Modelling of Surface Runoff Estimation through Geoinformatics Techniques. A Case Study of Osman Sagar Reservoir, Ranga Reddy District and Telangana State

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Abstract

On Earth, there is about 71% of water, including 96.5% of the water vapour found in rivers and lakes. These natural water supplies were successfully used by humans in domestic, agricultural, industrial, and environmental settings. Thus, rainwater was captured and kept in both natural and man-made reservoirs. Among the natural reservoirs examined in this research was Osman Sagar Reservoir, which captured rainfall and surface runoff from the catchment area. The SCS-CN approach was one such methodology. To obtain the CN values, soil texture, the Hydrological Soil Group, the Digital Elevation Model, and precipitation data were used. Then, using the nearby rainfall gauges' rainfall data, the delineation of sub-basins, the SCS CN Loss Method, and the SCS UH Transform Method were applied. The field data's inflow discharge, which is likewise measured in cusecs, was used to validate the discharge acquired from creating the model. In that, the inflow from the field and the inflow from the model peaked on September 17, 2020, and September 20, 2020, respectively were the same. On September 22, the peak increased to 166 cusecs. In all categories of data, it started to decline in 2020, and on September 27, 2020, there was a peak of 341 cusecs. The water bodies therefore be extracted from satellite images, such as Sentinel 2, with greater precision than with other satellite images due to the volume assessment accuracy. The volume of the reservoir derived from field data was verified after receiving the volume from the satellite image, and there was a difference of 0.037 TMC between those quantities. As a result of this work, it will be possible to estimate the surface runoff using a variety of techniques and models, as well as to determine the volume of the reservoir from satellite images and validate it with actual field data.

Keywords: Osman Sagar reservoir, Hydrological soil group, Transform method

Introduction

On Earth, the availability of freshwater is 3%, and 97% of water is dissolved in solids. Domestic and industrial, as these water after removing the dissolved substances. Although freshwater is not readily available, it is located in remote places. The water quality is polluted due to the pollutants entering, whether natural or man-induced. The movement of water in the form of water vapor from surface water, groundwater, and vegetation into the atmosphere and back to the earth's surface as precipitation. (Martin Wanielista). The hydrological model depends on the available data, such as rainfall, discharge data, and meteorological data, Rainfall-runoff modelling depends on the records from the point rain gauges to give an estimation of rainfall over time. The estimated runoff was calculated using the CN values of land use and land cover, soil types, and hydrological soil groups, from which the weighted CN values of HEC-HMS calibrate the volume of runoff. So, in this study, the calibrated volume of runoff is meant to be found by finding differences in spatial changes in the spread of water using certain perspectives. (Ali Alsubeai & Suzette R. Burckhard,2021) has described hydraulic modelling and flood hazards using precipitation for monthly and annual calculations; land use and land cover were derived from drainage basins; and precipitation was classified based on annual and monthly classifications; the SCS CN was identified using the loss method with rainfall and LULC. Peak discharge and volume of drainage basins were computed using the hydrological modelling software HECHMS. HEC RAS was efficiently utilized for hydraulic modelling. (Ali Hagras, 2023) has made Runoff simulation utilizing SCS-CN and the GIS method in the Tayiba Valley Basin Furthermore, they discussed water resource management, particularly during flood seasons. Thus, the data used in this work for calculating CN values were hydrological soil group, land use/land cover, and rainfall data. GIS techniques were employed for data interpretation and specialization. As a result of this method, the yearly average surface runoff computed was 8.62 mm, with a volume of runoff of 3080.02 sq. m. (Manash Jyoti Bhuyan & Debashree Borah et al., 2022) has estimated the runoff in the Kolong River basin utilizing the NRCS-curve number method and GIS techniques They briefly discussed how rainfall and runoff contribute to the hydrological cycle's function. The rainfall data from 2004 to 2018 was examined. The data was processed to investigate the runoff of a specific basin over time using the NRCS-CN model and incorporating remote sensing and GIS tools. Satellite pictures were used to construct the stream flow, HSG, slope, and LULC maps. (Natarajan, Surendar & Radhakrishnan et al., 2020) has discussed flood-prone locations in urban situations for each 10-year interval from 1986 to 2016. To generate the LULC map over a 10-year interval, the temporal data of rainfall is extracted from the spatial data of Landsat photos with a resolution of 30m. Soil maps are then gathered from NBSS and LUP and reclassified for CN numbers for HEC RAS and HEC HMS analyses. DEM was utilized to delineate streams and basins, as well as for topography. HEC-Geo HMS and HEC-Geo RAS were used in this work to create rainfall-runoff models with specific meteorological data and sub-basin delineation. (Satheeshkumar & Venkateswaran, 2017) has estimated the SCS-CN number for runoff and rainfall in this paper using the following data: satellite data from LISS III for creating the land use and land cover (LULC) map; toposheet collected from the Survey of India; DEM from the USGS; and rainfall data from the PWD for the years 2000-2014. To obtain the hydrological soil group (HSG), the soil data is processed for usage in SCS-CN, and LULC is integrated as one polygon. Furthermore, the rainfall data is converted into a Thiessen polygon by grouping with mean area precipitation for a catchment area and calculating CN selection, as well as producing an antecedent moisture condition (AMC) for rainfall, HSG, LULC, and calculating CN selection.

