# Chapter 11
# Comparing Runoff of the NRCS-CN Method and Observed Runoff Data: A Case Study

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**Abstract** In the present study, morphometric characterization, runoff estimation, and comparison of observed and estimated runoff for the Tunga River catchment, tributary to the Tungabhadra River of the Krishna Basin, are carried out. Runoff estimation is carried out using the NRCS-CN method. The study is performed in a GIS environment by considering land use/land cover and soil texture. The area of the Tunga River catchment is 2950 $Km^2$. The catchment is delineated using Survey of India (SOI) topo maps of 1:50000 scale using GIS software. The average annual rainfall observed in the area is 2247.35 mm. The runoff data is collected from CWC, Bangalore. The study is carried out for soil infiltration rates of 0.2S and 0.3S. The estimated and observed runoff are being compared, and the reasons for the differences in runoff are discussed.

**Keywords** Runoff estimation · NRCS-CN (Natural Resource Conservation Service) · GIS (Geographical Information System)

## 11.1 Introduction

Estimating runoff from a watershed is a critical component in flood prediction and mitigation, water quality management, hydropower production, and a number of other water resource operations. Seepage from tanks, canals, streams, and functional irrigation are all significant sources of recharge. Hydrometeorological and hydrological data play a critical role in determining the accessibility of water sources for the planning and design of artificial recharge structures (Goyal and Ojha 2010; Das et al. 2020; Poonia et al. 2021). Rainfall runoff modeling can be done in a variety of ways (Goyal et al. 2022). One of the most basic and simple methods for rainfall runoff modeling is the Soil Conservation Services and Curve Number (SCS-CN) technique. Runoff data is essential for watershed management in order to conserve

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and develop natural resources (Goyal and Ojha 2012; Goyal et al. 2018). The morphometric analysis of the drainage basin and channel network is critical for understanding the drainage basin's geohydrological behaviors and reflecting the catchment's climate, geology, and geomorphology. Morphometric analysis gives information about the physical characteristics of the watershed and contributes in the calculation of catchment parameters. Morphometric analysis provides the physical characteristics of the watershed and also helps in the derivation of parameters within the catchment. The runoff estimation carried out by using the NRCS-CN method will help in proper planning and management of catchment yield for better planning of river basin (Subramoniam et al. 2022). Rainfall information is essential for estimations and calculations of design flows. Generally, this information is summarized in tables or depicted as graphs indicating the rainfall depth in a specific area for a specific duration. The main aim of the study is to estimate runoff by the NRCS-CN method for the Tunga catchment, compare observed runoff with the estimated runoff, and analyze the percentage difference in estimated runoff with respect to observed runoff.

## 11.2 Objectives of the Study

The main aim of the study is to estimate runoff by the NRCS-CN method for the Tunga catchment, compare observed runoff with the estimated runoff, and analyze the percentage difference in estimated runoff with respect to observed runoff.

## 11.3 Catchment Area and Data Products Used

### *11.3.1 Catchment Area*

In this work, the hydrological process of the catchment was intended to be studied by constructing thematic maps utilizing remotely sensed data and a database using ArcGIS software.

The Tunga River runs through Shivamogga and Chikkamagaluru districts and is located at 75° 40′ 0″ longitude and 14° 0″ latitude. It has a total area of 2950 km$^2$. The location map of the research area is shown in Fig. 11.1. Using 1:50000 SOI toposheets, the catchment is delineated/digitized in ArcGIS software.

