and Waylen 2006), TOPMODEL (Beven and Kirkby 1979; Warrach et al 2002), HEC-1, HEC-HMS (HEC 1990, 2001), KINEROS (Woolhiser et al 1990), GIUH (Kumar et al 2007).

The Soil Conservation Service Curve Number (SCS-CN) method is widely used for predicting direct runoff volume for a given rainfall event. This method was originally developed by the US Department of Agriculture, Soil Conservation Service and documented in detail in the National Engineering Handbook, Sect. 4: Hydrology (NEH-4) SCS, 1956, 1964, 1971, 1985, 1993).

The annual average rainfall of Ethiopia ranges between 400 and 1300mm, and rainfed agriculture is predominantly practiced agricultural system in the country. Even though, 3.5 million hectare of land is suitable for potential irrigated agriculture practice, in terms of the water resources for water supply and agricultural purposes, only 0.2 million hectare of land is currently under irrigation. The present water requirement of the land to produce a one season crop will require around 3% of the total runoff (Getachew, 1999; Fitsum et al., 2014).

Some studies indicate that of the total area of Arsi zone about 21,410 hectares of land can be irrigable by using surface water. From this, only 8,507 hectares or 38.7 percent were under irrigation with modern small-scale irrigation by farmers and state farms. There are also traditional irrigations, which are carried out by diverting streams and springs by local farmers. Awash, Katar and some small rivers are used for modern and traditional irrigation (Yazachew E. and Kasahun D., 2011).

Generally, Arsi Zone receives abundant and well-distributed rainfall both in amount and season, which is conducive for different types of vegetation growth and agricultural activities. On average, the Zone gets an annual mean rainfall of 1000mm (Getachew Haile, 2017). This ample amount of rainwater occurred only during the summer season which couldn't be accessible for irrigation during the dry season. Rainwater Harvesting is being encouraged to overcome water scarcity as a supplementary source for agricultural uses in semiarid regions (Rusa and Bertu ,2018). To overcome the problem of water shortage, it is believed that estimation of rainwater harvesting amount using an empirical model is one of the superlative options. Therefore, this study was designed to identify potential water harvesting sites in the watershed determine the amount of water for irrigation use, and recommend appropriate water harvesting sites for future irrigation water accessibility in Kulumsa watershed.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Kulumsa watershed, Tiyo district of Arsi Zone Oromia regional state, Ethiopia. The study area lies between 7°54′30′′ to 8°01′30′′ N latitude, 39°10′25′′ to 39°16′00′′ E longitude, and situated to an elevation 2200m.a.s.l. (Figure 1). Its climate is tropical which can be classified into two major seasons, wet and dry. The study area climatic condition is characterized by distinct wet and dry seasons. The average annual rainfall is 809.15 mm, with minimum and maximum air temperatures recorded at 9.90°C and 23.08°C, respectively.

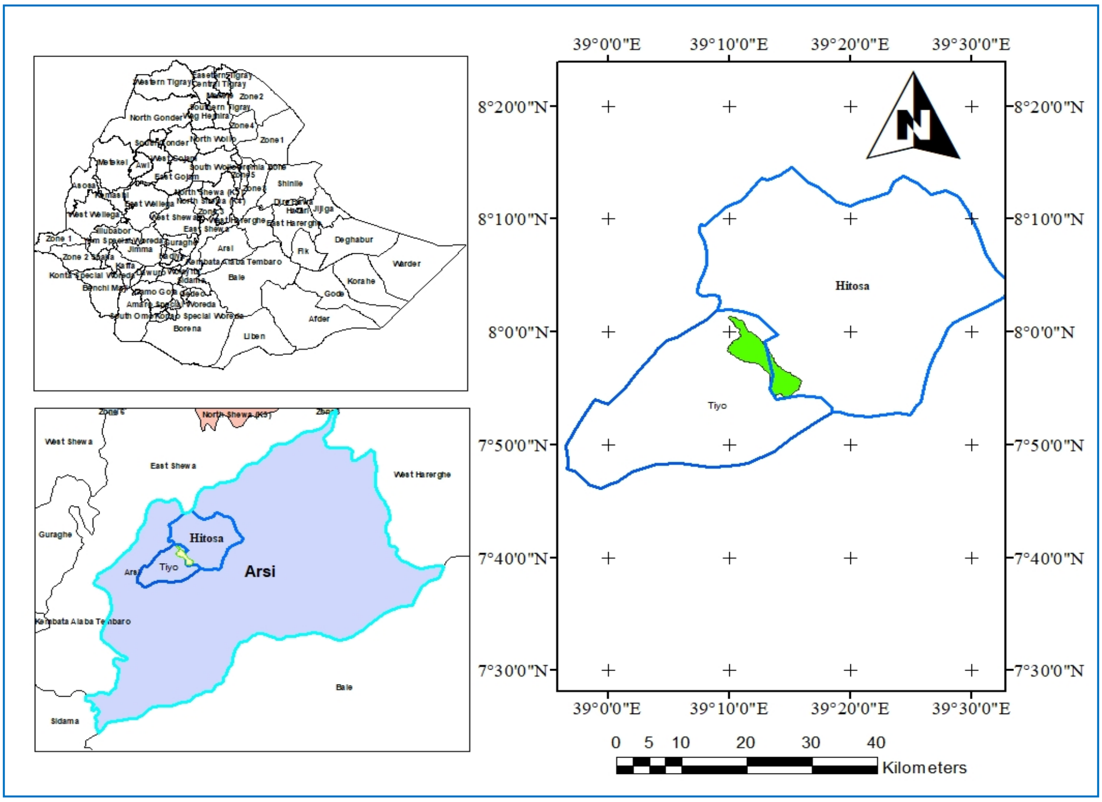

Figure 1: Map of the study area

Data Collection and Preparation

In this study, a variety of data including the Digital Elevation Model (DEM 30m), and Metrological data of rainfall have been obtained for the years 1987-2018 from the National Meteorological Agency of Ethiopia. A land use map was obtained by classifying the Landsat 8 image from the USGS website. Th work flow process for estimation runoff is summarized in a flowchart as shown in Figure (2)

