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ARTICLE

Exploring Hydrological Processes and Land Management Impacts in the Hamp River Basin—A SWAT Model Approach

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ABSTRACT

Rainfall-runoff modeling is a critical component of hydrological studies, aiding in analyzing river basin responses to climatic variations. This paper examines the rainfall-runoff behaviour of the Hamp River Basin, part of the Mahanadi River System, using the Soil and Water Assessment Tool (SWAT). SWAT, a physically based, continuous-time model, predicts land management effects on water, sediment and agricultural yields in large watersheds. This study calibrates and validates SWAT for the Hamp River Basin to assess its effectiveness in simulating stream flow. Additionally, it explores the implications of land management policies on hydrological processes, examining policy-model interactions to understand regulatory impacts on runoff and sediment yield. Simulated policy scenarios predict hydrological changes under different land management strategies. By integrating socio-economic characteristics, the study analyses hydrological changes affecting local communities, particularly regarding land use and agricultural sustainability. Soil conservation strategies are evaluated to recommend measures for mitigating sediment loss and enhancing resource conservation. The Hamp River watershed, within the Seonath sub-basin of the upper Mahanadi basin, was studied to estimate sediment yield and nutrient loss. Critical agricultural sub-watersheds

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and associated Hydrological Response Units (HRUs) were identified using ArcSWAT. The area was divided into 16 sub-watersheds based on topographical features from a Digital Elevation Model (DEM) and drainage networks. Land cover, soil and DEM data were used to create HRUs, enabling annual runoff analysis across calibration and validation periods (2017–2023).

Keywords: Rainfall-Runoff Modelling; Mahanadi River System; SWAT Model; Hydrology; Stream Flow Simulation; Sediment Yield; Nutrient Loss

1. Introduction

Hydrological modelling plays a dynamic role in effective water resource management, flood forecasting and assessing the impacts of climate change on river systems [1, 2]. The Hamp River Basin, a part of the Mahanadi river system in India, holds significant agricultural and socio-economic importance, making precise rainfall-runoff modelling crucial for sustainable water management [3, 4]. The Mahanadi River, one of India's major peninsular rivers, is divided into Upper, Middle and Lower sub-basins, with this study focused on its left tributary, the Hamp watershed.

Accurate modelling of rainfall-runoff interactions in this basin is critical, as water resources are among the most precious assets essential for ecological and human sustenance [5]. Uncontrolled water flow, however, can lead to catastrophic events such as floods and mudslides, underscoring the need for reliable runoff estimation. This process is influenced by factors such as local topography, vegetation and climatic conditions, which are essential to minimising risks and enhancing water resource planning [6, 7].

The Soil and Water Assessment Tool (SWAT) is recognised as a robust and tangible model for simulating the effects of land management on water, sediment and agricultural yield across diverse landscapes [8]. Initially developed by Arnold for the USDA, SWAT has gained global prominence as a distributed-parameter model for both small and large basin studies [9, 10]. It integrates weather data, topography, vegetation and land use practices, providing comprehensive insights into watershed dynamics over extended periods.

To apply SWAT effectively, watersheds are divided into sub-watersheds and further segmented into Hydrological Response Units (HRUs), representing unique combinations of land use, soil type and slope [11]. SWAT provides two primary methods for watershed delineation, i.e., a Digital Elevation Model (DEM)-based approach, which uses the area's topography and a predefined method, which is tailored manually. The DEM-based approach is often favoured due to its precision in delineating complex terrain features, which aids in analysing sediment and runoff yields within river basins [12].

In this study, SWAT's capabilities are harnessed to model the hydrological responses of the Hamp watershed, aiming to generate actionable insights for sustainable management while identifying high-risk zones for sediment yield and nutrient loss. Through GIS integration, ArcSWAT is used in this research to establish a framework for optimised water management strategies in the Hamp River Basin [10].

This study also considers the impact of land management policies on hydrological behaviour and appraises potential strategies for improving watershed sustainability. It considers the socio-economic trepidations to bridge the gap between veracity and implications of land management.

2. Study Area

The Hamp River Basin, part of India's Mahanadi River System, exhibits diverse topography that spans from hilly terrains to expansive plains, and it experiences a tropical monsoon climate with distinct wet and dry seasons. The primary land use includes agriculture, forest cover, and urban areas, underscoring the region's socio-economic and environmental significance. For this study, the Hamp watershed, situated in the Seonath subbasin of the upper Mahanadi basin, was selected, with the Andhiyarkhore gauging station of the Central Water

Commission (CWC) as its outlet.

The Hamp River, originating in the Kawardha district, flows through the newly formed Bemetara district and merges with the Seonath River in Raipur district, Chhattisgarh. Geographically, the study area extends from 81°01' E to 81°36' E longitude and 21°45' N to 22°30' N latitude, covering an altitude range from 267 to 1,193 meters above mean sea level (MSL) and a total area of approximately 2,210 km^2.