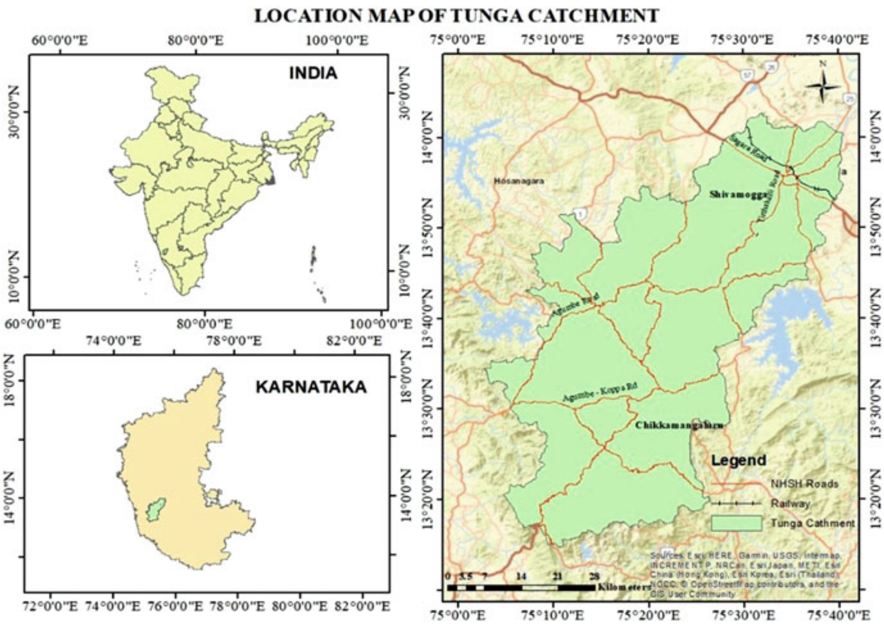


Fig. 11.1 Location map of the Tunga catchment

### 11.3.2 Data Sets

- Survey of India (SOI) topographical maps (1987–1988) at 1:50,000
- Soil map of the year 2005 from the National Bureau of Soil Survey and Land Use Planning, Hebbal, Bangalore
- Land use/land cover map of the year 2016 from the USGS Earth Explorer
- DEM SRTM (30 m resolution) from Bhuvan
- Daily rainfall data (1998–2018) from Director, Statistics Department, MS Building, Bengaluru
- Daily runoff data (1998–2018) from CWC, Bengaluru

## 11.4 Methodology

### 11.4.1 Morphometry

The drainage map was prepared using SOI topo maps on a 1:50000 scale. A stream order map is developed, and the morphometric parameters are discussed.

## *11.4.2 Runoff Estimation*

For the estimation of runoff, the methodology of the NRCS-CN method is followed, the estimated runoff is compared with the observed runoff, and the percentage difference is analyzed.

### 11.4.2.1 Soil Map

Soil is one of the most important natural resources in the growth of both agricultural and non-agricultural sectors. For optimal land use planning, information on different types of soils, their limitations, and capacities is required to assess their suitability for various crops. Soil mapping and attribute information in terms of physical, chemical, and morphological aspects are provided through soil surveys.

### 11.4.2.2 Land Use and Land Cover Map

Land use/land cover knowledge is crucial for any planning and management operations, and it is also regarded as an essential component for modeling and comprehending the planet as a system. Land use refers to the human activities linked to a piece of land, such as agriculture, urbanization, and so on. The characteristics are referred to as land cover (Fig. 11.2)

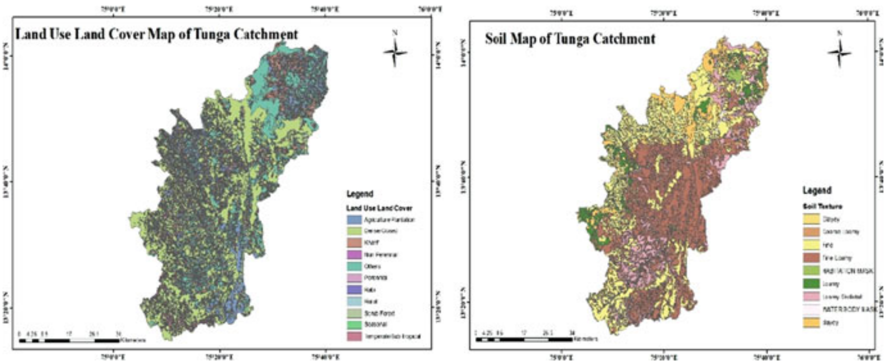


**Fig 11.2** Land use/land cover map and soil map of the Tunga catchment

## 11.5 Results and Discussion

### *11.5.1 Morphometric Analysis*

Using SOI toposheets, the catchment area and streams are delineated/digitized, and the stream ordering is determined. Basic morphometric properties such as stream numbers and length, as well as other data, are extracted and tabulated.

Quantitative morphometric analysis is used to investigate the various characteristics of the watershed. The methodology suggested by Strahler (1964) was used to rank streams in the present study. The highest stream order determined using Strahler's method of stream ordering is seventh order, and hence, the catchment is designated as seventh order. The overall length of stream segments is often highest in first-order streams and decreases as stream order increases. The drainage density reflects land use, infiltration effects, and the duration between precipitation and discharge in the catchment (Figs. 11.3 and 11.4, Table 11.1).