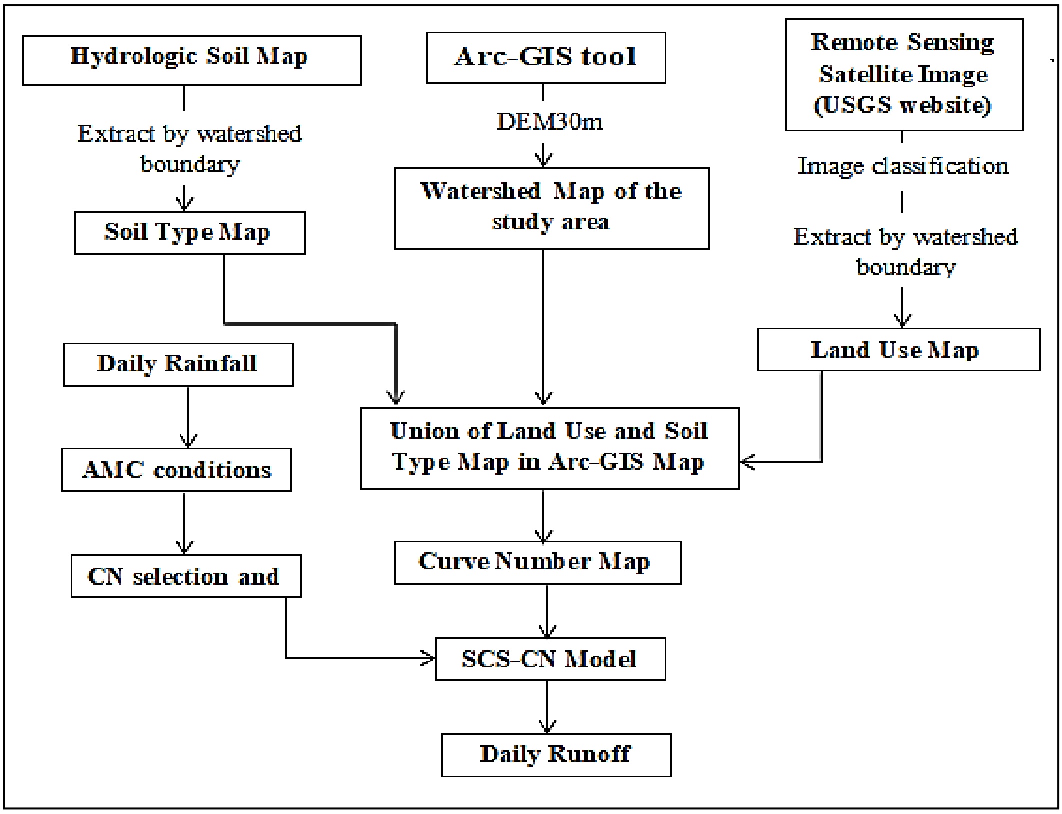

Figure 2: Flowchart of Rainfall-Runoff Estimation processes

Soil Mapping

The soil map obtained from Alemu et al, 2018, was digitized using ArcGIS 10.6 following the map digitization procedure and extracted to fit the study watershed using GIS tools (Figure 4).

Land Use and Land Cover Classification and Accuracy Assessment

The land use and land cover of the study area were an additional factor influencing the curve number. Utilizing the Landsat 8 image and ArcGIS version 10.6, a land use/land cover map was generated to illustrate the land-use patterns of the study area (Figure 6). Land-use land cover types of the study area were grouped into six classes: settlement, poorly cultivated agricultural, cultivated agricultural land, shrubs land, grazing land, and forest land. Figure 5 shows the percentage of land use classes after classification is satisfied.

For this study, only supervised classification was performed. Supervised classification according to Eastman, J.R. (2003) is where "the user develops the spectral signatures of known categories, such as urban and forest, and then the software assigns each pixel in the image to the cover type to which its signature is most comparable". "Supervised classification is the process most frequently used for quantitative analyses of remote sensing image data" Richards, J. and Jia, X. (2006). The supervised classification was applied after defined area of interest (AOI) which is called training classes. More than one training area was used to represent a particular class. The training sites were selected in agreement with the Landsat Image and Google Earth Map.

SCS-CN Runoff Estimation

Hydrologic Soil Group (SG) is defined by the grading of a soil's runoff potential and water transmission rate. HSG D have a high runoff potential and a low water transmission rate, HSG A soils have a low runoff potential and a high-water transmission rate, while HSG B soils have a moderate runoff potential and a moderate water transmission rate (USDA, 1986). Runoff was estimated using the SCS Runoff CN Method which relies on a composite curve number of an average antecedent moisture condition, assigned to each catchment and rainfall depth of 31 years. The method incorporated the runoff properties of the catchment by integrating soil and land use information for an average antecedent moisture condition. For each catchment, the runoff properties were characterized by an empirical curve number derived from the soil and ground cover. The soil parameter was defined by the hydrologic soil group (HSG), determined by the soil texture. The HSG for the different soil textures is presented in Table 1.

Table 1: Hydrologic Soil Group Description (USDA, 1986)

Soil Group	Description
A	Sand, loamy sand or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay Loam, silty clay loam, sandy clay, silty clay or clay

The curve number for an average antecedent moisture condition in the study area was calculated using the categories in Table 1. The Soil Conservation Service (SCS) model developed by the United States Department of Agriculture (USDA) was used to compute direct runoff and potential water harvesting structures through an empirical equation that requires rainfall and a watershed coefficient as inputs. The watershed coefficient is called the curve number (CN), which represents the runoff potential of the land cover soil complex. This model involves the relationship between land cover, hydrologic soil class and curve number. This method is based on an assumption of proportionality between retention and runoff in the form. Normally the SCS model computes direct runoff with the help of the following relationship (Hand book of Hydrology, 1972)

Thirty-two years of rainfall data of the watershed was collected from National Meteorology to analyze the runoff depth. Computation of CN variables and discharge were carried out for events with mean precipitation. Normally the SCS model computes direct runoff with the help of the following relationship (Handbook of Hydrology, 1972).

