RAINFALL-RUNOFF ESTIMATION BY USING GEOGRAPHICAL INFORMATION SYSTEM(GIS)

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Abstract - *Rainfall-runoff modeling is nowadays a computing developing department of hydrology and water management. Rainfall and runoff are important parameters for recharge of groundwater in the watershed. The catchment area of the cooum river is 400km2. Assessment of water availability by an understanding of rainfall and runoff is important. Curve Number method is most commonly used to estimate the runoff. The Soil Conservation Service-Curve Number method is useful for calculation of peak discharge from the land surface meets in the river or streams. The output is useful for the watershed growth and designing of water resources successfully. Rainfall and Runoff are important components partly responsible for the hydrological cycle. Assessment of direct rainfall-runoff is always well organized but is not possible for most of the location at the desired time. The use of remote sensing and GIS technology can be useful to solve the problem in standard methods for calculating runoff. In this paper, the SCS-CN method is used to calculate peak discharge.*

***Key Words*: Arcgis, Qgis, HEC-HMS, Google Earth, Runoff, SCS-CN.**

1. INTRODUCTION

Globally the availability of fresh water is a limited resource and needs sustainable management of this resource. Given the varied bio-climatic zones, rainfall patterns vary and each geographic area receives a certain annual rainfall. However, in certain areas with changing water demand, there is a perceived sense of inadequate rainfall over the years and hence overall yield resulting of this precipitation Runoff, in hydrology, a quantity of water discharged into surface streams. The total runoff is equal to the total precipitation less than the losses caused by evapotranspiration, storage, and other such abstractions.This can occur when the soil is saturated to full capacity, and rain arrives quicker than the soil can absorb it. Surface runoff occurs because impervious areas do not allow the water to soak into the ground. Surface runoff is an important component of the water cycle. It is a primary agent of soil erosion by water.The land area which produces runoff that drains to the common point is called a drainage basin. Further, with uneven and uncertain rainfall events, there is a perceived sense of inadequate rainfall calling for declaring the region as 'drought' prone despite a decent mean annual rainfall in the catchment. In this backdrop, it becomes pertinent to assess the potential yield of runoff from rainfall in the catchment. This can be achieved by delineating the watershed and analyzing the stream network in the watershed for possible yield using appropriate methods. This project will demonstrate the accuracy levels and practically of Geographical information design software packages.

1.1. OBJECTIVES

* To analyze hydrological data

* To determine peak discharge

* To determine the lean flow

* To delineate the watershed of River Cooum using toposheet and Satellite-based DEM

2. RAINFALL ANALYSIS

Rainfall is the major component of the hydrologic cycle and is the primary source of runoff. Rainfall is essentially required to fulfill various demands including agriculture, hydropower, industries, environment, and ecology. It is implicit that the rainfall is a natural phenomenon occurring due to atmospheric and oceanic circulation (local convection, frontal or orographic pattern) and has large variability at different spatial and temporal scales. However, this input is subjected to uncertainty and stochastic errors. Worldwide many attempts have been made to model and predict rainfall behavior using various empirical, statistical, numerical, and deterministic techniques. These data are usually collected using rain gauges, and therefore they are point precipitation data. However, the application of a single rain gauge as precipitation input carries lots of uncertainties regarding the estimation of runoff. This creates a lot of problems for the discharge prediction, especially if the rain gauge is located outside the basin. As a result, some utilities such as hydrological modeling need spatially continuous rainfall data. The quality of such a result is therefore estimated by the quality of the continuous spatial rainfall. Various spatial interpolation techniques to obtain representative rainfall over the entire basin or sub-basins have also used in the past.

