*<u>Original Research Article</u>*

# Estimation of Runoff by SWAT Model in Noyyal River Basin


## ABSTRACT

Accurate assessment of water balance components holds paramount importance for the sustainable management of water resources in river basins. This study specifically concentrates on the application of the Soil and Water Assessment Tool (SWAT) model to evaluate water balance elements within the Noyyal River basin. Originating from the Vellingiri hills in Western Tamil Nadu, the Noyyal River basin, a tributary of the Kaveri River, grapples with escalating water stress brought about by both anthropogenic activities and climatic fluctuations.

The methodology adopted encompasses the harmonious integration of diverse spatial and temporal datasets. These datasets are seamlessly incorporated within the confines of a Geographic Information System (GIS) framework. Through the process of watershed delineation 21 sub-basin was partitioned and which is further subdivided into 217 unique Hydrological Response Units (HRUs) are derived, each corresponding to a distinct hydrological reaction. The simulation employs 33 years of daily precipitation, coupled with minimum and maximum temperature records, enabling the continuous execution of the SWAT model for runoff prediction. The findings elucidate fluctuating runoff volumes over time, spanning from a minimum of 11.17 mm to a maximum of 610.32 mm. Notably, the annual average runoff stands at 206.7 mm, representing approximately 25.6% of the cumulative rainfall experienced within the Noyyal river basin.



***Keywords:*** *ArcGIS, ArcSWAT, Runoff, Water balance and Noyyal River basin*


## 1.INTRODUCTION

Growing population coupled with sustainable developmental efforts has an increasing stress on water resources. The uneven distribution over time and space of water resources and their modification through human use and abuse are sources of water crises in many parts of the world. All these result in intensifying the pressure on water resources leading to tensions, conflict among users and excessive pressure on the environment. This demands the planners and policy makers for a proper management of water resources. This, in turn, calls for a reliable and adequate statistics on water and related aspects. Manoj Kumar Awasthi et al . (2022). Comprehending water availability at a micro level proves indispensable in discerning the primary factors underpinning constraints in water distribution (Suman Bera et al., 2021). Amid a global context, India constitutes 18% of the world's populace but only possesses approximately 4% of its water resources. A case in point is Tamil Nadu, an Indian state, which harbors merely 2.5% of the nation's water resources despite accommodating 6% of its population. The Coimbatore district within this region also grapples with groundwater depletion due to insufficient rainfall. In locales grappling with water scarcity, hydrological modeling of river basins serves as a pivotal instrument, facilitating the formulation of strategic watershed management and planning approaches (Tundisi and Tundisi, 2010; Almeida et al., 2018). The water balance equation stands as a vital means to quantify major hydrological processes, enabling the identification of periods marked by rainfall deficits or surpluses and enabling the precise determination of available water at any given juncture.

## 2. LOCATION OF THE STUDY AREA

The Noyyal River is a tributary of Kaveri River originates from the Vellingiri hills of Western Tamil Naduand flows through 340 villages of Coimbatore, Erode Karur and Tirupur districts. The total area of Noyyal river basin is about 3537.5 sq.km which extends from 10° 53' 49" to 11° 19' 18" of North latitudes and 76° 39' 21"to 77° 57' 10" of East longitudes. The length of the basin is about 180 km and 25 km wide on average. The Noyyal river typically follows a seasonal pattern, with its flow occurring primarily during the months of the north-east monsoon.