$$S = \frac{25400}{CN} - 254 \tag{1}$$

The weighted curve number is calculated after recognizing the CN for N number of land classes using equation (2).

$$Cw = \frac{\sum(CN_i * A_i)}{\sum(A_i)} \tag{2}$$

Where: CN_w is the weighted curve number, CN_i is the curve number for a particular land class unit i to n, and A_i is the area of the particular land class i. The estimation of runoff through the SCS Runoff CN method was calculated by implementing the following equations (USDA, 1986):

$$Q = (P - I_a)^2 / (P - I_a) + S \text{ For } I_a = 0.2S$$

$$Q = \frac{(Pday - 0.2S)^2}{(Pday + 0.8S)} \tag{3}$$

Where, Q = the direct runoff (mm), P_{day} = daily precipitation (mm); S = the potential maximum retention (mm)

The CN (dimensionless number ranging from 0 to 100) is determined from a table, based on land cover, HSG, and AMC. HSG is expressed in terms of four soil groups (A, B, C, and D), according to the soil's infiltration rate, which obtained for bare soil after prolonged wetting.

Antecedent Moisture Condition (AMC)

Antecedent moisture condition (AMC) of the rainfall-runoff event refers to the amount of moisture content found in the soil at the beginning before the rainfall. Both initial abstraction and infiltration are governed by AMC. If the summation of rainfall for the previous five days is less than 13mm for dormant and 36mm for the growing season; the dry condition of the soil is assumed, and CN is converted to (CNI) using equation (4).

$$\mathrm{CNI} = \frac{\mathrm{CNII}}{(2.281 - 0.01281\mathrm{CNII})} \tag{4}$$

But, if the summation of rainfall for the previous five days is greater than 28mm for dormant and 53mm for growing season; then wet condition of soil is assumed, and CN is converted to (CNI_{II}) using equation (5).

$$\mathrm{CNIII} = \frac{\mathrm{CNII}}{(0.427 + 0.00573\mathrm{CNII})} \tag{5}$$

AMC is expressed in three levels (I, II and III), according to rainfall limits for dormant and growing seasons. Although the SCS method was originally designed for use in watersheds of 15 km², it has been modified for application to larger watersheds by weighing curve numbers with respect to watershed/land cover area. In this study, the curve numbers are weighed with respect to the micro-watershed area (generally <5 km²).

Table 2: Antecedent Moisture Condition (AMC)

AMC	**Total 5-days antecedent RF (mm)**	
	Dormant season	**Growing season**
I	<13	<36
II	13-28	36-53
III	>28	>53

RESULTS AND DISCUSSION

This section presents the results from the collection and preparation of data, image classification and accuracy assessment, curve number determination for the catchments and runoff estimation from the SCS Runoff CN method.

Watershed Delineation

Kulumsa watershed was mapped from a DEM having a dimension of (30mx30m) using hydrology extension of ArcgGIS watershed delineation process. Kulumsa watershed is a sub-watershed of the Rift Valley basin and has an area of 46.55 sq. km. These catchments were designated as an area of land where rain is collected naturally by the landscape and drains off into a common channel.

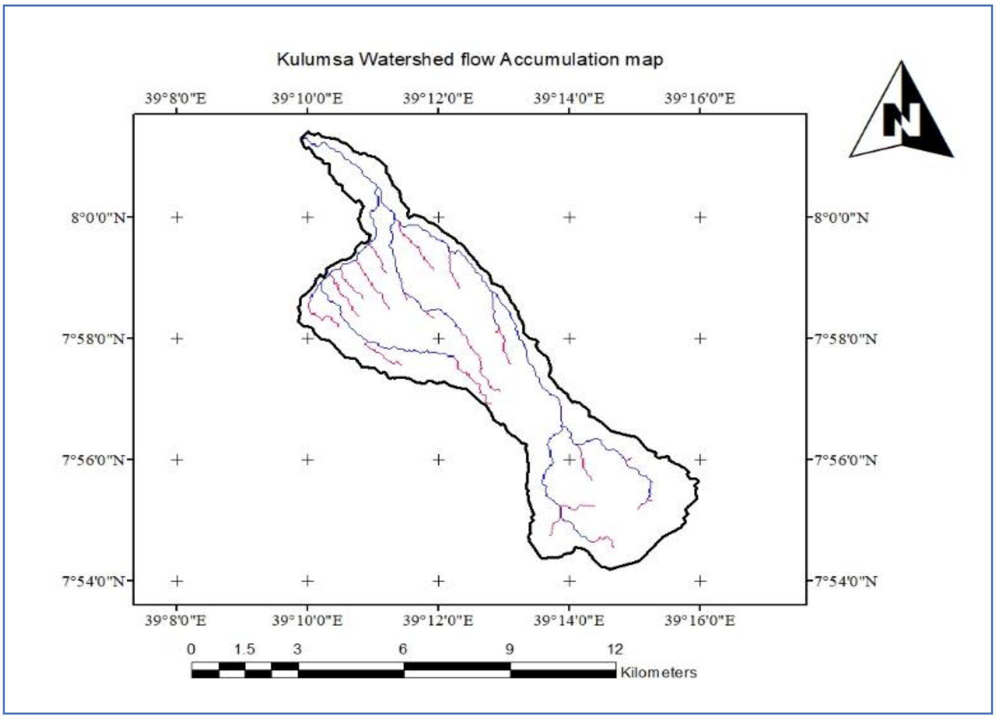

Figure 3: Flow network of Kulumsa Watershed

Soil Mapping

The soil map obtained from Alemu et al, 2018, was digitized using the ArcGIS 10.6 map digitization procedure and extracted to fit the selected watershed using GIS extension tools as shown in Figure (4). Eight soil types were identified and categorized within the Kulumsa watershed. The primary hydrologic soil groups in the study area were C and D, detailed in Table (1). HSG D, which includes clay loam, silty clay loam, sandy clay, silty clay, and clay, was predominant covering 69% of the total area. The remaining 31% was characterized by HSG C (sandy clay loam) (Table 3). Alemu et al.'s 2018 soil data helped define the soil texture for the various soil classes in this area. The spatial distribution of these soil types is depicted in Figure 4.