3. RUNOFF ANALYSIS

Further, rainfall generated runoff is very important in various activities of water resources development and management, such as flood control and its management, irrigation scheduling, design of irrigation and drainage works, design of hydraulic structures, hydropower generation, and so on. The method of transformation of rainfall to runoff is highly complex, dynamic, nonlinear, and exhibits temporal and spatial variability. It is further affected by many parameters and often inter-related physical factors. The amount of rainfall on watershed produces high or low runoff depending on the small or large time duration. The infiltration and evaporation losses depending on how long the water remains in the watershed. Determining a robust relationship between rainfall and runoff for a watershed has been one of the most important problems for hydrologists, engineers, and agriculturists. Many approaches are being used to estimate runoff, in which the soil conservation service curve number (SCS-CN) method (SCS 1956) converts rainfall to surface runoff (or rainfall-excess) using a CN derived from watershed characteristics and 5-days antecedent rainfall is one. SCS-CN method is simple, and this is at the root of its popularity. The curve number method is an infiltration loss model; where infiltration is the most important loss for short term storm analysis, although it may also account for interception and surface storage losses through its initial abstraction feature

3.1 Watershed

A watershed, also called a drainage basin or catchment area, is defined as an area in which all water flowing into it goes to a common outlet. It is bounded by the highest contour called ridgeline from where precipitated water is collected by the surface and subsurface flows and drained out through the natural river.People and livestock are a part of a watershed and their activities affect the productive status of watersheds and vice versa. The different phases of the hydrological cycle in a watershed depend on the various natural features and human activities.

4. LITERATURE REVIEW

Assessment, simulation, and prediction of rainfall and corresponding runoff are essential for stakeholders and policymakers to plan or adapt the required policies. There are various techniques available in the literature to assess, simulate, and predict hydrological variables. However, the selection of these techniques normally depends on the objectives of the study, availability of required input data, the quality of available models, and some pre-defined assumptions. To facilitate an adequate level of accuracy, the developer has to be responsive to the characteristics of different methods, and determine if a particular method is appropriate for the undertaken situation before embarking its usage in the real application. As a result, the choice of a model is one of the important factors that will influence the forecasting accuracy.

In the following sections literature review on the application of various hydrological and SCS-CN models for rainfall and runoff assessment, simulation, and prediction has been summarized. The design runoff values derived from design storm and design CN-values were found quite close to the conventionally derived design runoff for a given rain duration.

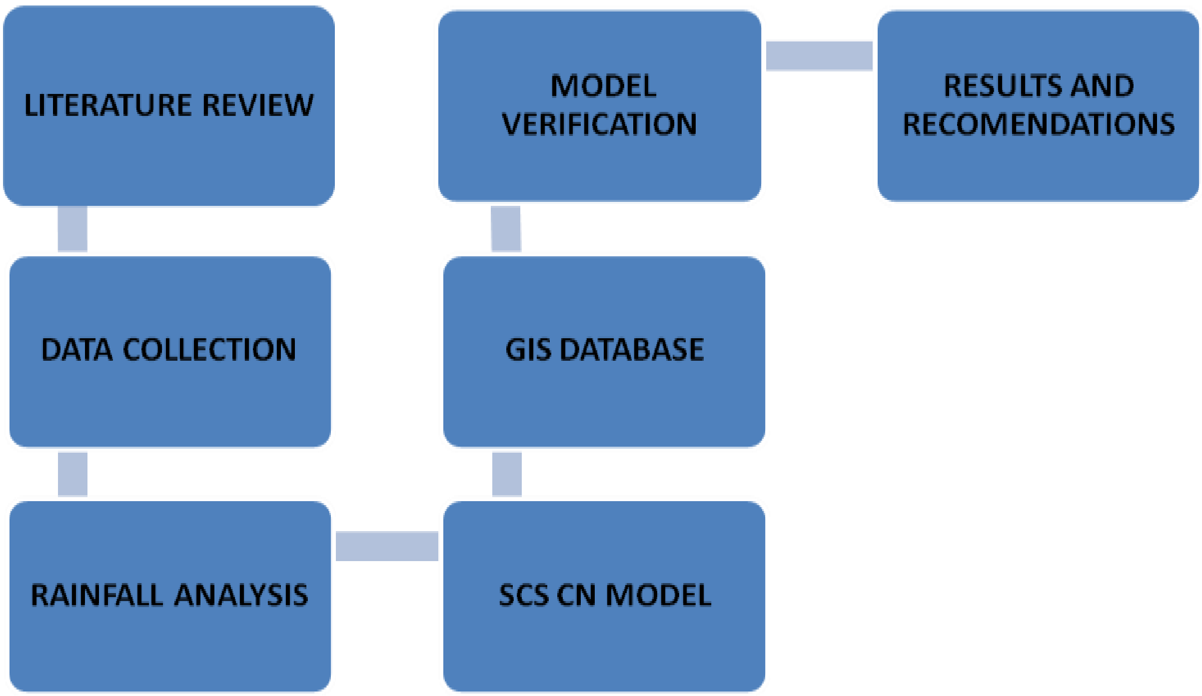
It was observed that for a given duration, as the wetness level (wet through dry) decreases, the CN value decreases, and for a given AMC, as the duration increases, the CN value decreases, and vice versa. They concluded that the study will be very helpful for hydrologists.