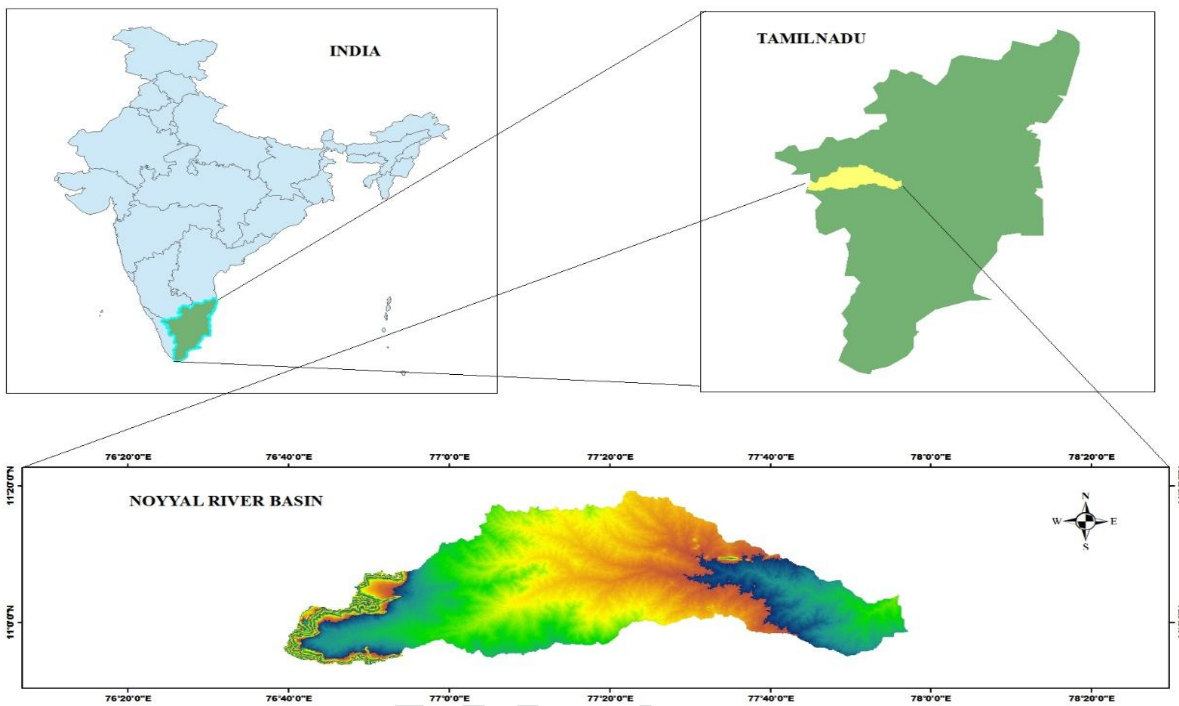


**Fig.1. Location map of Noyyal River Basin**

## 3. MATERIALS AND METHODS

Soil andWaterAssessmentTool (SWAT) model uses DEM to divide a watershed into sub-basin and develop Hydrological Response Units (HRUs) based on topography, landuse, soil and other factors has been used to estimate runoff, making it favorable for comprehending water availability (Wu and Xu, 2005). The model output all water balance components (surface runoff, evaporation, lateral flow, recharge, percolation, sedminent yield etc.) at level of each watershed and are available at daily, monthly or annual time steps. The hydrological cycle as simulated by SWAT is based on the water balance equation:

$$SW_t = SW_0 + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw})$$

where $SW_t$ is soil water content on day t (mm), $SW_0$ is the initial soil water content in mm, t is the time (days), $R_{day}$ is precipitation on day i (mm), $Q_{surf}$ is surface runoff on day i (mm), $E_a$ is evapotranspiration i (mm), $W_{seep}$ is water entering the vadose zone from the soil profile i (mm) and $Q_{gw}$ is return flow i (mm).