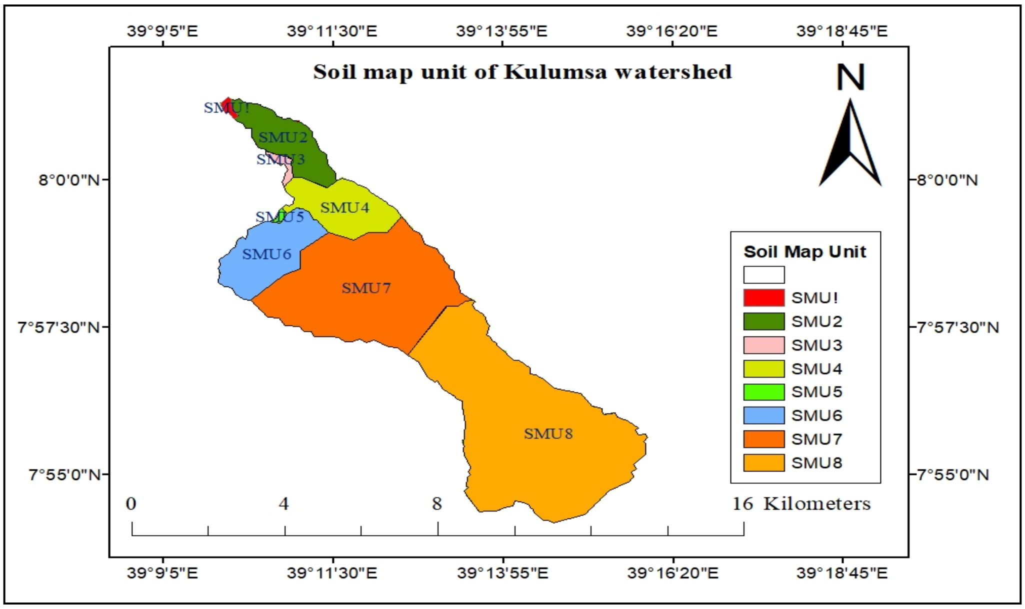

Figure 4: Soil map of Kulumsa watershed

Table 3: Soil type distribution of Kulumsa Watershed (Alemu et al, 2018)

No	Dominant soil groups	Dominant soil type	Area (ha)	Percentage (%)
1	Umbrisols and Alisols	loam and clay	2,105	45.22
2	Retisols and Regosols	loam to clay loam	1,394	29.95
3	Planosols and Vertisols	Sand clay and clay	430	9.24
4	Vertisols	Heavy clay	8	0.17
5	Cambisols	Loamy to clayey	361	7.75
6	Chernozems	Clay loam to clay	28	0.60
7	Luvisols and Kastanozems	Clay	315	6.77
8	Kastenozems and Regosols	Loamy	14	0.30
	Total		**4,655**	**100**

Land Use and Land Cover Classification

In the research area, supervised classification was used. The area of each class was computed by taking the pixel count and overall area (study area) into account. The watershed has a total size of 4655ha. Figure 5 shows the allocations of each classed land use land cover. Farmland1 (2.24%), Settlement (1.25%), Farmland2 (30.20%), Shrub land (6.67%), grazing (35.78%), and forest land (23.85%) are the percentages of areas classified. Grazing land was found to be the most prevalent kind of land use identified, accounting for approximately 35.78% of the total research area, followed by agricultural farmlands, and the least classified as settlement area, accounting for 1.25% (Figure 5).