Positioned at the uppermost boundary of the Mahanadi basin, the Hamp River region is dominated by upland farming, which often results in significant soil erosion and decreased crop productivity. The socio-economic impacts of these hydrological processes on local communities are substantial, particularly in terms of land use changes. Agricultural practices and water availability directly affect livelihoods, necessitating an integrated approach that considers both hydrological dynamics and community well-being. The agricultural landscape in the Chhattisgarh agro-climatic zone is distinguished by four soil types: Bhata (Entisols), Matasi (Inceptisols), Dorsa (Alfisols), and Kanhar (Vertisols). Bhata lands, prevalent in the uplands, have slopes exceeding 5%, shallow soil depths (less than 30 cm), and loamy fine sand to silt loam textures, making them particularly vulnerable to erosion. The area faces increasing gully erosion, which has become a notable source of soil loss, further exacerbated by low infiltration capacities in these soils [13, 14].

The Hamp watershed was chosen specifically to assess soil loss and prioritise critical sub-watersheds and HRUs to improve sediment and nutrient management strategies. This study area, as shown in **Figure 1**, provides a representative setting for evaluating sustainable watershed management practices in a region facing complex hydrological and land-use challenges.

3. Data and Materials

In this study, various datasets were collected to set up the SWAT model for the Hamp River Basin. The primary data sources include DEM, Land Use and Land Cover (LULC), Soil Properties Data, Meteorological Data and Hydrological Data.

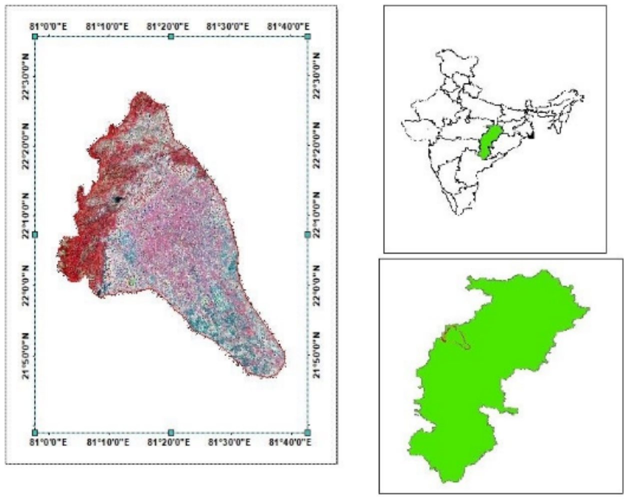

Figure 1. Location map of the study area.

The DEM, sourced from the Shuttle Radar Topographic Mission (SRTM) provided by the US Geological Survey (USGS), was used to represent the topography of the basin. This DEM data, at a 1 arc-second (30 meters) resolution, was reprojected to the Universal Transverse Mercator (UTM) coordinate system, Datum WGS 1984 (Zone-44), to ensure consistency in spatial data. A visual representation of the DEM for the Hamp River Basin is shown in **Figure 2**.

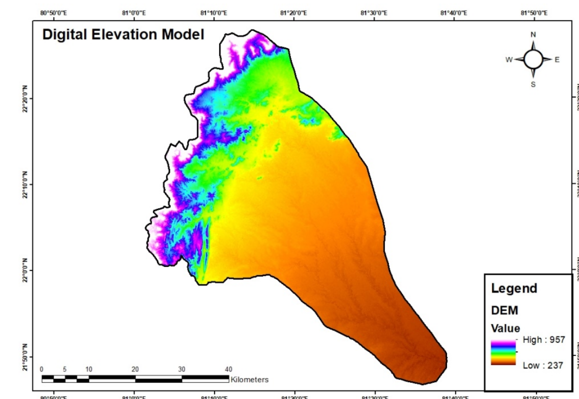

Figure 2. DEM Map of the Hamp River Basin.

To capture the spatial distribution of land cover, Land Use and Land Cover (LULC) data was derived from Landsat 8 satellite imagery, using bands 5, 4, and 3 at a 30-meter resolution. This data was classified into seven distinct LULC categories: Built-up Area, Water Body, Range Land, Trees, Crop Land, and Barren Land. These classifications were essential for assigning accurate hydrological parameters within the SWAT model. The pro-

Table 1. Major LULC Classes in the Hamp River Basin.

S. No	Field Name	Area in Sq.km.	Area in Percentage
1	Range Land	289.86	12.84
2	Trees	428.97	19
3	Crop	1,430.38	63.36
4	Water	16.87	0.74
5	Built up Area	91.09	4.03
6	Barren Land	0.01	0.03
7	Total Area	2,257.20	100

portions of each LULC class in the study area are summarised in **Table 1**, with a detailed LULC map shown in **Figure 3**.