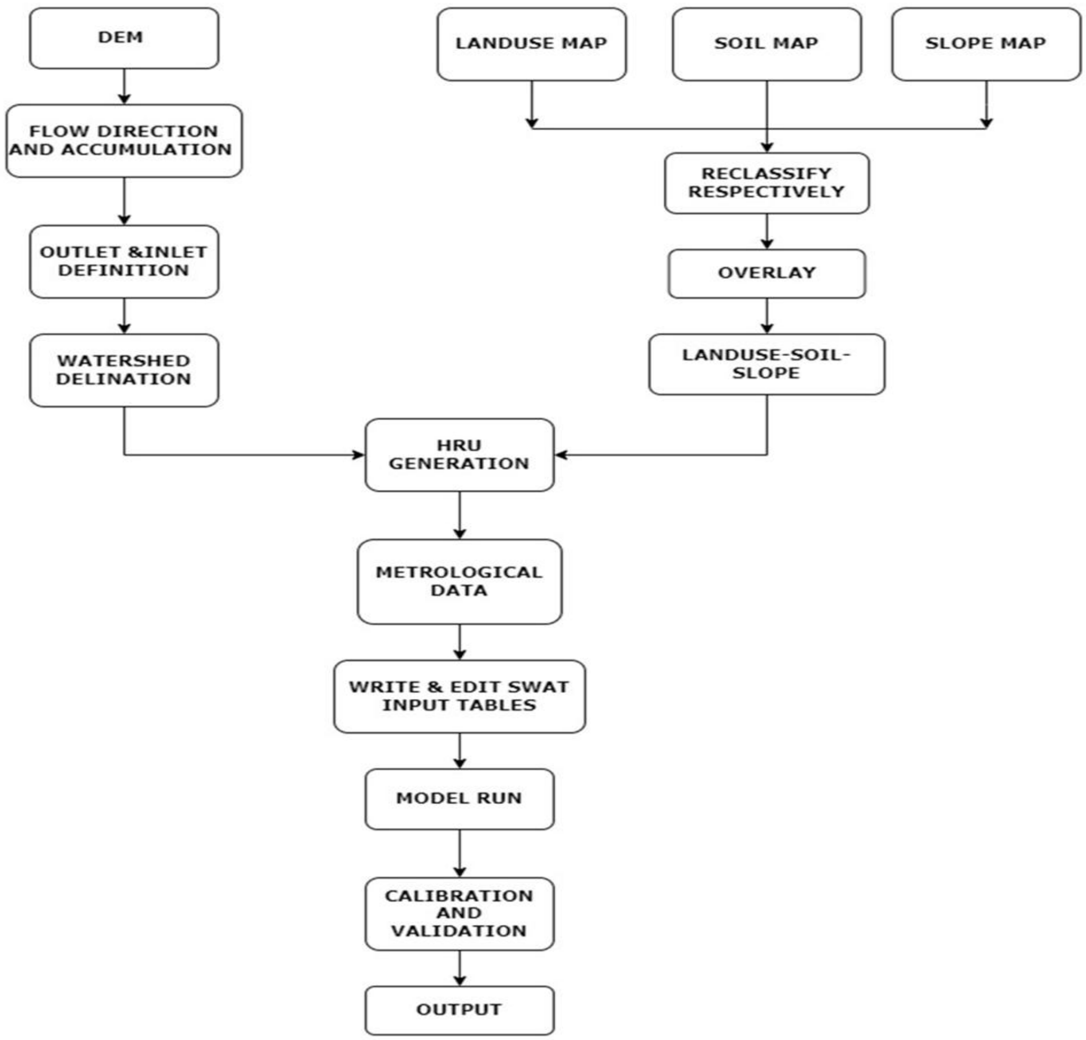


**Fig.2. Flowchart for Runoff assessment using SWAT**

### 3.1 Preparation of Input data for SWAT Model

**3.1.1. Digital Elevation Model (DEM):**A high-resolution DEM provides information about the topography, elevation, and flow direction within the watershed. The DEM is used to delineate the watershed boundary, derive the flow network, and calculate slope and flow accumulation. In this study DEM was prepared with the SRTM (Shuttle Radar Topography Mission) 1 Arc-second global data which is downloaded from the USGS earth explorer. The DEM for our study area was obtained using the "Extract by Mask" tool, isolating the relevant geographic region. Subsequently, the DEM was projected onto the WGS 1984 Transverse Mercator coordinate system.

**3.1.2. Land Use/Land Cover (LULC):**Land Use/Land Cover (LULC) data is crucial for HRU analysis. It classifies different land uses within the watershed, dividing it into sub-basins based on land use patterns. HRUs are then delineated by combining LULC data with soil and slope information. Each HRU represents a homogenous area with similar hydrological responses. SWAT uses LULC-specific runoff coefficients to calculate surface runoff from each HRU, and LULC-specific ET rates to estimate water loss through evapotranspiration. This LULC is prepared with Esri Sentinel-2 10m Resolution Landuse/Landcover data. The data set describes the different land cover types present in the River basin shown in table 1.