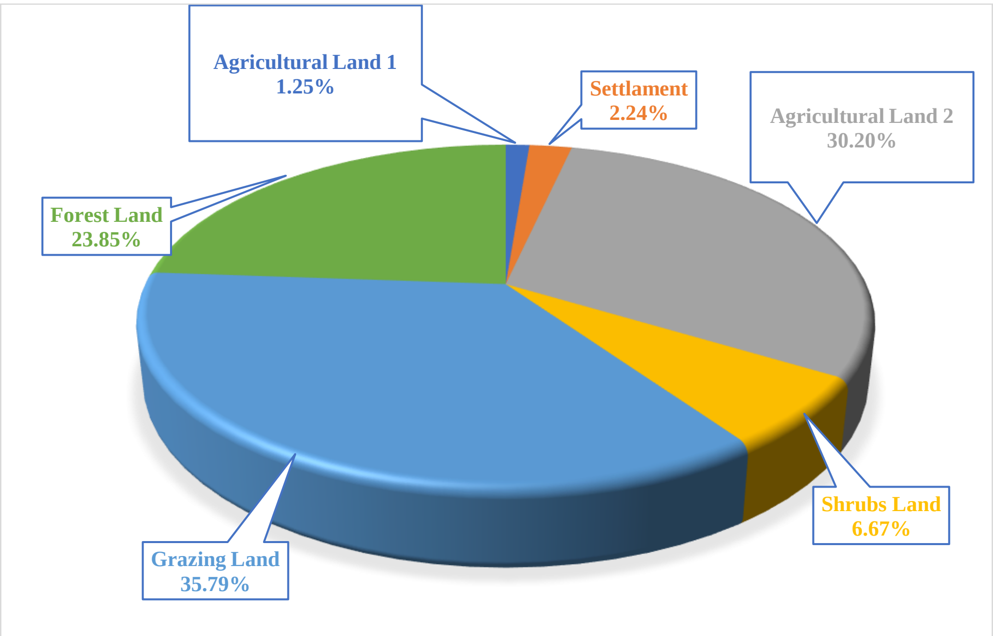

Figure 5: Land use land cover ration

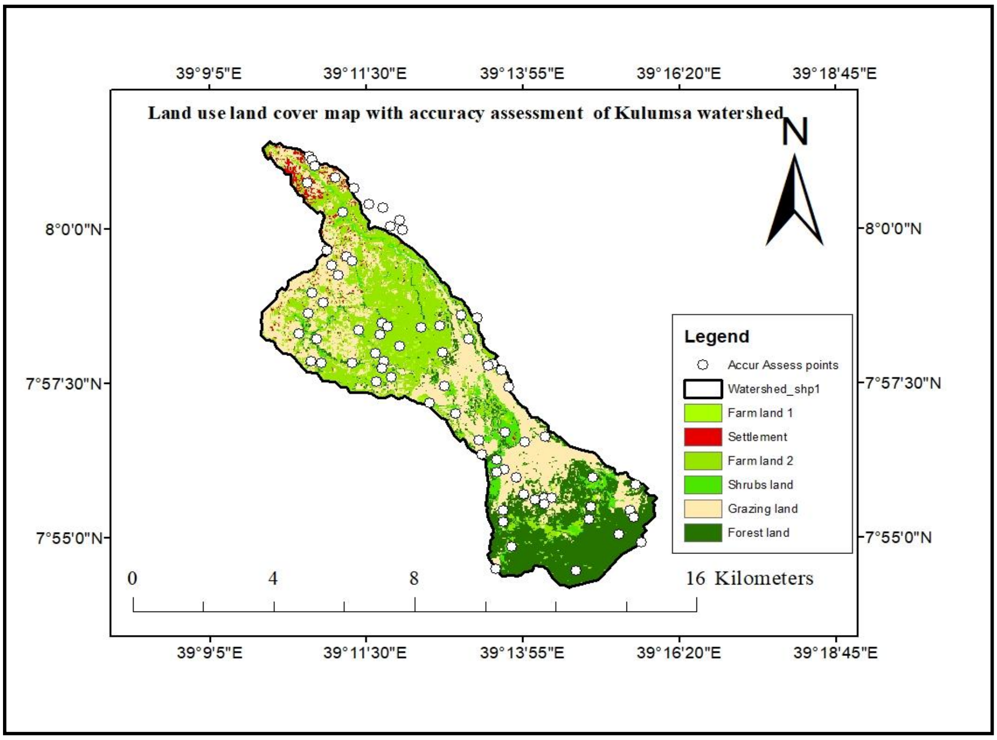

Figure 6: Land Use/Land Cover Map

Land Use Land Cover Classification Accuracy Assessment:

Accuracy assessment is performed by comparing the map produced by remote sensing analysis to a reference map based on a different information source. Classifications done from images acquired at different times, classified by different procedures, or produced by different individuals can be evaluated using a pixel-by-pixel and point-by-point comparison. The results must be considered in the context of the application to determine which is the most correct or most useful for a particular purpose.

One of the most important final steps in the classification process is accuracy assessment. The aim of accuracy assessment is to quantitatively assess how effectively the pixels were sampled into the correct land cover classes. Moreover, the key emphasis for accuracy assessment pixel selection was on areas that could be clearly identified on both Landsat high-resolution images and Google Earth satellite images. A total of 75 points (locations) were created in the classified image of the study area. The Accuracy Assessment Cell Array Reference column was filled according to the best guess of each reference point. Google Earth Map was used as a reference source to classify the selected points.

The results from the accuracy assessment showed an overall accuracy obtained from the random sampling process for the image of 65%. The user's accuracy ranged from 20% to 100% while the producer's accuracy ranged from 50% to 100%. The broad range of accuracy indicates a severe confusion of farmland 1 with other land cover classes. Moreover, the measure of the producer's accuracy (Sensitivity) reflects the accuracy of the prediction of the particular category. The User's accuracy reflects the reliability of the classification to the user. User's accuracy is the more relevant measure of the classification's actual utility in the field. Shrub's land was found to be more reliable with 100% of user accuracy (Table 4).

Table 4: Land use land cover Accuracy assessment using confusion matrix of ArcGIS 10.6

Class Value	Farm1	Setl	Farm2	Shrub	Grass	Forest	Total	U Accuracy	Kappa
Farmland	7	-	-	1	1	1	10	**0.70**	-
Settlement	2	2	2	1	3	-	10	**0.20**	-
Farmland	-	-	11	2	4	-	17	**0.65**	-
Shrubs	-	-	-	8	2	-	10	**1**	-
Grazing	1	-	-	2	13	1	17	**0.76**	-
Forest	-	-	-	4	1	6	11	**0.55**	-
Total	**10**	**2**	**13**	**20**	**22**	**8**	**75**	**-**	**-**
P Accuracy	**0.70**	**1**	**0.85**	**0.50**	**0.59**	**0.75**	**-**	**0.65**	**-**
Kappa	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**0.58**

SCS-CN Runoff Estimation

The curve number Grid map can be constructed by integrating land use and soil type maps using the GIS extension, as shown in Figure (6). The Kulumsa watershed had a weighted curve number of 85.15. The CN for the normal condition (AMCII) is rounded 85, and the CN for the other two conditions; the dry condition (AMCI) was 71, and the wet condition (AMCIII) was 93, as determined by equations (4) and (5) and shown in Figure (8).