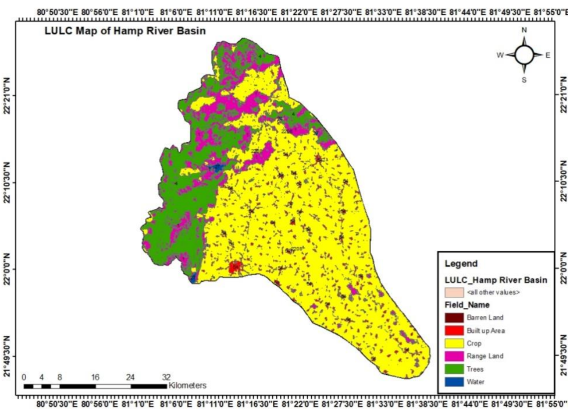

Figure 3. Land Use and Land Cover (LULC) Map.

Soil Properties Data was obtained from the Soil Texture Map for Chhattisgarh, developed by the National Bureau of Soil Survey and Land Use Planning (NBSSLUP). For increased precision, soil classifications were further refined based on soil health card data. The dominant soil textures include clay, gravelly sandy loam, clay loam, among others. The spatial distribution of these soil types is displayed in **Figure 4**, while **Table 2** outlines the specific properties and SWAT codes of these soils.

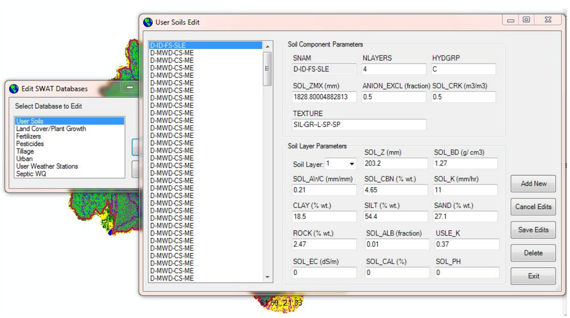

Figure 4. Soil Properties in the Study Area.

Meteorological Data used in this study consisted of rainfall, temperature, humidity, wind speed, and solar radiation records, essential for SWAT model simulation of hydrological processes. Furthermore, Hydrological Data was obtained in the form of daily river discharge measurements from 2017 to 2023, recorded at the Andhiyarkhore gauging station at the watershed outlet of the Hamp River Basin. This data, provided by the CWC Regional Office, Mahanadi & Eastern Rivers Organization in Bhubaneswar, served as the baseline for model calibration and validation efforts. Each dataset contributed to the spatial and temporal accuracy required for effective SWAT model implementation, with tables and figures providing an overview of the model's inputs.

4. Methodology

This section details the methods employed to set up, calibrate and evaluate the SWAT model for the Hamp River Basin. The methodology framework engaged in the study is shown as a flowchart in **Figure 5**.

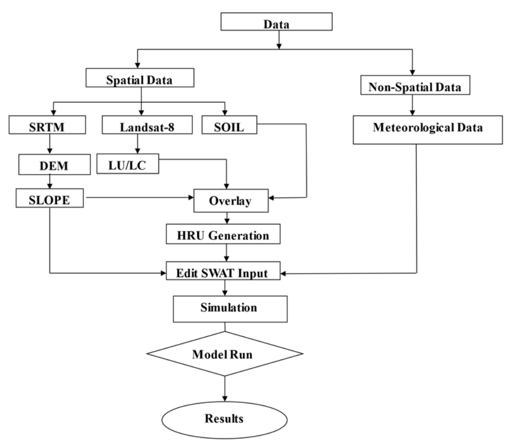

Figure 5. Methodology flow chart of the study.

Table 2. Properties of Soil with SWAT Codes.

S.No.	Soil Numbers	Soil Description	SWAT CODE
1	9	Moderately Shallow, Somewhat Excessively Drained, Fine-Loamy soils, severe erosion.	MS-SED-FLS-SE
2	10	Deep poorly drained fine cracking soil with clayey surface with slight erosion	D-PD-FCS-SLE
3	70	Deep, moderately well drained, fine soils, severe erosion	D-MWD-FS-SE
4	72	Deep, moderately well drained, fine loamy soils, moderate erosion	D-MWD-FLS-ME
5	95	Extremely shallow, somewhat excessively drained, loamy soils, severe erosion	ES-SED-LS-SE
6	96	Very shallow excessively drained, loamy skeletal soils, severe erosion.	VS-ED-LS-SE
7	99	Deep, very poorly drained, very fine cracking soils, slight erosion	D-VPD-VFCS-SLE
8	101	Deep, well drained, Loamy soils, moderate erosion	D-WD-LS-ME
9	103	Shallow, somewhat excessively drained, loamy soils, moderate erosion	S-SED-LS-ME
10	114	Deep, moderately well drained, clayey soils, moderate erosion	D-MWD-CS-ME
11	668	Deep, well drained, Loamy soils, moderate erosion	D-WD-LS-ME
12	687	Deep, moderately well drained, clayey soils, moderate erosion	D-MWD-CS-ME
13	688	Deep, well drained clayey soils, moderate erosion	D-WD-CS-ME
14	691	Deep, Moderately Well Drained, Clayey Soils, Moderate Erosion	D-MWD-CS-ME
15	692	Deep, Moderately Well Drained, Clayey Soils, Moderate Erosion	D-MWD-CS-ME
16	699	Deep, Moderately Well Drained, Clayey Soils, Moderate Erosion	D-MWD-CS-ME
17	707	Deep, moderately well drained, clayey soils, moderate erosion	D-MWD-CS-ME

