SPATIAL ANALYSIS AND PYTHON IMPLEMENTATION OF THE ECKHARDT DIGITAL FILTER FOR BASEFLOW SEPARATION IN SARADA BASIN

ABSTRACT

This study focuses on the estimation of baseflow in the Sarada River Basin, Andhra Pradesh, using spatial analysis and Python programming. Baseflow is the groundwater-supported component of streamflow that maintains river discharge during dry and non-monsoon periods. Accurate quantification of baseflow is essential for sustainable groundwater management, irrigation planning, and ecological flow maintenance. In this study, the Eckhardt (2005) digital filter method was implemented to separate baseflow and quick flow from daily discharge data. Geographic Information System (GIS) techniques were employed to delineate the watershed and analyses terrain characteristics influencing runoff and infiltration. The results indicate a strong groundwater contribution to total streamflow in the basin.

INTRODUCTION

Water resources play a vital role in socio-economic development and environmental sustainability. Rivers derive their flow from rainfall, surface runoff, and groundwater contribution. Among these, baseflow represents the sustained discharge supplied by groundwater storage and is critical during periods of low rainfall. Understanding baseflow behavior is essential for managing river basins, especially in regions experiencing seasonal rainfall variability.

Traditional baseflow separation methods rely on graphical techniques that involve subjective judgment and are difficult to apply consistently to long-term datasets. With the advancement of computational tools, digital filter methods provide automated and objective solutions for baseflow estimation. Python programming offers flexibility, accuracy, and reproducibility in hydrological analysis. This study integrates GIS-based spatial analysis with Python-based modelling to estimate baseflow in the Sarada River Basin.

STUDY AREA

The Sarada River Basin is located in Visakhapatnam district of Andhra Pradesh, India, and covers an area of approximately 2,180 km². The river originates in the Eastern Ghats at an elevation of about 1,000 meters and flows eastward before joining the Bay of Bengal. The basin experiences a tropical monsoon climate with most of the rainfall occurring during the southwest monsoon season.

The basin is characterized by hilly terrain in the upper reaches and gentle slopes towards the coastal plains. Geological formations mainly consist of crystalline rocks, which influence groundwater movement and storage. Agriculture is the dominant land use, and the river supports several irrigation projects, making it an important water resource in the region.

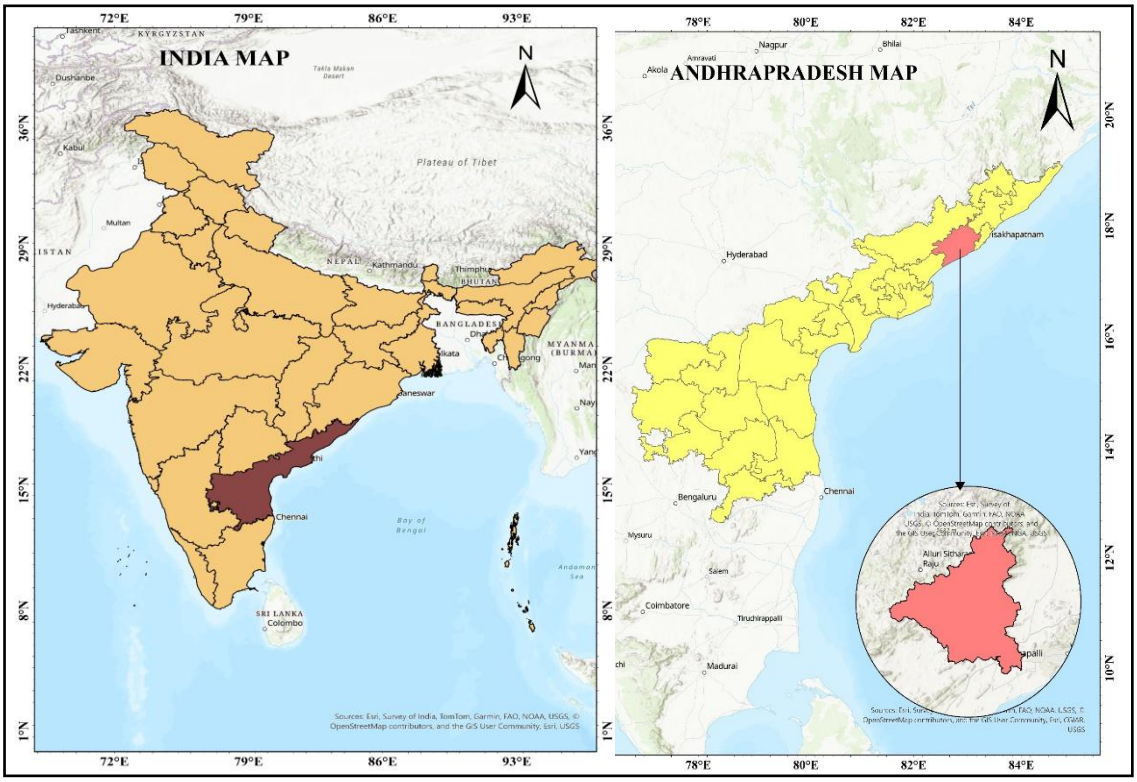

Fig: Study Area of Sarada Catchment

OBJECTIVE S OF THE STUDY

The objective of the present study is:

1. To delineate the Sarada River Basin using Digital Elevation Model (DEM) and GIS techniques.

2. To apply the Eckhardt (2005) digital filter method for baseflow separation using Python programming.
3. To estimate the Baseflow Index (BFI) and assess model accuracy using Mean Absolute Error(MAE).
4. To analyse seasonal variations of baseflow and its contribution to total streamflow.