Tunga watershed has a stream order ranging from 1 to 6; stream number (Nu) 3535; a stream length (Lu) of 3747.53 m; a mean stream length ratio of 2.24; a mean bifurcation ratio ($R_b$) of 5.07, which is >5, hence to say that it is structurally uncontrolled; and a main channel length (Cl) of 96.35 m. Basin geometries are basin area of 2950 km$^2$; basin perimeter of 377.28 km; shape factor of 3.148, which is greater than 0.9, hence circular in shape; form ratio (Ff) of 0.317; elongation ratio

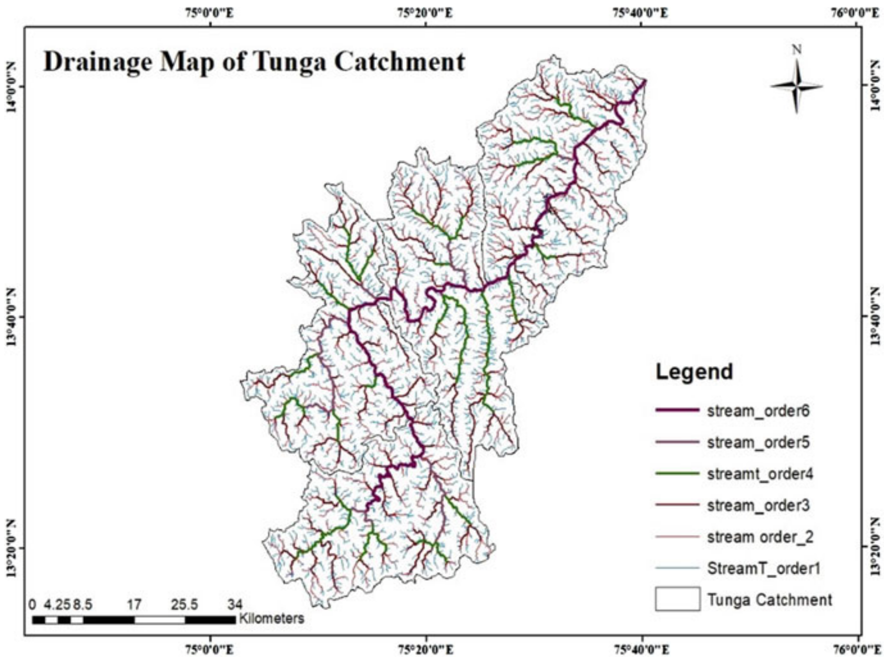


**Fig 11.3** Drainage map of the Tunga catchment

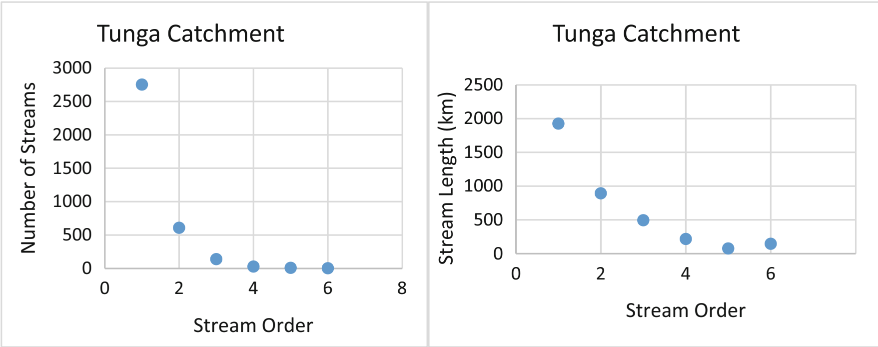


**Fig. 11.4** Stream order vs. No. of streams and stream order vs. stream length for the Tunga catchment

**Table 11.1** Morphometric characteristics of the Tunga catchment

| Stream order | No. of streams | Stream length | Mean stream length | Mean stream length ratio | Bifurcation ratio |
|---|---|---|---|---|---|
| *Su* | *Nu* | *(Lu) (km)* | *(Lsm) (km)* | *(Lur)* | *(Rb)* |
| 1 | 2752 | 1925.494 | 0.699 | | |
| 2 | 608 | 892.162 | 1.467 | 0.476 | 4.526 |
| 3 | 138 | 493.250 | 3.574 | 0.410 | 4.405 |
| 4 | 28 | 217.0236 | 7.7508 | 0.461 | 4.928 |
| 5 | 8 | 74.952 | 9.369 | 0.827 | 3.5 |
| 6 | 1 | 144.635 | 144.635 | 0.0647 | 8 |