4.1. Soil

The soil texture map of Chhattisgarh, prepared by the National Bureau of Soil Survey and Land Use Planning (NBSSLUP), Nagpur, using a 10 km^2 grid sampling, was utilised in this study. The map was further refined and reclassified based on soil sample analysis and point data from soil health cards provided by the Department of Agriculture, Government of Chhattisgarh. The identified soil textures in the study area included clay, gravelly sandy loam, clay loam, silty clay, gravelly sandy clay loam, sandy clay loam and sandy loam as shown in **Figure 6.**

4.2. Watershed and Sub-Watershed Delineation

Watershed subdivision is a critical step in hydrological modelling, as it allows for a more precise representation of hydrological processes. In this study, the watershed delineation tool within Arc SWAT was utilised to define the boundaries of the Hamp River Basin. Employing the eight-pour point algorithm [15], streams were extracted from the DEM, as depicted in **Figure 7**. This figure illustrates the delineated stream network and the identified watershed boundaries.

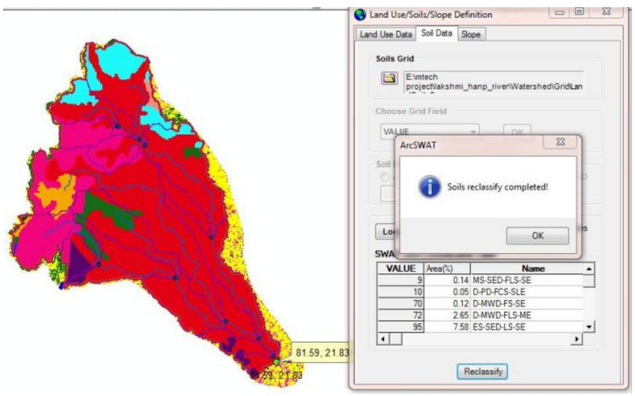

Figure 6. Map showing the distribution of different Soil categories in Hamp basin.

To define HRUs, a combination of land use, soil types, and slopes was analysed. HRUs were categorised based on these criteria to represent unique hydrological characteristics across the basin. Any land use, soil, or slope classes that covered less than the specified threshold were merged with adjacent classes, ensuring complete land area modelling for the entire watershed [8].

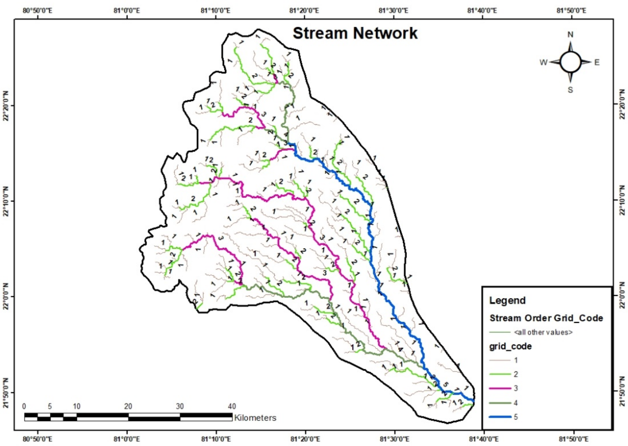

Figure 7. Hamp River Basin drainage with sub-watersheds.

4.3. Model Setup

The setup of the SWAT model for the Hamp River Basin was carried out using the Arc SWAT GIS interface. The delineated watershed was divided into multiple subbasins, each characterised by distinct hydrological features. The HRUs were defined based on the distribution of land use, soil types, and slope gradients, which is illustrated in **Figure 8**. This figure provides a visual representation of the defined HRUs within the basin, highlighting the diversity of land cover and soil characteristics critical for accurate hydrological simulation [16].

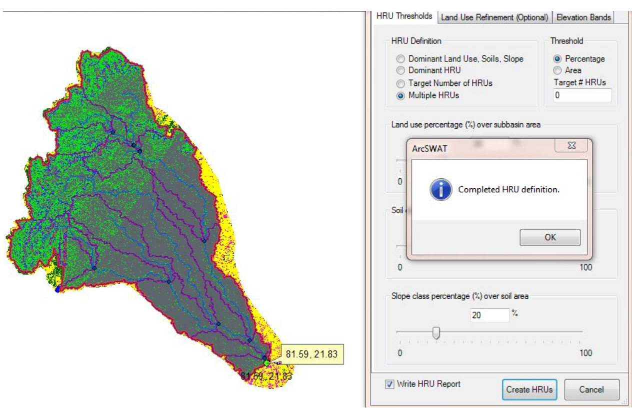

Figure 8. HRU Definition for Sub-watershed Delineation.