**Table 1. Area of Land Use/ Land Cover**

| S.no | Name | Area (Sqkm) | Percentage |
|---|---|---|---|
| 1 | Water | 177.12 | 5.01 |
| 2 | Forest | 296.43 | 8.37 |
| 3 | Pasture | 0.24 | 0.01 |
| 4 | Agricultural Land Generic | 1986.18 | 56.10 |
| 5 | Agricultural Land Close grown | 1079.66 | 30.50 |
| 6 | Residential | 0.69 | 0.02 |
| 7 | Barren land | 0.01 | 0.00 |
| | **Total** | **3540.33** | **100** |

**3.1.3. Soil Map:**Soil map includes information about soil properties and characteristics within the watershed, such as soil texture, depth, permeability, and water-holding capacity. These properties influence infiltration, groundwater recharge, and water retention in the soil. The soil map is prepared from the Food and Agriculture Organization (FAO) soil database. FAO provides comprehensive soil data, including soil properties and classifications, which are incorporated into the SWAT model to accurately simulate hydrological processes, erosion, and nutrient transport in watersheds. The study area which is classified into 5 types of soil majorly covered with clay loam soil.

**3.1.4 Slope:**Slope is a critical factor in runoff estimation as it directly influences the speed and volume of water movement across a landscape. The degree of slope impacts surface runoff by affecting the rate of infiltration, soil erosion, and ultimately the generation of streamflow. Steeper slopes generally result in faster runoff, reduced water retention, and increased potential for erosion, leading to more rapid response to rainfall events. In contrast, gentler slopes allow for greater water infiltration and slower runoff, contributing to better groundwater recharge and decreased erosion potential.

**3.1.5 Meterological Data:**SWAT necessitates daily records of rainfall, minimum and maximum temperatures, daily solar radiation, daily relative humidity, and wind speed for various activities. The data for rainfall and temperature in the Noyyal river basin are sourced from the State Ground and Surface Water Resource Data Centre located in Taramani, Chennai.Here 33 years from 1989 to 2021 of daily weather information is used.