(Re) of 0.6362, hence circular and less elongated; and circularity ratio (Rc) of 0.2603, which implies infiltration is uniform. Drainage texture analysis is stream frequency (Fs) of 1.1983, which ranges from 0 to 5, thus low stream frequency. Drainage density (Dd) of 1.27 $Km/Km^2$ range is between 1.24 and 2.49, hence coarse texture. The relief characteristics are that the height of the basin mouth is 556 m, the maximum height of the basin is 1006 m, the total basin relief is 450 m, the relief ratio is 4.607, the relative relief ratio is 0.001, and the ruggedness number is 0.571.

### *11.5.2 Runoff Estimation*

The primary parameters used to estimate runoff are land use/land cover, soil groups, rainfall, and curve numbers. The analysis is performed with Ia = 0.2 S as well as Ia = 0.3 S. For both scenarios, graphs are created, and the results are compared to the observed runoff. The depth of runoff in cumecs is translated to mm. The Thiessen polygon map and curve number maps are constructed using the soil and land use/land cover maps, and runoff is estimated (Figs. 11.5, 11.6 and 11.7).

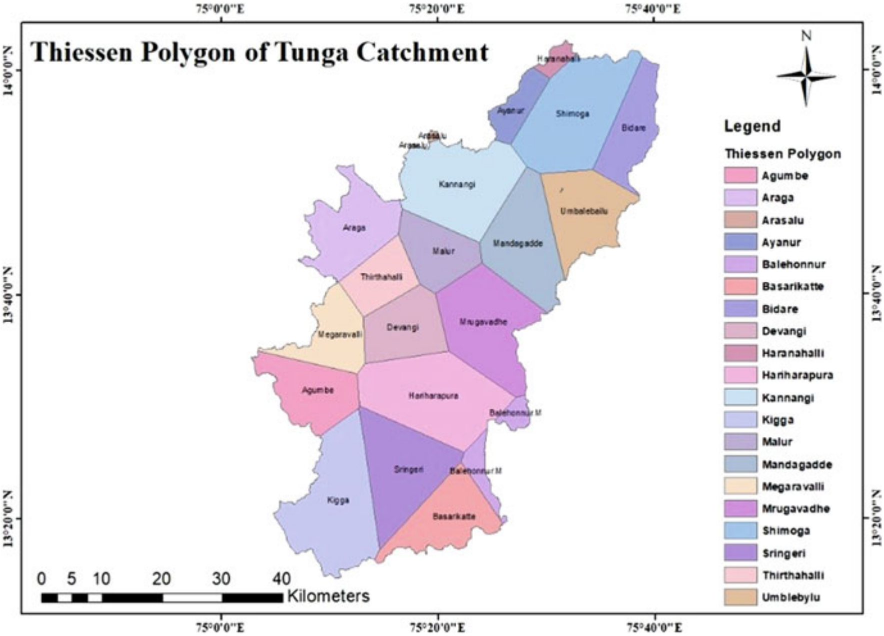


**Fig. 11.5** Thiessen polygon of the Tunga catchment

The Tunga catchment receives an average annual rainfall of 2247.35 mm, and the observed average annual runoff is 278.08 mm. The maximum rainfall is in the year 2007, which is 3011.65 mm, and the minimum rainfall is in the year o2003, which is 1579.71 mm. The maximum observed runoff is 398.91 mm in 2013, and the minimum observed runoff is 180.1 mm in 2003.

## 11.6 Conclusions

### *11.6.1 Morphometric Analysis*

- Tunga's catchment area is 2950 km2, with a boundary of 377.28 km2. The highest order assigned is sixth, making it a sixth-order catchment.
- The low drainage density of 1.27 km/km$^2$ shows that the catchment has a coarse drainage texture; the circularity ratio of 0.26 indicates that the catchment is circular in character, with little elongation.
- The term bifurcation ratio (Rb) refers to the relationship between the number of streams in one order and the number of streams in the next higher order. The bifurcation ratio of more than 5 (3–4.7) from first to second order shows stronger infrastructural erosion, implying that the catchment is not structurally controlled or that structural disturbance is minimal.