4.4. Calibration and Validation

Model calibration was performed using observed streamflow data collected from the Andhiyarkhore gauging station. The Sequential Uncertainty Fitting (SUFI-2) algorithm was employed to adjust the model parameters systematically, aiming to minimise the discrepancies between the observed and simulated stream flow data [17]. This calibration process is essential to ensure that the model accurately reflects the hydrological dynamics of the basin.

Once calibrated, the model underwent validation to assess its predictive accuracy. This involved comparing the SWAT model outputs against independent datasets not used in the calibration process [17]. This step is critical for verifying that the model can generalise well to different conditions and time periods.

4.5. Performance Evaluation

The performance of the SWAT model was assessed using three key statistical indicators: Nash-Sutcliffe Efficiency (NSE), Coefficient of Determination (R^2), and Percent Bias (PBIAS). The details of these performance evaluation criteria, including their acceptable ranges and categories for model accuracy, are summarised in **Table 3**. This table provides a clear overview of how model performance is categorised based on the values obtained for NSE and PBIAS, enabling a comprehensive understanding of the model's reliability in simulating stream flow within the Hamp River Basin [18].

By following these systematic methods for watershed delineation, model setup, calibration, validation, and performance evaluation, this study ensures a robust framework for accurately simulating hydrological processes in the Hamp River Basin using the SWAT model.

5. Results and Discussion

The hydrological analysis of the Hamp River basin from 2017 to 2023 reveals considerable insights into spatial runoff variability, seasonal trends, and the effects of local terrain and rainfall patterns on water flow. This study investigates how existing land management policies influence hydrological processes in the Hamp River Basin. By analysing runoff, sediment yield and nutrient transport, it is evident from the outcomes that regulatory measures play a crucial role in shaping basin hydrodynamics of Hamp basin. The findings underscore the

Table 3. Performance Evaluation Categories and Criteria.

Performance Rating	ENS	PBIAS (%)	PBIAS (%)
Unsatisfactory	ENS < 0.50	PBIAS > ± 25	PBIAS > ± 55
Satisfactory	0.50 < ENS < 0.65	± 15 < PBIAS < ± 25	± 30 < PBIAS < ± 55
Good	0.65 < ENS < 0.75	± 10 < PBIAS < ± 15	± 15 < PBIAS < ± 30

necessity for integrating policy frameworks with hydrological modelling to ensure sustainable watershed management. An in-depth examination of the region's existing policies reveals gaps in enforcement and effectiveness, necessitating new frameworks that better incorporate hydrological data and environmental sustainability principles.

Figure 9 illustrates the relationship between rainfall and runoff across the Hamp River basin, showing a pronounced correlation, particularly during the monsoon season. Here, rainfall peaks from July to October lead to corresponding surges in runoff, with nearly 75% of the annual runoff occurring within these months. This observation aligns with other monsoon-driven basins in India, highlighting a dependency on monsoon rains for water availability [19].

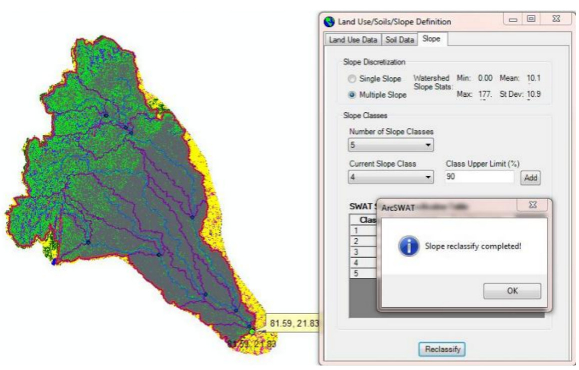

Figure 9. Spatial Variability of Runoff across Watersheds in the Hamp River Basin.

Spatially, the basin demonstrates significant variability in runoff production across its watersheds, as shown in **Figure 9**. Watersheds 12, 13, and 18 generate notably higher runoff, which can be attributed to steeper slopes, reduced vegetation, and impervious soils. These factors contribute to rapid surface flow, especially during heavy rains. In contrast, Watersheds 1 and 2 exhibit relatively low runoff due to flatter terrain and more permeable soils, which promote groundwater recharge instead of direct surface runoff. This variability underscores the need for tailored water management strategies: high-runoff areas could benefit from water storage structures, whereas low-runoff areas may be better suited for techniques such as contour bunding to enhance groundwater retention.