Materials and Methods

Land use and land cover 2015-2016 are classified for their respective durations. According to the NRSC classification, land use and land cover were classified into six types: built-up, agricultural, forest, grass/grazing barren, uncultivated, wasteland, and wetlands/water bodies. So, in this study, LULC is classified based on the NRSC classification (Type II). Soil types 2015-2016 are based on the study area. Soil types were classified based on surface texture as sandy, loamy, clayey, course loamy, clay skeletal, and rock outcrops. DEM are fixed with grid size and are known to be raster data. Water has a tendency to flow downhill, so knowing about the transmission should have some utility in hydrological modelling. The flow path can be identified by using DEM data. Rainfall data (2020) is obtained from IMD AWS (Indian Meteorological Department-Automatic Weather Stations) on a daily basis. The daily rainfall data has been collected from the Telangana State Development Planning Society, for which AWS records the rainfall automatically and transmits it. Then the elevation of the water extent was taken from the SRTM DEM data used for obtaining the elevation of a certain water spread area. The resolution of this DEM was 30 m. In this study, the surface water extent was measured on two dates, such as October 25 and November 4, 2020. The water spread area on October 25, 2020, was 51488830.66 sq. ft., and on November 4, 2020, it was 5268245.6 sq. ft. The threshold for finding the water extent area was 0.2 to 1. By using bathymetry, DEM can be used to identify the elevation, which is useful for finding the volume of a certain reservoir or water extent area. Thus, the resulting water extent area and elevation can be obtained from multispectral satellite imagery with high resolution and also from high-resolution digital elevation models that were derived from drainage networks. Hydrological Engineering Centre Hydrological Modelling System: This software is used to simulate runoff in a watershed system. The working environment in this software contains a database, data entry utilities, a computation engine, and reporting tools. Hydrological Engineering Centre Geospatial Hydrologic Modelling Extension: It performs a number of administrative tasks that help the user manage GIS data derived from the Programme. It includes integrated data management and a graphical user interface (GUI). This performs the conversion for translating GIS spatial information into model files for HEC-HMS. Thus, the end result of the GIS processing is a spatial hydrology database that consists of the digital elevation model (DEM), soil types, land use information, rainfall, etc. The CN grid can be calculated from the utilities menu, which is available at HEC-GeoHMS. The tool generates a CN grid, which can be used after the merging of two layers such as land use and soil type, resulting in the creation of lookup tables. For the preparation of the CN grid, LULC soil is created from a soil map according to the Hydrological Soil Group (HSG) classification. Both maps are layers, and they are joined with the help of the software ArcGIS. Then a raster file of both maps is used for creating curve number grids. Using the Zonal Statistics Table, curve number values were found by giving the input raster or feature zones as sub-basins of the respective catchment area and the input value raster as a CN grid. The resultant output was a database file of curve number values, which are found as the mean of the number of sub-basins.