Mishra and Kansal (2014) suggested a simple approach for the derivation of the design CN for different durations, AMCs, and return periods. In this study design, CNs were derived by employing the long-term daily rainfall-runoff data of three hydro-meteorologically different watersheds, viz. Ramganga watershed in Uttarakhand (India), Maithonwatershed in Jharkhand (India), and Rapti watershed in Mid-Western Region (Nepal) and tested their validity using the design runoff computed from observed data conventionally. The study revealed that for a given duration, as AMC level (AMC III through AMC I) decreases CN decreases and, for a given AMC, as duration increases, CN decreases, and vice versa. For a given Antecedent Moisture Condition and return period, Curve Number decreases as rain duration increases, and vice versa, furthermore, for a given AMC and duration, CN increases as return period increases. Further, the study observed that for a given duration and return period, CN increases as the AMC level increases from AMC I to AMC III. The results were found reasonable for return periods up to 10-year, 50-year, and 50-year for Maithan, Ramganga, and Rapti watersheds, respectively.

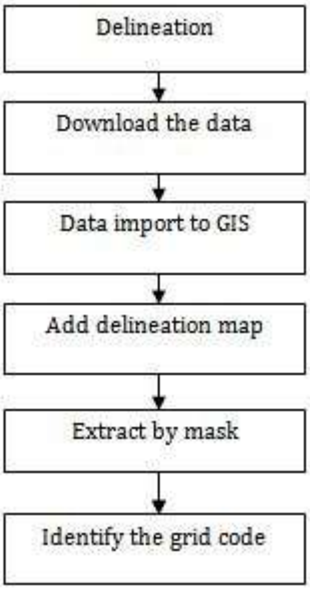
(Waikar & Nilawar, 2014), had carried out morphometric analysis and prioritization of basin based on the integrated use of remote sensing and GIS technique for the Charthana area in the Parbhani district of Maharashtra.

5. METHODOLOGY

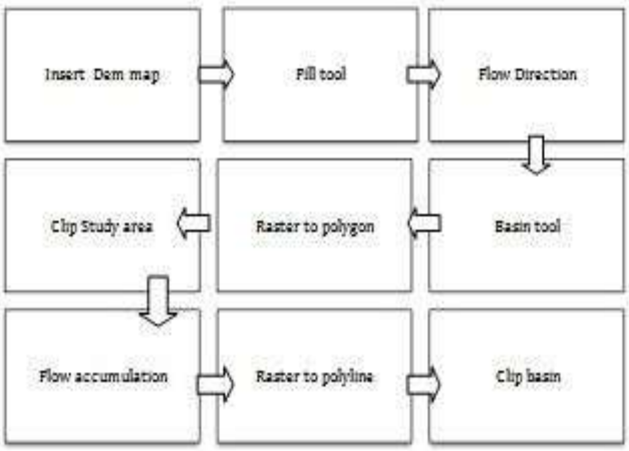
Relating to a fixed pattern is at the heart of geography, a field dedicated to understanding where things are and why. Water systems, for example, can act as a powerfully unifying resource. To truly assess water resources in their most holistic sense, one needs to include the many aspects of the hydrological cycle, from meteorology to surface hydrology to soil sciences to groundwater to limnology to aquatic ecosystems. And that is just the physical system. The thematic map developed from a variety of perspectives of the basin provides a view of the watershed and is being used for hydrological analysis.