Monthly runoff patterns (**Figure 10**) across the watersheds, as visualised in **Figures 11**, **12** and **13**, further demonstrate the monsoon's influence. Watershed-specific responses to rainfall illustrate differences in hydrological behaviour across the basin. For instance, Watershed 3 shows a pronounced peak in October, with runoff reaching 7,232.55 cubic meters, while Watershed 4 peaks slightly later in November at 7,808.79 cubic meters. This delayed response suggests that local topographic and soil characteristics in Watershed 4 may retain water longer before releasing it as surface runoff. These patterns support findings in hydrology research, where flatter or permeable terrains are known to delay runoff peaks [20].

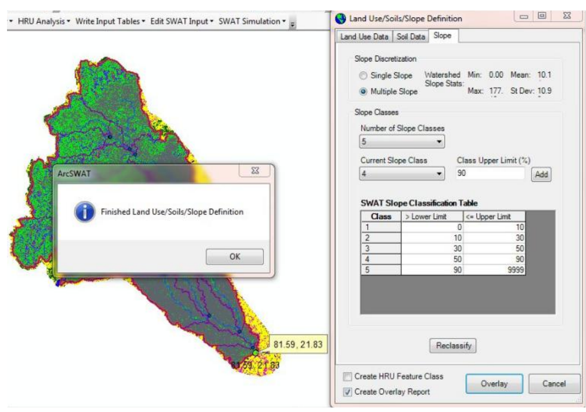

Figure 10. Monthly Runoff Patterns in the Hamp River Basin by Watershed.

The analysis of extreme runoff events is presented in **Figures 14** and **15**, highlighting watersheds with particularly high runoff rates, such as Watersheds 12, 13, and 18. These figures illustrate how localised rainstorms can significantly amplify surface flows in these areas. For example, Watershed 18 experiences a remarkable peak runoff of 29,288.9 cubic meters in May, indicating the potential for severe hydrological responses during extreme weather conditions. The extreme runoff observed in these steep and sparsely vegetated watersheds suggests an elevated risk of soil erosion and sedimentation downstream. This observation underscores the urgent need for implementing erosion control strategies, including checking dams and riparian buffers, to mitigate sediment loss and enhance water quality in downstream ecosystems.

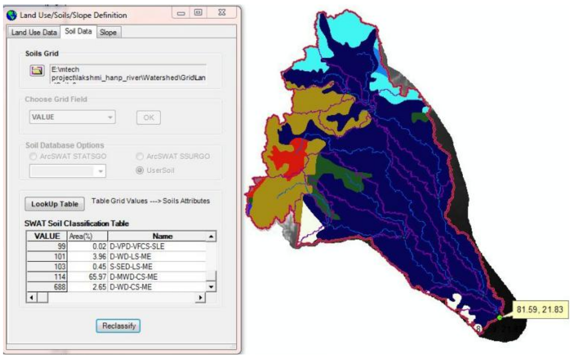

Figure 11. Comparison of Peak Runoff Events across Different Watersheds.

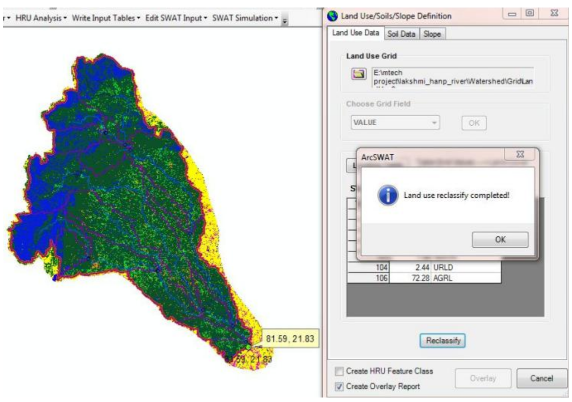

Figure 12. Temporal Distribution of Runoff across Watersheds during the Monsoon Season.

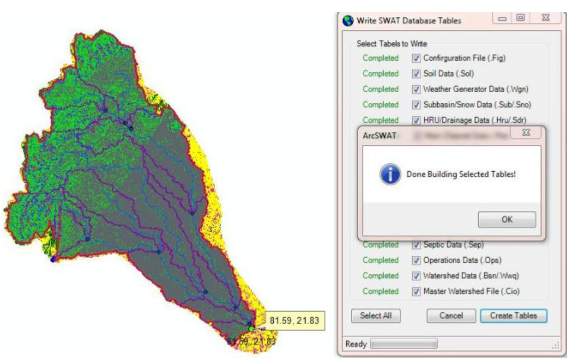

Figure 13. Extreme Runoff Events in High-Runoff Watersheds of the Hamp River Basin.

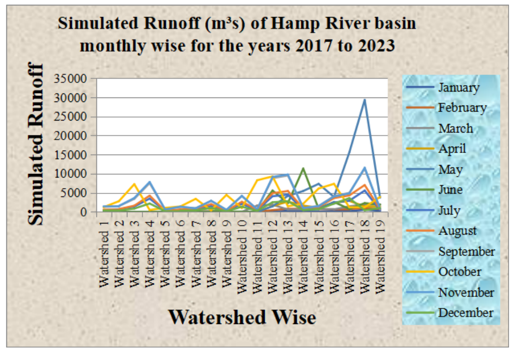

Figure 14. Impact of Localised Rainstorms on Runoff in Selected Watersheds.