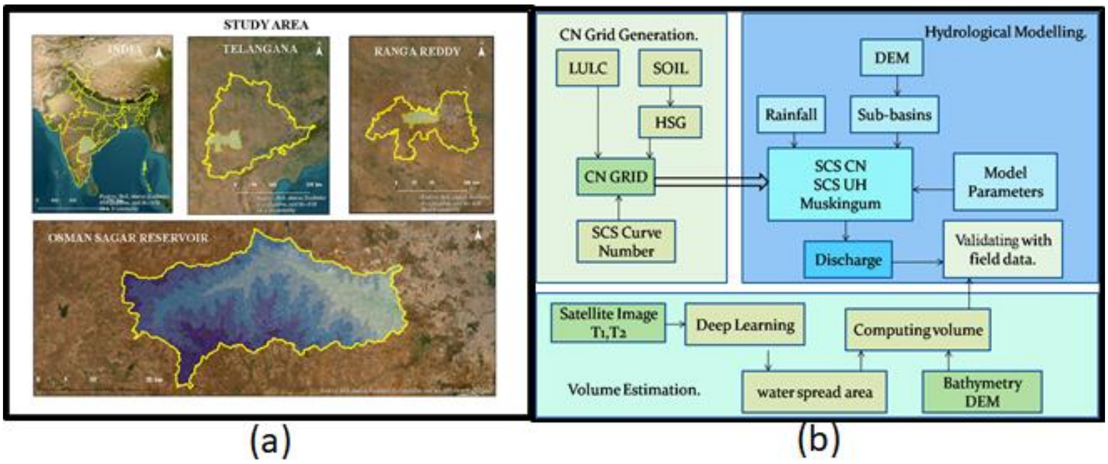

Fig. 1 (a) Study Area, (b) Methodology flow chart.

Results

Hydrological Soil Group:

Group A: This group has low runoff potential because the soil texture is fine, with 90% sand or gravel and 10% clay. This has an area of 533 sq km, and it is in every area, mostly in the area of agricultural land or cropland. Though it has a high infiltration rate and low runoff potential.

Group B: This group has moderately low runoff potential; they have 10–20% clay and 50–90% sand and loamy sand. This covers an area of 136 square kilometres. The soil is mostly found adjacent to the water body in the eastern part of the study area. Though it has a moderate runoff potential rate and infiltration rate.

Group C: This group has moderately high runoff potential; they have 20 to 40% clay and less than 50% sand, which has a lower infiltration rate. So that the water on the surface would transmit slower than groups B and A. They occupied an area of 10 sq. km, and the places with this type of soil are urban, rural, and mines.

Group D: This group of soils has high runoff potential when thoroughly wet. This is found in the eastern part of the study area, where the soils are mostly clayey and have a low infiltration rate. This type of soil has 40% clay and less than 50% sand. Most of the water bodies have this type of soil.

Curve Number (CN GRID): The CN values are determined by the cover type, with more impermeable areas in metropolitan areas having higher CN values since runoff potential is higher than in other locations. In this study region, strong runoff potential with a low infiltration rate is observed in the central, northern, eastern, and certain parts of the western areas, which are largely urban and aquatic bodies. Low runoff is located near canals or rivers, despite having a huge quantity of sand or gravel with a low runoff potential and a high infiltration rate; these are also largely cultivated land, fallow land, and barren land.

Cumulative Rainfall of Stations (mm): According to the above data, there are 7 rainfall gauges. They are situated around the catchment area. Shankarpalle has the highest rainfall with 344.10 mm during the southwest monsoon from September to October, meanwhile in Mominpet has 190.40 mm which was the lowest rainfall. Moreover, the rainfall was high on

17 September 2020 with 410.7 mm which was the peak of a single storm event and it decreased on 18 September 2020 with 36.4 mm Moreover it again peaked on 26 September 2020 with 491.8 mm and decreased on 28 September 2020.

Validating Discharge Flow from the Model: The given rainfall data shows the inflow discharge from the rainfall that occurred was computed to get the peak of discharge at a certain time and date. Therefore, the outflow discharge was identified on September 17, 2020, and there exists a peak in discharge; also, there is a peak discharge on September 25, 2020, and a reduced discharge on September 28, 2020. Thus, the model used in this study can be easily identified for finding the surface runoff volume. It is easy to find out the hydrological with all the above parameters.

Validating Hydrological Model Output Using Field Data: The field data show the inflow in cusecs (cubic seconds) for the interval of September 11, 2020, to October 2nd, 2020. Moreover, in the given field data, there is a peak on September 17, 2020, with 40 cusecs and on September 20, 2020, with 166 cusecs; after that, there is a slight fall in inflow, whereas, on September 27, 2020, there is a peak of inflow rate with 341cusecs. Thus, the computed inflow discharge remains the same when compared, to the inflow increases. So, while the model processed using HEC-HMS was useful to create and obtain the volume of inflow, other parameters proved that the rainfall data for a certain catchment area in a single storm.