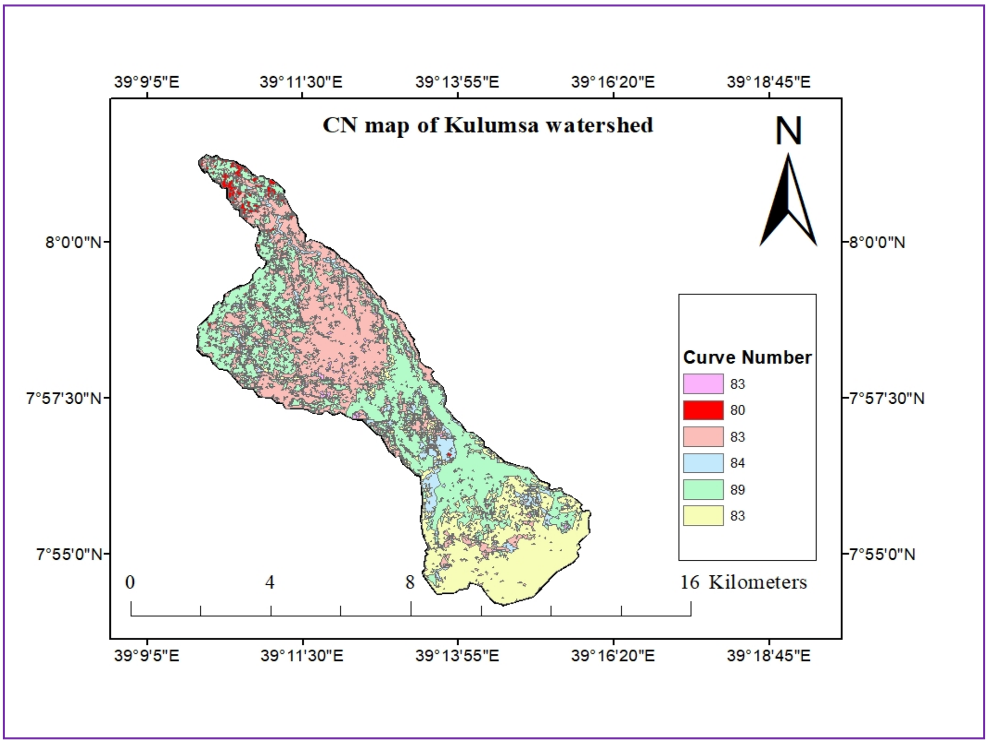

Figure 7: The composite curve number map of Kulumsa watershed

Before estimation of the runoff depth Q in equation (3) the value of (S) must be determined for each antecedent moisture condition (AMC) as summarized in Table (6). The CN value for each soil hydrologic group and corresponding land use classes are presented in Table (5) (USDA, 1986).

Table 5: Values of curve number (CN)

Land Use	Hydrologic Conditions	HSG	CNII	Percentage (%)	Areal Cover (ha)
Urban Area					

Compacted soil surface (roads, streets, and right of way)		D	80	2.24%	104.13
Agricultural Land					
Straight row + residual cover	Poor	C	83	1.25%	58.07
	Good	C	83	30.20%	1405.81
Non-cultivated land					
Pasture lands, grass lands, and range lands	<50% ground cover	D	89	35.79%	1665.15
	50% to 75% ground cover	D	84	6.67%	310.40
Woods	Grazed or regularly burned	D	83	23.85%	1110.43
			85.15	**100%**	**4,655.00**

Retention Potential (S):

Maximum soil water retention potential (S) of 101 was calculated from CN I using equation (4) and the minimum retention of 19 was recorded from CNIII calculated by equation (4) shown in Figure (8). The highest S values are found in areas covered with grass and shrubland, whereas the lowest S values are found in agricultural and settlement land. This result is consistent with Shimelis Sishah (2021) discovery that the highest S values are found in areas covered with agriculture and vegetation, whereas the lowest S values are found in places covered with bare ground or little vegetation and built-up.

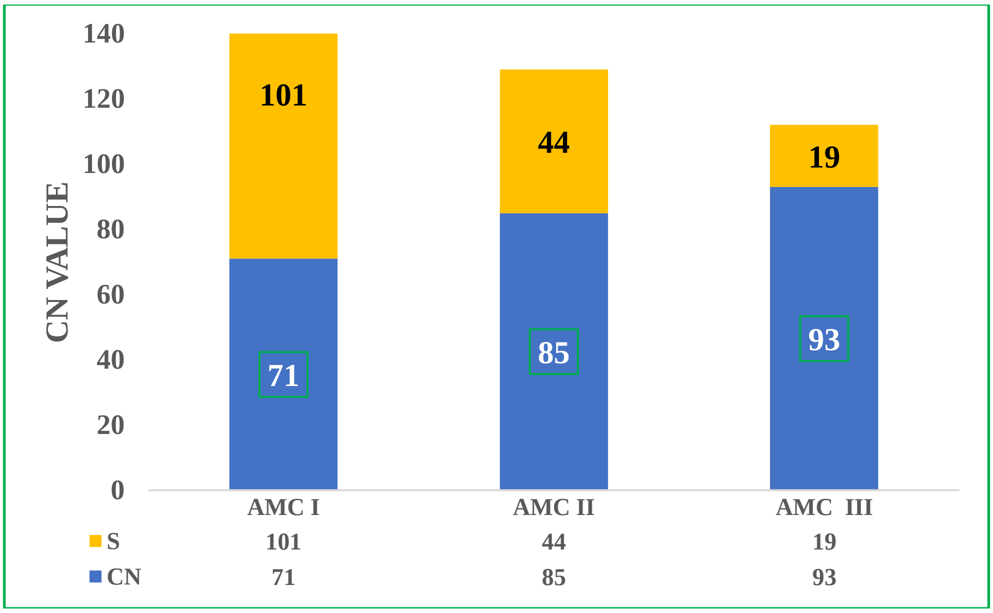

Figure 8: Values used in hydrological equations

Runoff Estimation:

In the Kulumsa watershed, which experiences an average annual rainfall of approximately 821mm, analyzing the data using the Soil Conservation Service (SCS) method revealed some significant findings for the period spanning 1987 to 2018. Firstly, the average annual surface runoff depth during this timeframe was estimated at around 78.9mm. This indicates the average amount of water that flowed over the land surface after rainfall, contributing to the overall runoff within the watershed. Moreover, the computed average volume of runoff generated from this watershed during the same period was calculated to be approximately 3,673,024 cubic meters. This volume represents the cumulative amount of water runoff in the area over those years. A notable observation was that this calculated runoff volume accounted for approximately 9.61% of the total annual rainfall received in the area during those years. This percentage indicates the portion of rainfall that didn't infiltrate into the soil or get absorbed by vegetation but instead contributed to runoff. Negash et al. (Citation 2020) estimate that 10% to 40% of rainfall is converted to surface runoff. Similarly, Sishah (2021) confirmed that rainfall variability across the study region and curve number resulting from land use land cover and hydrological soil group caused a variation in runoff depth observed in the Awash River basin ranging from 83.95mm/year to a maximum of 1,416.75mm/year. The Zahraa (2021) research at the Gali Bandawa Watershed using CN and GIS revealed that the average annual runoff was 70.33 mm, accounting for 11.4% of the average annual rainfall.

Table (7) likely provides a detailed breakdown of the annual rainfall and runoff data in the years from 1987 to 2018, offering a more comprehensive view of these specific values and their variations across different years within the study area.