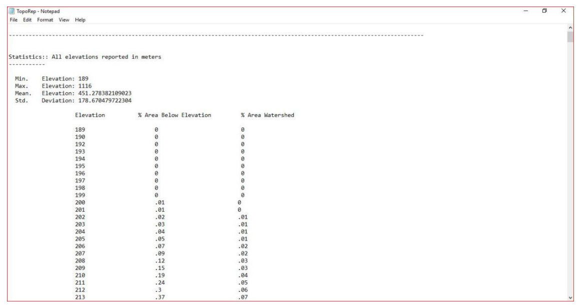

Figure 15. Seasonal Contribution of Monthly Runoff to Total Annual Runoff in the Hamp River.

An integrated view of seasonal and cumulative runoff patterns in **Figures 16** further underscores the monsoon season's dominance in the basin's hydrology. **Figure 16** reveals that monsoon months contribute approximately 85% of the total annual runoff and demonstrates how average monthly runoff significantly declines from January to June. These observations suggest that effective water management in the Hamp River basin would benefit from strategies aimed at capturing and storing excess runoff during monsoon months, thus ensuring a more stable water supply throughout the dry season.

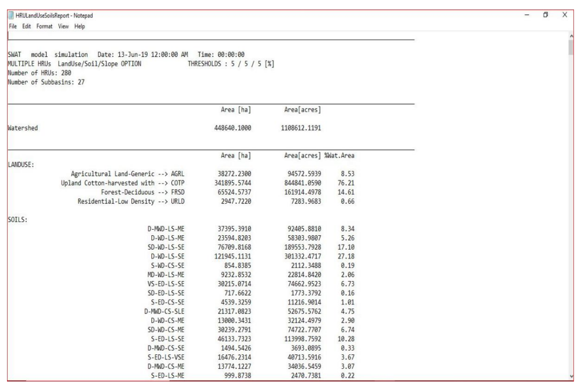

Figure 16. Average Monthly Runoff Decline from January to June in the Hamp River Basin.

The synthesised findings from these figures, along with **Table 4** data on monthly runoff, highlight critical implications for water management in the Hamp River basin. High-runoff watersheds, particularly those with steep terrain and reduced vegetation cover, should prioritise water storage infrastructure such as reservoirs or check dams to capture monsoon flows and mitigate downstream erosion risks [21]. Low-runoff watersheds, which generally have flatter, permeable soils, are ideal candidates for soil conservation techniques and groundwater recharge initiatives that allow for gradual release and sustained water availability. In erosion-prone areas, particularly in high-runoff regions, implementing vegetative barriers and soil stabilisation measures would mitigate sediment loss and improve water quality downstream.

Table 4. Monthly Runoff Data of Hamp River Basin by Watershed (2017–2023).

Watershed No	January	February	March	April	May	June	July	August	September	October	November	December
Watershed 1	29.41	19.18	0.511	0	0	0	433.96	577.12	1276.69	1203.75	1432.09	351.33
Watershed 2	7.33	0	0	0	0	0	663.27	734.3	1489.03	2787.44	1542.47	333.15
Watershed 3	0.04	0	0	0	0	0	1376.77	1601.53	3383.06	7232.55	3618.93	845.2
Watershed 4	29.52	13.11	0	0	0	4.68	3463.62	4232.24	7518.56	477.79	7808.79	2176.17
Watershed 5	74.98	44.59	7.402	0	0	23.16	280.05	283.42	613.24	1031.27	625.76	158.32
Watershed 6	48.56	41.12	10.539	1.545	0	103.69	536.63	601.69	1272.13	1400.28	1346.88	354.44
Watershed 7	81.13	86.12	66.539	18.106	9.182	9.76	573.66	834.28	953.31	3402.24	901.71	378.37
Watershed 8	94.63	75.18	34.658	18.621	7.404	158.29	1500.52	2008.81	2881	390.32	2875.53	995.5
Watershed 9	23	4.19	1.283	0	0	62.01	233.49	240.32	500.21	4432.16	509.18	132.97
Watershed 10	32.92	15.36	0	0	0	1.85	2080.58	2623.65	4120.65	996.03	4173.68	1327.28
Watershed 11	142.96	0	1640.34	0	0	133.53	407.13	591.88	678.12	8257.3	637.78	267.95
Watershed 12	0	451.98	1857.58	1498.67	1432.07	5569.62	4081.21	4853.75	8814.18	9264.6	9126.1	2504.67
Watershed 13	296.43	789.29	600.29	2680.57	4173.68	2291.88	4493.25	5452.81	9498.68	1458.95	9771.4	2775.71
Watershed 14	133.08	884.42	702.39	1619.69	5452.81	11318.3	611.53	869.62	1017.45	2134.05	978.09	444.46
Watershed 15	0	679.8	679.32	1094.53	7318.24	806.377	848.26	1265.45	1504.98	6097.58	1485.25	702.07
Watershed 16	285.67	631.13	633.82	2369.89	3894.68	2572.91	2453.46	3598.06	4124.72	7318.24	3996.29	2134.78
Watershed 17	148.87	723.37	1433.75	2853.37	15559.1	735.12	2912.07	4301.37	4955.84	1188.78	4833.47	3575.14
Watershed 18	543.96	966.8	1966.08	1421.09	29288.9	2281.73	5569.62	7007.09	11318.3	1184.25	11534.6	386.93
Watershed 19	262.25	697.8	1780.9	1255.7	3698.62	1876.29	444.28	681.94	806.377	3894.68	813.28	1016.07