SCOPE OF THE STUDY

The scope of this study is limited to the estimation and analysis of baseflow characteristics in the Sarada River Basin. The study integrates spatial data analysis with hydrological modelling to understand groundwater contribution to streamflow. The methodology focuses on automated digital filtering techniques that reduce subjectivity and improve reproducibility. The approach can be extended to other river basins for water resource planning and groundwater sustainability studies.

DATA AND MATERIALS

Both spatial and non-spatial data were used in this study. Spatial datasets include SRTM Digital Elevation Model (DEM), soil maps, geology maps, geomorphology maps, and land use/land cover maps, which were processed using ArcGIS Pro software. These datasets were used for watershed delineation and terrain analysis.

Non-spatial data consist of daily river discharge and rainfall data obtained from the Central Water Commission (CWC) and meteorological sources. Python programming was used for data processing and analysis with the help of libraries such as NumPy, Pandas, and Matplotlib.

METHODOLOGY

The methodology adopted in this study includes GIS-based watershed delineation and Python-based hydrological analysis. DEM preprocessing involved sink filling, flow direction, and flow accumulation operations to generate a hydrologically correct terrain model. Drainage networks were extracted using threshold-based flow accumulation techniques.

The Eckhardt (2005) recursive digital filter was implemented in Python to separate baseflow from total streamflow. Model parameters were selected based on basin characteristics and previous studies. Baseflow Index (BFI) and Mean Absolute Error (MAE) were computed to evaluate model performance.

RESULTS AND DISCUSSION

The results indicate that baseflow contributes significantly to total streamflow in the Sarada River Basin. The estimated Baseflow Index value of 0.79 suggests strong groundwater support to river discharge. Seasonal analysis shows that quick flow dominates during monsoon months due to intense rainfall and surface runoff.

During non-monsoon periods, baseflow sustains river flow, highlighting the importance of groundwater storage in the basin. The low MAE value indicates good agreement between observed and estimated flows, confirming the reliability of the digital filter approach.

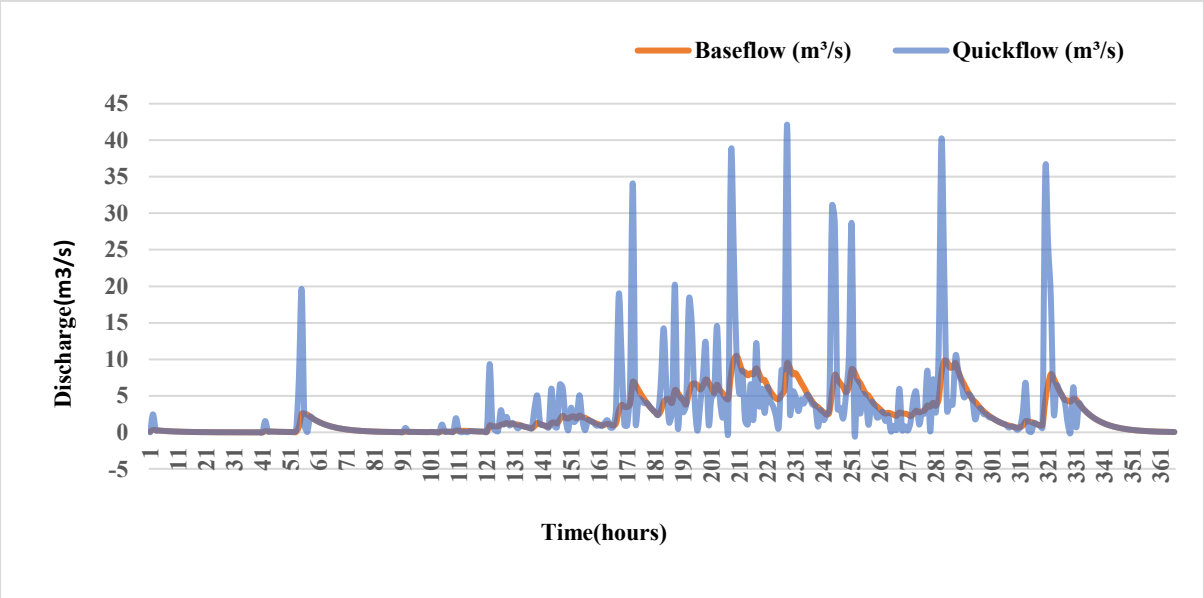

Fig: Baseflow and Quick flow variation Hydrograph for the year(2005) Sarada River Basin.

CONCLUSION

i). The study successfully applied the Eckhardt (2005) recursive digital filter using Python programming to separate baseflow and quick flow in the Sarada River Basin for the year 2005, providing an automated and reproducible alternative to manual methods.

ii). The model performance was reliable, with a Baseflow Index (BFI) of 0.79 and a Mean Absolute Error (MAE) of 0.71 m³/s, indicating a strong groundwater contribution and accurate representation of basin hydrology.

iii). Hydrograph analysis revealed pronounced seasonal variation, with quick flow peaks during rainfall events and sustained baseflow during dry periods, demonstrating the importance of groundwater storage in maintaining perennial river flow.

SCOPE OF FURTHER STUDY

Further studies can focus on comparing multiple digital filter methods, such as Lyne Hollick, Chapman, and Baseflow Separation Models, to evaluate their suitability for various hydrological conditions within semi-humid tropical basins. The integration of remote sensing and GIS-based tools can enhance spatial representation and provide a better understanding of terrain characteristics, infiltration zones, and groundwater recharge potential. Coupling the digital filtering technique with machine learning algorithms or statistical optimization approaches could improve parameter calibration and enhance the predictive capability of baseflow estimation models. Such advancements would contribute to developing more adaptive, data-driven hydrological models for future applications.