General Procedure for Land Use Land Cover map



General Procedure for Watershed Delineation



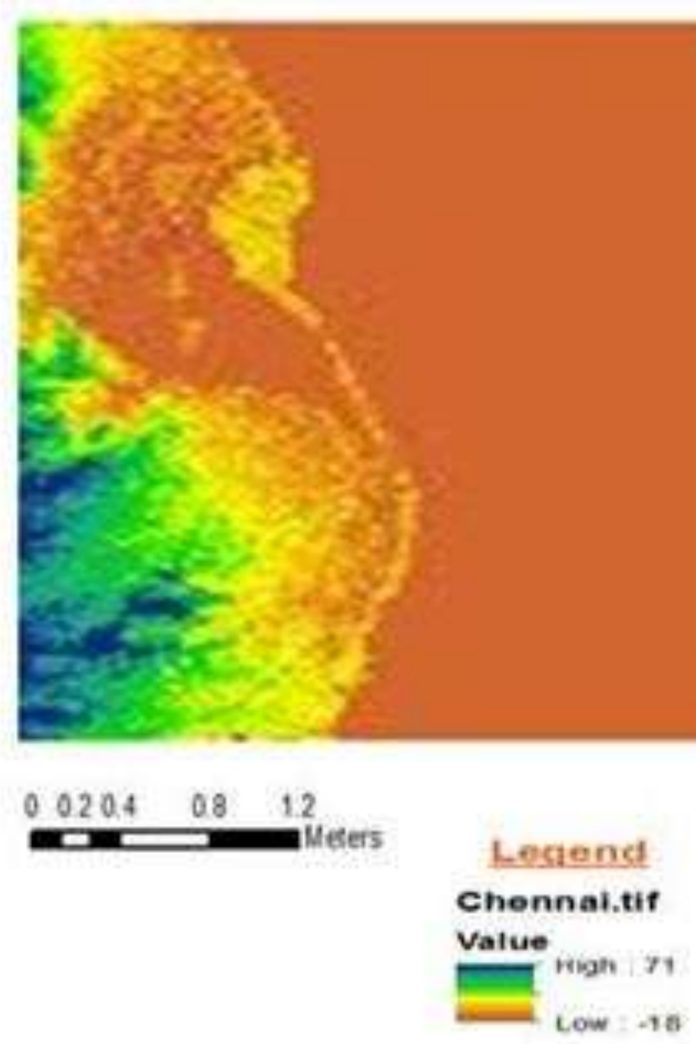
6. DATA COLLECTION

The adopted methodology of the present study is shown in this Fig.5 which shown the flowchart for the model development of runoff. The land use and land cover map are obtained from satellite image MCD12Q1 (COOUM RIVER, CHENNAI). Digital Elevation Model (DEM) is downloaded from Earth data login(SRTM DEM 30M RESOLUTION). After studying satellite image, develop the land use land cover map using grid code. Determine the land use and land cover (LU/LC) area of both types of land. Determine the soil types. Convert them into Hydrological soil groups like A, B, C & D based on the Infiltration capacity of the soil.

7. STUDY AREA

The Cooum River starts in a village of Tiruvallur district, about 70 km from Chennai, the river divides into two regions the northern and the southern arms. The total catchment area of the river is about 400 km2 and the bed width ranges from 40 to 120 m. The capacity of the river is 19,500 cubic meters per second, and the anticipated flood discharge is around 22,000 cubic meters per second. The annual precipitation in mm in the Chennai region is 1200 mm and relative humidity will be at 70 to 80%, the maximum rainfall in the Chennai region will be during the northeast monsoon and it will be during November month of each annum.

8. DEM MAP



9. GEOGRAPHICAL INFORMATION SYSTEM

9.1 General

A GIS is a software that provides the following four sets of capabilities to handle geo-referenced data.

Data capture and preparation

Data management, including storage and maintenance

Data manipulation and analysis

Data presentation

Data used in GIS are generally positional data, also called as spatial data. Spatial data refers to where they were or will be in the geographic space which is defined relative to Earth's surface.This includes such information as the location of rivers and roads, hills, and valleys. Data from Remote Sensing satellites in a variety of spatial, spectral, and temporal resolutions are used for various applications of resources survey and management can be imported into Geographical Information System flawlessly. GIS is the science underlying geographic concepts, applications, and systems.

9.2 Data representation in a GIS

Conventionally, there are two broad methods of storing the data in a GIS.

1. Vector

Examples of Vector data:

Points of towns, trees, electric pole, etc.

Lines for highways, streams, sewer lines, etc.

Polygons for houses, tanks, playgrounds, etc.