These targeted recommendations align with the basin's variable hydrology, highlighting the need for adaptive, site-specific approaches to water management. By integrating findings across multiple figures and monthly runoff data, this analysis underscores the importance of strategic planning to optimise water availability and ecosystem health across the Hamp River basin's diverse landscapes and seasonal conditions. This study also highlights the need for targeted land resource conservation measures. Specific soil conservation techniques, such as contour bunding, afforestation, and check dam installations, are recommended to reduce erosion and mitigate sediment loss. The sediment yield analysis further informs potential conservation strategies that align with the identified land-use patterns.

The calibrated SWAT model is employed to simulate potential future land management policies. Various scenarios, including afforestation programs, soil conservation techniques, and agricultural land-use modifications, are assessed to determine their impact on stream flow and sediment transport. The model outcomes provide actionable insights for policymakers to optimise land-use strategies that mitigate environmental degradation while enhancing water availability. By forecasting hydrological shifts under different land-use policies, the study offers predictive insights that can aid in proactive decision-making and adaptive land management planning.

The study has noted that changes in stream flow patterns are due to deforestation, urbanisation and agricultural expansion in the basin influencing water availability which is being used for domestic, agricultural and industrial use. Examination of socio-economic conditions revealed an altered hydrological scenario, emphasising the need for community-centric land management practices. Agricultural productivity varies under different hydrological conditions highlighting the pressing need for adaptive policies that balance economic development with environmental conservation.

Various soil conservation measures are recommended for maintaining stability of Hamp watershed. Sediment yield patterns helped in suggesting specific soil conservation measures such as contour bunding, afforestation and checking dams in various locations of the basin area. These conservation strategies are suggested in line with existing land-use patterns, which ensure long-term soil fertility and minimise erosion. This is critical in maintaining land productivity and mitigating the adverse effects of excessive sediment transport on aquatic ecosystems.

6. Conclusions

This study successfully calibrated and validated the SWAT model to analyse the rainfall-runoff dynamics of the Hamp River Basin within the Mahanadi River System. The integration of various datasets, including DEM, Land Use and Land Cover (LULC) information, soil properties, and meteorological data, facilitated a comprehensive representation of the watershed's hydrological characteristics. The delineation of the basin into subwatersheds and the identification of HRUs were pivotal in enhancing the precision of hydrological simulations. The calibration and validation phases revealed that the SWAT model effectively mimicked observed stream flow, as evidenced by satisfactory performance metrics, including Nash-Sutcliffe Efficiency and Percent Bias. The outcomes of this research provide valuable insights into the hydrological behaviour of the Hamp River Basin, identifying critical areas prone to sediment yield and nutrient loss. Beyond hydrological assessment, this study underscores the broader implications for land management policy. Findings from the SWAT simulations can guide policymakers in refining conservation strategies, ensuring that both ecological and socio-economic factors are considered. Moreover, the simulation of future land management policy scenarios provides a proactive framework for sustainable watershed management. These findings are crucial for formulating sustainable water resource management strategies, particularly in agricultural settings where erosion and nutrient runoff pose significant challenges. The application of SWAT in this context demonstrates its potential as a robust tool for hydrological modelling, offering a framework that can be adapted for similar studies in diverse river basins, ultimately contributing to improved water management practices and environmental sustainability. The study also highlights the necessity of land conservation efforts, particularly in erosion-prone areas, to ensure long-term watershed stability and agricultural productivity. The study contributes to ongoing efforts in integrating hydrological processes with land management policies and ensures optimal utilisation of water and land resources for a sustainable future.

Author Contributions

Conceptualization, M.R. and M.K.G.; methodology, M.R.; software, M.R.; validation, M.R., M.K.G. and B.V.S.; formal analysis, M.R.; investigation, M.R.; resources, M.K.G.; data curation, M.R.; writing—original draft preparation, M.R.; writing—review and editing, M.K.G.; visualization, M.R.; supervision, M.K.G.; project administration, M.K.G.; funding acquisition, N.B.R. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data supporting the findings of this study are available upon reasonable request from the corresponding author.

Conflicts of Interest

The authors declare no conflict of interest.

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