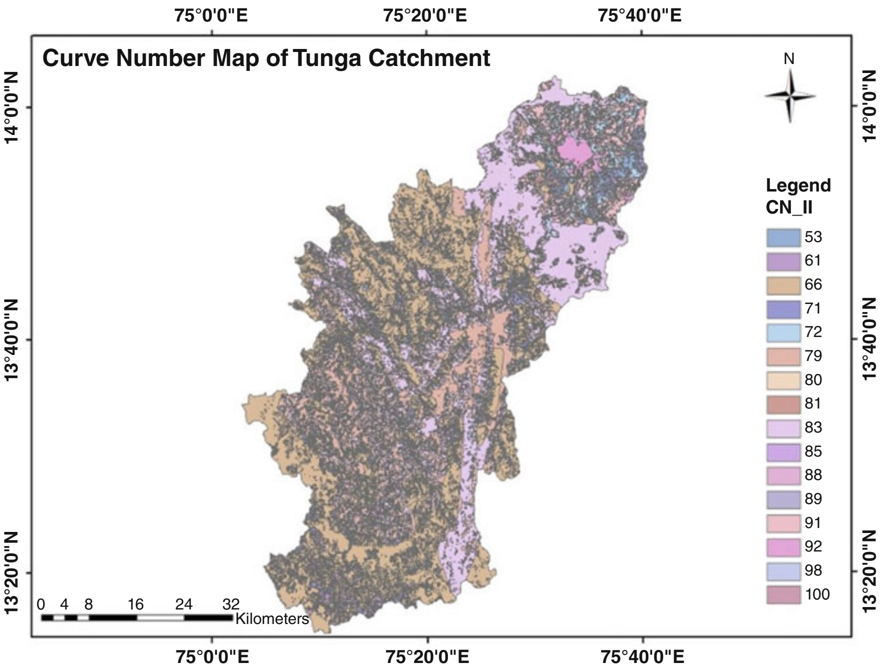


**Fig. 11.6** Curve number map of the Tunga catchment

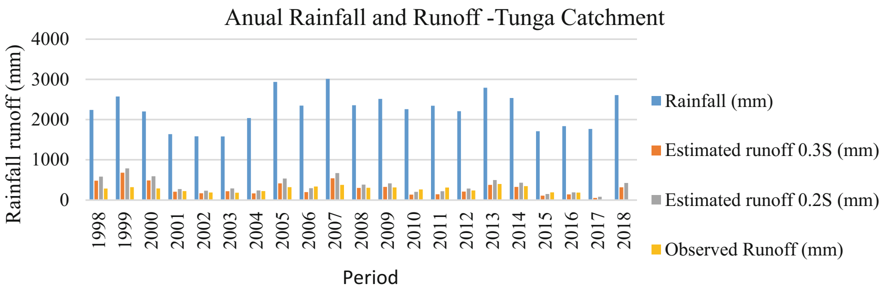


**Fig. 11.7** Rainfall and runoff of the Tunga catchment

## *11.6.2 Runoff Estimation*

The SCS model was used to simulate the surface runoff for the Tunga watershed. Daily rainfall data was obtained for a period of 20 years, from 1998 to 2018, with the data related to the southwest monsoon period of June to October, which accounts for 95% of the yearly rainfall in the area.

The soil being coarse-loamy in nature and the region having low runoff potential and maximum infiltration are also due to the thick vegetation in the region.

It is recorded that the estimated runoff is higher than the observed runoff. The difference in estimated runoff might be because of not considering any anthropogenic activities in the region.

The Tunga River receives an average annual rainfall of 2247.35 mm, with a maximum rainfall of 3011.35 mm and a minimum rainfall of 1579.50 mm.

The maximum observed runoff ratio is 14.29 mm, and the estimated runoff ratio is 17.83 mm.

The range of deviation in estimated runoff for 0.2S is varying between 18% and 0.5%, and for 0.3S, it is 13% to 0.2% with respect to observed runoff.

### *11.6.3 Limitations*

The current study underlines the need for more research into the factors that influence and control runoff processes in the region, as well as the creation of design approaches that are appropriate for the region's hydrological characteristics.

A method for calculating the revised CN values required to simulate daily direct runoff is being developed.

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