Accuracy Analysis of volume information from Satellite data volume using field data: Thus, using the Sentinel 2 satellite image, which has high-resolution data, can be able to find the surface water extent using the count of pixels found in the water area using a convolutional neural network in deep learning. This helps in identifying water extent areas effectively. Then, the surface water extent on October 25, 2020, was 0.478 sq. km and on November 4, 2020, it was 0.489 sq. km, with the extent area, width, and height of bathymetry DEM, and the volume obtained from these two datasets being 0.1037 TMC. While the field data had 3.220 TMC on October 25, 2020, and 3.320 TMC on November 4, 2020, at the time, the difference between the two sets of storage capacity was 0.1037 TMC, and it was assigned to be the volume. Whereas the volume obtained from satellite images and the volume obtained from field data had a difference of 0.037 TMC.

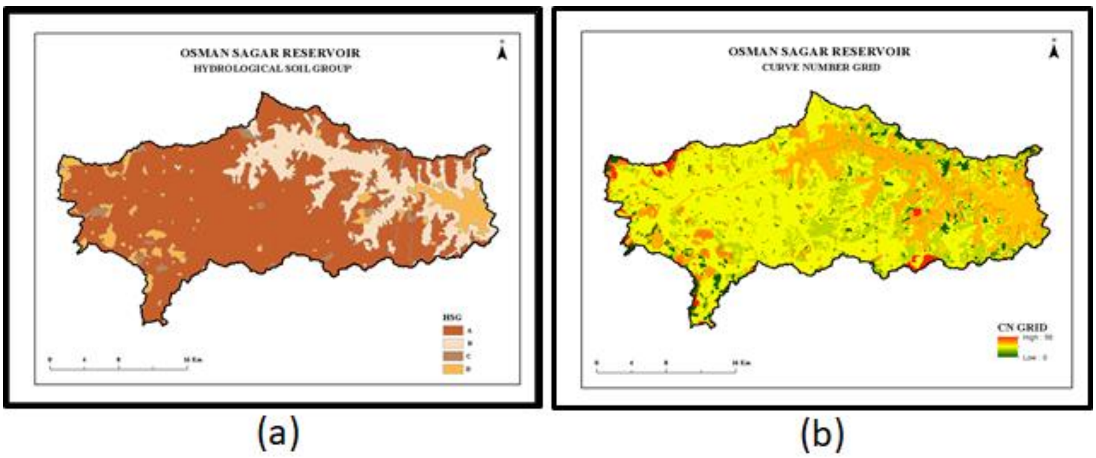

Fig. 2 (a) Hydrological Soil Group. **(b)** Curve Number Grid.

Table 1 Storage capacity (in TMC).

Date	Storage Capacity (in TMC)
25/10/2020	3.220
04/11/2020	3.320
Difference in storage capacity	0.1

Table 2 Surface water extent area (sq. km).

Date	Surface Water Extent area (sq. km)
25/10/2020	0.478
04/11/2020	0.489

Discussion

Moreover, surface runoff is the most important use in the field of irrigation purpose. So, there was a need to estimate the surface runoff during every single storm event of rainfall. Thus, the estimation was done by adopting the SCS-CN method and also by remote sensing and the GIS approach. Though it correlates with the precipitation dataset, the usage of land use and land cover, hydrological soil groups, soil, and digital elevation model maps were created to find out the CN values. Thus, hydrological modelling was done in the software, namely HEC-HMS, for estimating the volume of surface runoff. Then it was compared with field data on inflow discharge, which are both cusecs. It was related to the field data and the computed result from the output obtained. Thus, the satellite images of both dates were extracted by extracting the water extent area, and then bathymetry DEM was used to find the volume. Then it was assessed with field data on storage capacity for a particular date, and finally, it had a difference of 0.1037 TMC. Thus, it can be briefly explained that when rainfall occurs during a given time period, there will be high surface runoff accordingly.

Conclusions

Thus, conservation and planning should be well maintained for a sustained environment. The SCS-CN method was effectively used for finding runoff volume in the respective sub-watershed by analyzing and validating field data. Moreover, the satellite image plays another role in effectively estimating the volume of the reservoir using the deep learning method, and extraction of the water extent area and bathymetry DEM was used. This can result in the satellite image playing an important role in identifying the volume and validating the value with the field value. According to Sustainable Development Goal 6 (SDG), target 6.6 and indicator 6.6.1 have implemented the extension of water-related ecosystems in a large manner by maintaining proper management by the country's planners and researchers.

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