2. Raster

Examples of Raster data:

Satellite imagery

DEM

Scanned maps/toposheets

Online Map Layers

9.3 Geo referencing

The primary function of the map is to portray accurately real-world features that occur on the curved surface of the earth. Geographic referencing which is sometimes simply called geo-referencing is defined as the representation of the location of real-world features within the spatial framework of a particular system. The objective of geo referencing can be seen as the series of concepts and techniques that progressively transform measurements carried out on the irregular surface of the earth to a flat surface of a map, and male it easily and readily measurable on this flat surface utilizing a coordinate system.

9.4 Remote Sensing

Remote sensing is the science of obtaining information about objects or areas from a distance, It may be split into active remote sensing (when a signal is first emitted from aircraft or satellites or passive (e.g. sunlight) when information is merely recorded typically from aircraft or satellites. Remote sensing(RS) is possible to collect data from unreachable areas. Remote sensing(RS) applications include observing deforestation in areas such as the Amazon Basin, glacial features in Arctic and Antarctic regions.

9.5 Applications of GIS

GIS is involved in various areas. These include topographical mapping, socio-economic and environment modeling, and education. Some examples include,

- Urban planning
- Crime mapping
- GIS and Hydrology
- Remote sensing applications
- Transport and Road networking

- Wastewater and stormwater systems
- Waste management

9.6 Plugins in qgis

1. OPEN LAYER PLUGIN

2. SEMI-AUTOMATIC CLASSIFICATION PLUGIN

These two plugins are used for land cover classification

3. SRTM downloader – This plugin is used for downloading the DEM map.

4. Quick map services- This plugin is used for Catchment area calculation and watershed delineation.

10. ANALYSIS

10.1Precipitation losses

The runoff from the ground surface is initiated only after some providing of rainfall as losses. The various losses are due to interception, depression storage, infiltration, and evapotranspiration. The SCS-CN method in HEC-HMS is selected to account for the major infiltration loss. The curve number is utilized to quantify the infiltration capacity by the SCS method. The runoff is calculated as

$Q=(P-Ia)2/P-Ia+S$

The relation between initial abstraction and S is

$Ia=\lambda*S$

$S = (25400/CN)-254$

where Q = Runoff in cumec;

P =precipitation in mm

Ia = Initial abstraction

S = Maximum soil potential retention in mm.

The λ value ranges from 0.1 to 0.3.

Calculation of CNI and CNIII

$CNI = CNII / 2.281 - 0.0128CNII$

$CNIII = CNII/ 0.427+0.00573CNII$

Where CNII is curve number for normal condition.

The Antecedent Moisture Condition represents the average moisture condition of the soil before the occurrence of the rainfall event. The CN is given based on the AMC II condition. Similarly AMC I and AMC III conditions represent the dry and wet conditions. Generally, AMC is taken as five days before the storm event.

1. AMC I represents dry soil with a dormant season rainfall (5-day) of less than 12.7 mm and a growing season rainfall (5-day) of less than 35.56mm,

2. AMC II represents average soil moisture conditions with dormant season rainfall averaging from 12.7 to 27.94 mm and growing season rainfall from 35.56 to 53.34 mm, and
3. AMC III conditions represent saturated soil with dormant season rainfall over 27.94 mm and growing season rainfall over 53.34mm.

The dormant season is November to May and the Growing season is June to October.

10.2. Arcgis-10.5

within the present study, the basin area of the COOUM river system lying in Chennai and its sub-basins are delineated employing a tool of Geographic Information Systems (GIS) based software called Arc-GIS. Spatial Analyst tool which may be a graphical interface of in Arc-GIS delineates the basin into sub-basins using the digital elevation model (DEM) map, land use map. For modeling purposes, the basin is split into several sub-basins. the utilization of sub-basins during a simulation is especially beneficial when different areas of the basin are dominated by different land uses or soils, which can have an impression on hydrology. the traditional method of catchment area delineation is obtained by using the topographic map. The basin divide is drawn ranging from the outflow profile, drawing a line by using polyline over the world toposheet map, encompassing the headwaters and therefore the entire stream network. this is often usually done using scanned maps in GIS software, where the polygon properties are often easily calculated.