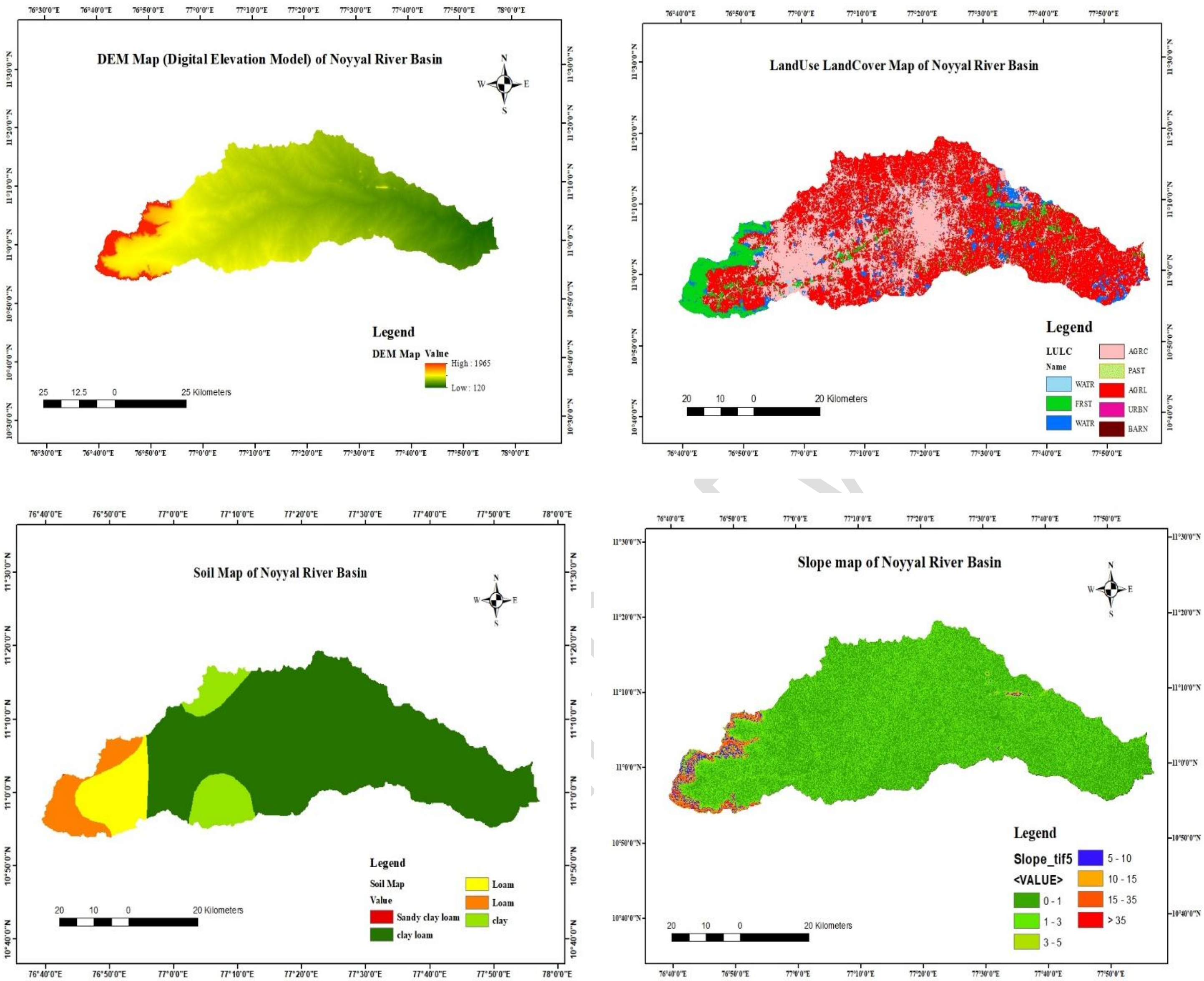


**Fig.3. DEM, LULC, Soil and slope map of Noyyal River Basin**

## 5.RESULT AND DISCUSSION

The SWAT simulation conducted over the watershed for the period 1989-2021, with a 5-year warm-up phase, revealed an average runoff depth of 206.70 mm over 28 years. The substantial variation in maximum runoff during 2015 (610.32 mm) and minimum runoff in 2013 (11.17 mm) underscores the dynamic nature of the watershed's hydrological behavior. The basin-wise analysis highlights sub-basins 19 and 21 as the highest contributors to runoff, indicating their susceptibility to factors promoting runoff generation. Conversely, sub-basins 4 and 18 exhibit the least runoff, potentially due to their topographical or land use characteristics. The presented graphical representations emphasize the annual and basin-specific runoff trends, providing insights into the temporal and spatial dynamics of runoff patterns.

**Table 2: Yearly Average Rainfall (mm) and Runoff (mm) from 1994 – 2021)**

| S.No | Year | Precipitation (mm) | Runoff (mm) |
|---|---|---|---|
| **1.** | 1994 | 717.96 | 209.57 |
| **2.** | 1995 | 494.81 | 81.68 |
| **3.** | 1996 | 652.68 | 124.03 |
| **4.** | 1997 | 642.27 | 107.91 |
| **5.** | 1998 | 606.24 | 141.22 |
| **6.** | 1999 | 771.62 | 285.85 |
| **7.** | 2000 | 604.8 | 101.92 |
| **8.** | 2001 | 671.15 | 179.64 |
| **9.** | 2002 | 413.95 | 83.51 |
| **10.** | 2003 | 685.81 | 161.31 |
| **11.** | 2004 | 660.41 | 134.02 |
| **12.** | 2005 | 988.56 | 325.43 |
| **13.** | 2006 | 783.09 | 247.75 |
| **14.** | 2007 | 620.55 | 126.89 |
| **15.** | 2008 | 768.71 | 199.05 |
| **16.** | 2009 | 514.95 | 93.91 |
| **17.** | 2010 | 564.26 | 99.69 |
| **18.** | 2011 | 729.98 | 208.65 |
| **19.** | 2012 | 227.01 | 20.06 |
| **20.** | 2013 | 241.67 | 11.17 |
| **21.** | 2014 | 865.58 | 237.68 |
| **22.** | 2015 | 1196.45 | 610.32 |
| **23.** | 2016 | 738.87 | 429.81 |
| **24.** | 2017 | 883.15 | 305.7 |
| **25.** | 2018 | 1200.69 | 439.98 |
| **26.** | 2019 | 1148.21 | 420.3 |
| **27.** | 2020 | 1073.92 | 200.7 |
| **28.** | 2021 | 1371.8 | 199.82 |