Table 6: The annual runoff from the period 1987 to 2018

Years	Annual RF (mm)	Runoff Volume (mm)	Runoff Volume (m^3)
1987	775.5	104.3	4,856,062.5
1988	874.4	49.9	2,323,064.2
1989	916.3	84.0	3,909,801.6
1990	984.0	117.0	5,447,640.0
1991	796.3	46.5	2,163,917.0
1992	809.5	35.2	1,638,828.2
1993	930.6	96.5	4,490,300.3
1994	727.0	55.3	2,576,040.4
1995	866.9	90.8	4,226,955.1
1996	877.0	80.4	3,741,469.8
1997	911.6	75.4	3,509,551.2
1998	874.5	82.7	3,849,560.3
1999	746.6	71.6	3,331,051.4
2000	797.5	118.0	5,494,785.6
2001	938.9	90.6	4,216,818.8
2002	708.4	43.4	2,021,000.5
2003	758.6	44.6	2,076,683.7
2004	728.0	75.8	3,526,217.2
2005	743.3	42.7	1,988,260.3
2006	805.7	65.6	3,053,888.6
2007	835.9	55.4	2,578,874.7
2008	807.6	86.3	4,016,326.7
2009	789.4	85.6	3,984,312.8
2010	917.8	105.6	4,914,492.1
2011	849.7	87.1	4,053,511.7
2012	961.2	132.3	6,158,398.2
2013	749.8	60.5	2,817,973.3
2014	868.3	136.6	6,359,052.1
2015	613.6	36.1	1,682,408.5
2016	892.0	122.8	5,715,697.1

2017	753.5	69.4	3,231,239.8
2018	664.8	77.0	3,582,598.8
Average	**801.8**	**78.9**	**3,673,024.5**

The data analysis of runoff depth and rainfall across different months within the study area. The highest average runoff depth, reaching 11.20mm, was observed in August, while the lowest, 0.10mm, was recorded in December, as shown in Figure (7). These variations were directly tied to the rainfall occurrences in the area. In August, the maximum average runoff depth coincided with the highest average monthly rainfall of 130mm. This alignment suggests that August experienced significant rainfall events, resulting in substantial surface water flow and runoff within the watershed. Conversely, December, with its minimal average runoff depth of 0.10mm, also registered the lowest average monthly rainfall of 9mm. This indicates comparatively lighter or intermittent rainfall during this period, leading to minimal runoff generation. The observed pattern indicates a direct correlation between rainfall and runoff depth. The area received the most significant rainfall during the summer season, particularly in August, which resulted in increased runoff due to higher precipitation levels. These findings highlight the influence of seasonal rainfall variations on the generation of runoff within the study area, emphasizing the relationship between rainfall intensity and subsequent runoff depth.

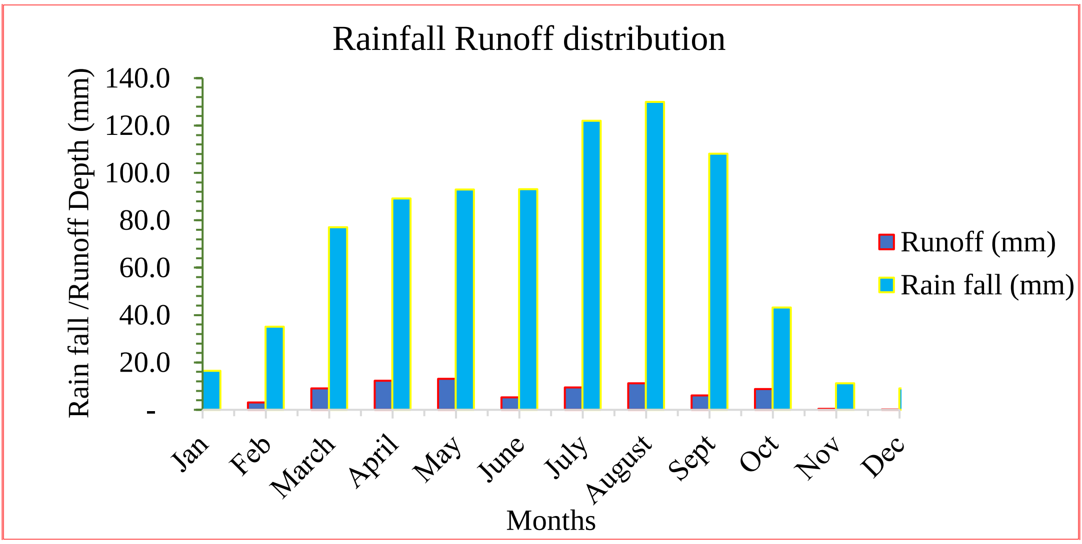

Figure 9: Monthly average rainfall and runoff for the period (1987-2018)

CONCLUSION

The research conducted in the Kulumsa watershed of Ethiopia employs an integrated approach, combining Geographic Information System (GIS) tools with the Soil Conservation Service (SCS) Runoff Curve Number (CN) method to estimate runoff. This method allows for a comprehensive understanding of the watershed's hydrological dynamics, essential for water resource management and irrigation planning.

The study methodically gathers and analyzes various data sets: rainfall distribution, land use/land cover, soil texture, and Digital Elevation Models (DEMs). This data forms the basis for delineating catchments and predicting runoff, crucial factors in determining the feasibility of water harvesting and irrigation. The watershed, covering approximately 4.66 km² and receiving an average annual rainfall of 821mm, serves as a relevant case study.

By combining information on soil types and land cover, the study derives composite curve numbers, providing insights into the watershed's runoff potential across different seasonal conditions. The weighted CN of 85 demonstrates variations between dry and wet seasons, showcasing the watershed's adaptability to changing conditions.

The results reveal valuable insights on average annual runoff depth of 78mm, translating to a runoff volume of 3,673,024 m³. This runoff volume accounts for about 9.61% of the total annual rainfall, indicating the potential for harnessing runoff water for irrigation purposes.

The study's significance lies not just in its findings but in the methodology employed. It advocates for the application of this approach beyond the Kulumsa watershed, suggesting its suitability for other Ethiopian watersheds. By emphasizing the importance of empirical models like the SCS-CN method and GIS in water resource management, the research underscores their potential for aiding sustainable water use, particularly in regions facing water scarcity.