The Arc-GIS requires one spatial raster data set: a digital elevation model (DEM). This map is made within the 3D Analyst Tool with the raster interpolation and elevation in meters. Here is that the procedure on the way to create DEM of the study area. First, we've to scan the toposheet and placed it in ARC- GIS software then georeferences that map. Georeferencing is the process which helps to register the map by using its frame of reference. Once the registration process completed then a map is prepared for the Digitization process. The digitization process may be a vital part of ARC-GIS. within the Digitization process, we've to make a shapefile folder with polyline shapefile.

Then we've to travel editing part within the main window then select the beginning editing then create a feature window will come. then select that polyline shapefile by use of mouse icon and draw the contour over the topo map. For DEM preparation we've to pick a relief map because of the main map and attend the Arc toolbox within the main window of Arc GIS. Select the 3D Analyst tool from the catalog and attend the Raster Interpolation and fillup the specified data and double enter in Topo to Raster. In Topo to raster fillup the Input feature data which are contour and boundary of the study area and in Output surface raster fill the situation where you've got to save lots of the info then press ok button. counting on your system process it'll take time and provides the output as a digital elevation model(DEM).

10.3 Qgis 3.10

QGIS desktop may be a geographic data system (GIS) application that gives data viewing, editing, and analysis. the appliance is out there from http://qgis.org/. QGIS allows users to make maps with many layers in several map projections. Maps are often assembled in several formats and for various uses. QGIS allows maps to be composed of raster layers. Typical for this type of software, the raster data is stored as either point, line, or polygon-feature. Different sorts of raster images are supported, and therefore the software can geo-reference images. (Figure 5.5) QGIS supports Dxf, shapefiles, coverages, and private geo-databases. MapInfo, PostGIS, and a few other formats. Web services, including Web Map Service and Web Feature Service, also supported to permit the utilization of knowledge from external sources. QGIS integrates with other open-source GIS packages, including PostGIS, GRASS, and MapServer to supply users with extensive functionality. Plugins are written in Python or C++ extends QGIS's capabilities. plugins perform geoprocessing through tools and it is often geocoded through application programming interface key provided by Google, which are equivalent tools found in ArcGIS, and interface with PostgreSQL, SpatiaLite, and MySQL databases.

10.4. Hec – hms

HEC – HMS was run with a real-time rainfall event of 1 Jan 2013 -31 Dec 2018. The sub-basin parameters mainly required are the lag time, infiltration parameter, and transform parameters. The infiltration parameter values are given for the sandy soil as laid out in HEC HMS technical manual. Percentage impervious values for every sub-catchment are calculated. the whole duration of the rainfall that's 1 Jan 2013 -31 Dec 2018 is given as control time and therefore the model simulation run is performed. The simulation output is obtained within the sort of a hydrograph at the outlet of each unit within the model (Sub catchment, junctions, and reaches). The hydrograph showing the riches with the utmost peak discharge is presented at each junction, reach, and sub-catchment. The result shows that the outlet that's having a peak discharge of 7m3/s during 03Dec 2015.

10.5. Hec-geo hms

HEC-Geo HMS is an extension of ArcGIS is used to pre-process the geospatial data for the HEC-HMS model. A series of terrain processing steps generate a reliable stream network from the surface topography. The accurate and high-resolution DEM undergoes by these terrain processing steps to delineate basin boundaries and stream network. The sub-basins were also be delineated using the features of HEC-Geo HMS. The background basin model file is exported to HEC-HMS.

10.6. Google earth

It maps the world by the superimposition of images obtained from satellite imagery, aerial photography, and geographic data system (GIS) onto a 3D globe. Google Earth was wont to geo-locate the rain gage stations of Tumakuru District and therefore the geolocated points were then exported to QGIS for further analysis.