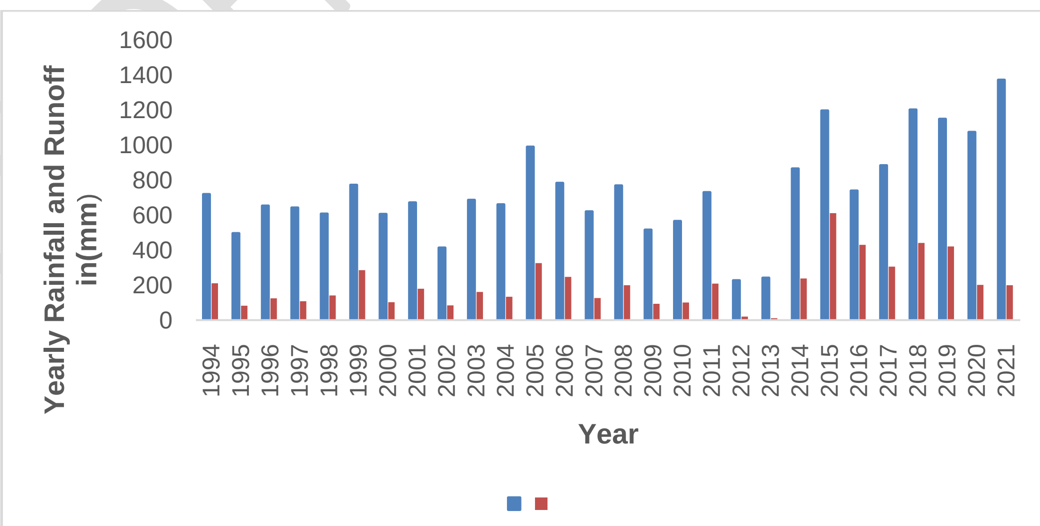


**Fig.4.Yearly rainfall and runoff for Noyyal River Basin**

**Table 3: Basin-wise Runoff (mm) depth from 1994 – 2021)**

| S.No | Sub-Basins | Runnoff (mm) |
|---|---|---|
| 1 | 1 | 127.99 |
| 2 | 2 | 127.99 |
| 3 | 3 | 232.29 |
| 4 | 4 | 89.68 |
| 5 | 5 | 148.36 |
| 6 | 6 | 170.68 |
| 7 | 7 | 229.33 |
| 8 | 8 | 173.40 |
| 9 | 9 | 170.68 |
| 10 | 10 | 170.68 |
| 11 | 11 | 170.68 |
| 12 | 12 | 170.68 |
| 13 | 13 | 170.69 |
| 14 | 14 | 170.68 |
| 15 | 15 | 170.68 |
| 16 | 16 | 170.69 |
| 17 | 17 | 170.69 |
| 18 | 18 | 89.22 |
| 19 | 19 | 298.07 |
| 20 | 20 | 238.17 |
| 21 | 21 | 276.49 |