REFERENCES

Al-Ghobari, H., Dewidar, A.Z., 2021. Integrating GIS-based MCDA techniques and the SCSCN method for identifying potential zones for rainwater harvesting in a semi-arid area. Water 13 (5), 704. https://doi.org/10.3390/w13050704.

Caletka, M., Šulc Michalková, M., Karásek, P., Fučík, P., 2020. Improvement of SCS-CN initial abstraction coefficient in the Czech Republic: a study of five catchments. Water 12 (7), 1964. https://doi.org/10.3390/w12071964

Eastman, J.R. (2003) Guide to GIS and Image Processing 14, 239-247. Clark Univer-sity Manual, USA.

Getachew Haile, 2017. Modeling Approach for Identification of Potential Rainwater Harvesting Sites in Arsi Zone, Eastern Ethiopia., Msc. Thesis Addis Ababa University,

Ibrahim, A., Zakaria, N., Harun, N., Muzamil, M., Hashim, M., 2021. Rainfall runoff modeling for the basin in Bukit Kledang, Perak. IOP Conf. Ser. Mater. Sci. Eng. 1106, 012033. https://doi.org/10.1088/1757-899X/1106/1/012033.

Kasdi SUBAGYONO and Hidayat PAWITAN 2007, Water harvesting techniques for sustainable water resources management in catchments area. Proceedings of International Workshop on Integrated Watershed Management for Sustainable Water Use in a Humid Tropical Region, JSPS-DGHE Joint Research Project, Tsukuba, October 2007. Bull. TERC, Univ. Tsukuba, No.8 Supplement, no. 2, 2008

Meraj, G., Singh, S.K., Kanga, S., Islam, M.N., 2021. Modeling on comparison of ecosystem services concepts, tools, methods and their ecological-economic implications: a review. Model. Earth Syst. Environ. https://doi.org/10.1007/s40808-021-01131-6.

Meshram, S.G., Sharma, S.K., Tignath, S., 2017. Application of remote sensing and geographical information system for generation of runoff curve number. Appl Water Sci 7, 1773–1779. https://doi.org/10.1007/s13201-015-0350-7.

Ministry of Agriculture, Govt. of India," Handbook of Hydrology", New Delhi, 1972

Mishra S K and Singh V P 2003 Soil Conservation Service Curve Number (SCS-CN) Methodology (Dordrecht, Germany: Kluwer Academic Publishers) ISBN 1-4020-1132-6.

Mishra S K, Tyagi J V, Singh V P and Singh R 2006 SCS-CN-based modeling of sediment yield; J. Hydrol. 324 301–322.

NEH 1985 National Engineering Handbook Section 4- Hydrology, U.S. Department of Agriculture, Washington, D.C., USA.

Negash T, Asfaw K, Dame Y. 2020. Modeling land use dynamics in the Kesem Sub-Basin, Awash River Basin, Ethiopia. Cogent Environ Sci. 6(1):868–873. doi: 10.1080/23311843.2020.1782006. [Taylor & Francis Online] [Web of Science ®], [Google Scholar]

Ogden, F.L., Hawkins, R.P., Walter, M.T., Goodrich, D.C., 2017. Comment on "beyond the SCS-CN method: a theoretical framework for spatially lumped rainfall-runoff response" by M. S. Bartlett et al. Water Resour. Res. 53 (7), 6345–6350. https://doi. org/10.1002/2016WR020176

Richards, J. and Jia, X. (2006) Remote Sensing Digital Image Analysis: An Introduc-tion. Springer, Berlin.

Rizeei, H.M., Pradhan, B., Saharkhiz, M.A., 2018. Surface runoff prediction regarding LULC and climate dynamics using coupled LTM, optimized ARIMA, and GIS-based SCS-CN models in tropical region. Arab. J. Geosci. 11, 53. https://doi.org/10.1007/s12517- 018-3397-6

Rusa M, Bertu A. 2018. Assessment of rainwater harvesting potential using GIS. In: IOP Conference Series: Materials Science and Engineering. Vol. 330. doi: 10.1088/1757-899X/330/1/012119. [Crossref], [Google Scholar]

Shadeed, S., Almasri, M., 2010. Application of GIS-based SCS-CN method in West Bank catchments, Palestine. Water Sci. Eng. 3 (1), 1–13. https://doi.org/10.3882/j.issn. 1674-2370.2010.01.001.

Satheeshkumar, S., Venkateswaran, S., Kannan, R., 2017. Rainfall–runoff estimation using SCS–CN and GIS approach in the Pappiredipatti watershed of the Vaniyar sub basin, South India. Model. Earth Syst. Environ. 3, 24. https://doi.org/10.1007/s40808-017- 0301-4

Sishah S (2021) Rainfall Runoff Estimation Using GIS and SCS-CN Method for Awash River Basin, Ethiopia. J Earth Sci Clim Change 12: 553.

USDA, 1986. Soil Conservation Service National Engineering Handbook, USA.

USGS, 2017. "Runoff: Surface and Overland Water Runoff". Water Science School. URL https://www.usgs.gov/special- topic/water-science-school/science/runoff-surface-and-overland-water-runoff (accessed 9.14.19).

Xiaojun, G., Peng, C., Xingchang, C., Yong, Li, Ju, Z., Yuqing, S., 2021. Spatial uncertainty of rainfall and its impact on hydrological hazard forecasting in a small semiarid mountainous watershed. J. Hydrol. 595, 126049. https://doi.org/10.1016/j.jhydrol.2021. 126049

Yazachew Etefa and Kasahun Dibaba, 2011 Physical and Socio-Economic Profile of Arsi Zone and Districts'. The National Regional Government of Oromia, Bureau of Finance and D Economic Development. Regional Data and Information Core Process Organized, January, Finfinne, Ethiopia

Zahraa Mahmood Klari1, Sayran Ahmed Ibrahim 2021. Application of SCS-Curve Number Method to estimate Runoff using GIS for Gali-Bandawa Watershed. Academic Journal of Nawroz University (AJNU), Vol.10, No.1. P. 318-325