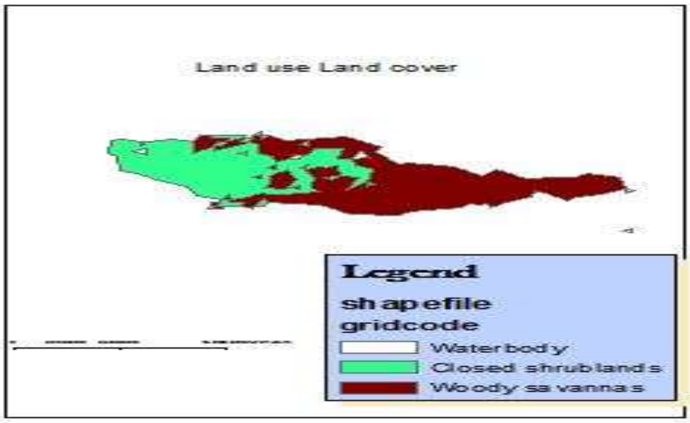
10.7. Open street map

Open Street Map (OSM) may be a collaborative project to make the free editable map of the planet. There are some major driving forces within the establishment and the growth of OSM is on restrictions and therefore the advent of cheap portable satellite navigation devices. OSM is taken into account as a prominent example of volunteered geographic information. To access the prevailing geospatial data, OpenStreetMap (http://www.openstreetmap.org) was utilized in the study.

11. RESULTS

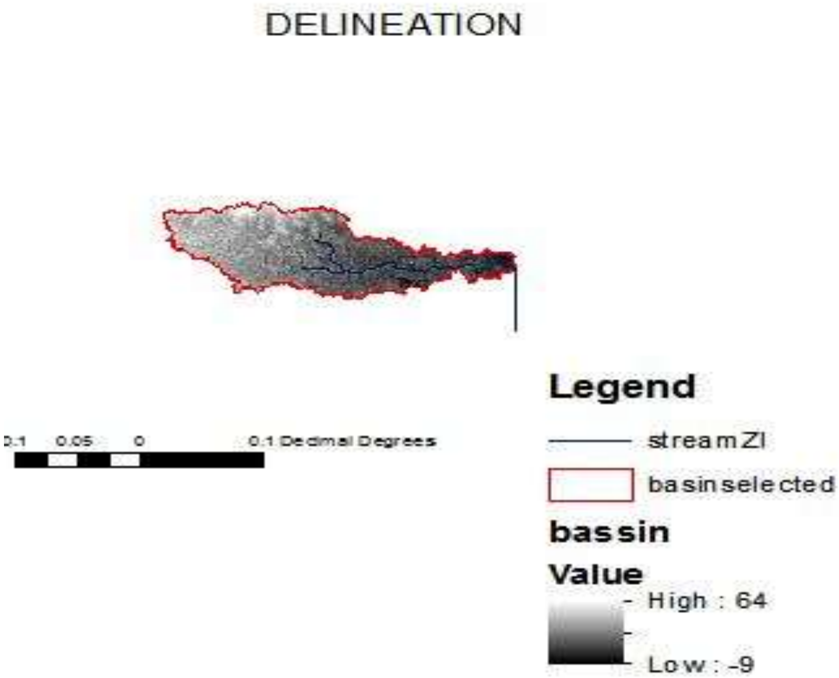
11.1. Land use land cover map

By using land use and land cover map we will get the sort of area covered within the study area like Shrublands, Woody savannas, and Waterbody and its occupied area in km2. size of the area covered by the polygons in GIS giving the results are Shrublands -3.7km2, Woody savannas- 114.71km2, and water bodies-1.65km2



11.2 Watershed delineation

The watershed of River Cooum has been delineated and has a neighborhood of 400 sq. km. With toposheets as a reference, the watershed of River Cooum was delineated by digitizing the streams and tanks from the map in GIS to produce a thematic map indicating various orders of stream network alongside tanks overlaid. Similarly, a thematic map was generated out of the DEM method by processing the stream segments derived supported the elevation of the bottom.



11.3 HEC-HMS

Using this software, runoff volume, peak discharge, precipitation volume are often computed by entering the values of hourly rainfall data and corresponding curve number.

SNO	YEAR	DATE	RAINFALL (mm)	Simulated Flow		Observed Flow (ML)
				DIRECT RUNOFF (QGIS) (ML)	DIRECT RUNOFF (ARCGIS) (ML)	
1	2013	17Nov	115	66	71	68
2	2014	24Oct	180	98	110	100
3	2015	02Dec	407	264	271	265
4	2016	13Dec	120	68	75	70
5	2017	03Nov	250	172	163	170
6	2018	22Nov	119	65	74	70

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RECOMMENDATION

By comparing the values of simulated flow from ArcGIS and QGIS and observed flow, we recommend using Qgis software for more accuracy.

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