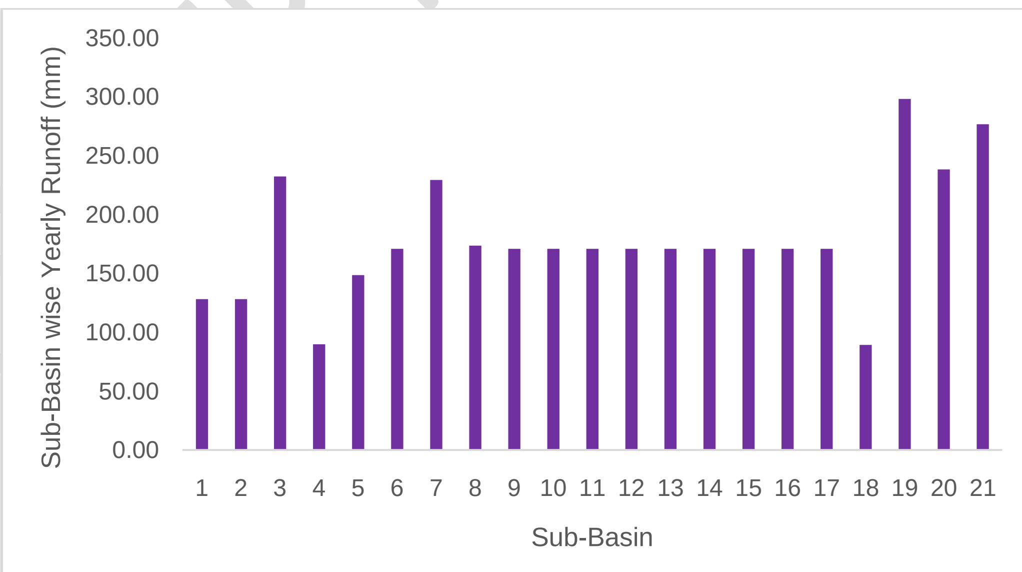


**Fig.5. Basin wise runoff depth for Noyyal River Basin**

## 6. CONCLUSION

ArcSWAT proves to be a user-friendly tool for efficiently delineating watersheds and calculating runoff using minimal input data. In this investigation, the watershed was subdivided into 21 sub-basins, resulting in an average runoff of 206.7 mm for the Noyyal river basin. Over a span of 28 years, from 1994 to 2021, the average rainfall measured 744.26 mm. This study unveils that approximately 25.6% of the water resources have manifested as runoff over the last three decades. The primary objective of this research lies in gauging the overall water availability for precise water budgeting, while also serving as a foundation for the implementation of soil and water conservation strategies within the Noyyal River basin.

## REFERENCE


1. Sabale, R., Venkatesh, B., & Jose, M. (2023). Application of Arc-SWAT model for water budgeting and water resource planning at the Yeralwadi catchment of Khatav, India.
2. Singh, L., Saravanan, S., & Jennifer, J. (2018, January). Assessing Impact of Land use/Land cover Changes on Stream flow in Noyyal River catchment using ArcSWAT model. In SWAT international conference (pp. 10-12).
3. Reddy, K., Kothari, M., Reddy, K. S., Singh, P. K., & Yadav, K. K. (2020). Assessment of Surface Runoff using ArcSWAT for Rela Watershed, Rajasthan, India. Journal of Geography, Environment and Earth Science International, 24(10), 22-32.
4. Bera, S., & Maiti, R. (2021). Assessment of Water Availability with SWAT Model: A Study on Ganga River. Journal of the Geological Society of India, 97, 781-788.
5. Kumar, V., Nagarajan, K., & Narwade, R. (2019). Determination of water budget of the lower godavari river basin using GIS and SWAT. International Journal for Research in Engineering Application & Management (IJREAM),(Oct-2019), ISSN, 2454-9150.
6. Nasiri, S., Ansari, H., & Ziaei, A. N. (2020). Simulation of water balance equation components using SWAT model in Samalqan Watershed (Iran). Arabian Journal of Geosciences, 13, 1-15.
7. Gautam, V. K., & Awasthi, M. K. (2020). Evaluation of water resources demand and supply for the districts of central Narmada valley zone. Int. J. Curr. Microbiol. App. Sci, 9(1), 3043-3050.
8. Jaiswal, R. K., Yadav, R. N., Lohani, A. K., Tiwari, H. L., & Yadav, S. (2020). Water balance modeling of Tandula (India) reservoir catchment using SWAT. Arabian Journal of Geosciences, 13, 1-13.
9. Saha, P. P., Zeleke, K., & Hafeez, M. (2014). Streamflow modeling in a fluctuant climate using SWAT: Yass River catchment in south eastern Australia. Environmental earth sciences, 71, 5241-5254.
10. Shanbor, K., & Manoj, J. (2017). Rainfall-Runoff Modelling of a River basin using SWAT model. International Journal of Engineering Research and Technology, 6(6).
11. USDA. Estimation of direct runoff fromstorm rainfall. Hydrology NationalEngineering Handbook; 1972.
12. Kangsabanik, S., & Murmu, S. (2017, May). Rainfall-runoff modelling of Ajay river catchment using SWAT model. In IOP Conference Series: Earth and Environmental Science (Vol. 67, No. 1, p. 012033). IOP Publishing.
13. Patel, D. P., & Nandhakumar, N. (2016). Runoff potential estimation of Anjana Khadi Watershed using SWAT model in the part of lower Tapi Basin, West India. Sustainable Water Resources Management, 2(1), 103-118.
14. Satheesh, B., & Ashwini, B. (2020). SWAT Based Rainfall-Runoff Modeling of Upper Godavari Basin India. In Roorkee Water Conclave.
15. Mistry, A. K., & Joshi, B. R. (2018). Rainfall runoff modelling of Shakkar River using SWAT model. International Journal of Science Technology & Engineering, 4(10), 49-52.
16. Vu, M. T., Raghavan, S. V., & Liong, S. Y. (2012). SWAT use of gridded observations for simulating runoff–a Vietnam river basin study. Hydrology and Earth System Sciences, 16(8), 2801-2811.