



RESEARCH ARTICLE

Assessment of rainfall–streamflow relationship and its dynamics across the Mahanadi River Basin, India

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Abstract

Understanding the rainfall-streamflow relationship is fundamental for effective water resource planning and agricultural management in river basins. This study presents a comprehensive, sub-catchment scale analysis of the rainfall-streamflow correlation, regression and runoff coefficients for 15 sub-catchments within the Mahanadi River Basin (MRB). High-resolution gridded rainfall data from the India Meteorological Department (IMD) and observed streamflow data from the Central Water Commission (CWC) were utilised from the year 1980 to 2024 to establish the relationships. The correlation analysis revealed a strong positive linear relationship between rainfall and streamflow across the basin, with a basin-average correlation coefficient (r) of 0.78. Sub-basin wise, the lower Mahanadi River Basin (LMRB) exhibited the strongest coupling (average $r = 0.83$), followed by the middle Mahanadi River Basin (MMRB, average $r = 0.77$) and upper Mahanadi River Basin (UMRB, average $r = 0.75$) sub-basins. The coefficient of determination (R^2) followed a similar pattern. The estimated runoff coefficients (C), representing the fraction of rainfall converted into streamflow, showed significant spatial variability, ranging from 0.13 to 0.43 across sub-catchments. The upper and middle sub-basins showed lower runoff coefficients (UMRB: 0.22, MMRB: 0.32), while the lower sub-basin demonstrated a higher runoff coefficient of 0.35. These spatial patterns are attributed to the attenuating effects of major dams and reservoirs in the upper and middle reaches, higher forest cover promoting infiltration and contrasting topography. The flatter, deltaic lower basin, influenced by cumulative flow and higher water tables, generates runoff more efficiently. These findings are critical for designing sub-basin specific water management strategies. This study provides vital quantitative insights for optimising agricultural water use and implementing climate-resilient practices across the Mahanadi basin.

Keywords: dams; land use; Mahanadi River Basin; rainfall–runoff correlation; runoff coefficient; water resources management

Introduction

The hydrological cycle, a dynamic and complex system, is increasingly being disturbed by climatic variability and intensive anthropogenic activities (1). Sustainable water resource management of a river basin depends on critical understanding of the rainfall-streamflow dynamics, which dictates the availability of freshwater for ecosystems, agriculture and human consumption (2). The relationship between rainfall as input and the resultant streamflow output, often quantified through statistical correlation, regression analysis and the runoff coefficient, serves as a fundamental indicator of a river basin's hydrological behaviour and efficiency (3). This relationship is not static; it is influenced by multiple factors including topography, soil characteristics, land use and land cover (LULC), groundwater level and human interventions such as dam construction and water abstractions (4). Recent studies highlight that the rainfall–streamflow relationship exhibits non-stationary behaviour under changing climate conditions and increasing human interventions, leading to shifts in

runoff generation and flow regimes over time (2). Anthropogenic factors such as reservoir regulation and irrigation withdrawals further alter the timing and magnitude of streamflow, weakening the historically stable linkage between precipitation and discharge. In the context of monsoon driven climates like India, where over 80 % of the annual rainfall occurs within a short span of four months, the efficiency with which this rainfall is converted into usable surface water resources becomes a matter of paramount importance for food and water security (5).

The Mahanadi River Basin (MRB) in eastern India is a peninsular river system whose hydrology and the agrarian economy are mostly dependent on the southwest monsoon. The basin, spanning the states of Chhattisgarh and Odisha, is a vital source of water for millions of people and for extensive irrigation networks (6). However, the basin is under increasing stress due to climate change and anthropogenic activities. Recent studies have documented significant spatio-temporal shifts in rainfall patterns within the basin, coupled with a consistent rise in temperatures

(7, 8). Such hydro-climatic changes can profoundly alter the rainfall-runoff response, potentially leading to reduced water yields during peak requirements periods like critical crop growth stages or during dry spells. The basin is one of the most regulated river basins in India, with a cascade of major reservoirs like Hirakud, Hasdeo and Ravishankar Sagar significantly modulating the natural flow regime (9). Furthermore, changes in LULC, including deforestation and urbanisation are altering the infiltration and runoff characteristics of the catchments (10).

In this study, an effort has been made to derive a systematic, sub-catchment scale rainfall-streamflow relationship and runoff coefficient using long-term observed data of the MRB. The runoff coefficient (C) represents the fraction of rainfall that is converted to runoff and it is a dimensionless factor which denotes catchment's water yield efficiency (11). It shows the overall result of all catchment processes, including losses due to evaporation, transpiration, infiltration and storage. To identify the "water-rich" or "water-deficit" sub-catchments, a thorough analysis of runoff coefficient throughout the MRB is essential.

This study is focused on a comprehensive assessment of rainfall-streamflow dynamics in various sub-catchments of MRB. Although rainfall-streamflow relationships can be analysed at multiple temporal scales, the present study focuses on annual relationship to capture long-term basin-scale hydrological response (6). The rainfall in the Mahanadi basin is dominated by the south-west monsoon which accounts 80–90 % of annual rainfall. The streamflow during the non-monsoon period is mostly contributed by groundwater as base flow and less correlated with rainfall. Hence, annual rainfall-streamflow relationship has been carried out through this study at different gauging sites of the basin. The specific objectives of the research are a) to assess the strength and correlation between streamflow and rainfall at different gauging

sites; b) to estimate runoff coefficient for each sub-catchment and sub-basins; c) to analyse the spatial variability of these hydrological indices over the basin. The results of the study are expected to provide a scientific basis for appropriate policy interventions so that water managers and agricultural planners will be able to develop appropriate strategies to optimise reservoir operations, adopt adequate soil and water conservation structures, promote water-efficient agricultural practices and eventually enhance climate resilience in the Mahanadi Basin.

Materials and Methods

Study area description

The MRB is a major peninsular river system of eastern India which falls within the latitudes 19°08' N to 23°32' N and the longitudes 80°28' E to 86°43' E. The basin has a geographical area of 141589 km², which is about 4.3 % of the total area of India (Fig. 1). The basin extends over Chhattisgarh (52 % area) and Odisha (47 % area) with marginal areas in Maharashtra, Jharkhand and Madhya Pradesh. The Mahanadi River originates from the Sihawa Hills in Chhattisgarh at an elevation of 442 m above mean sea level and traverses 851 km before draining into the Bay of Bengal at Paradeep of Odisha. For hydrological analysis, this basin is broadly divided into three sub-basins: the upper Mahanadi River Basin (UMRB), middle Mahanadi River Basin (MMRB) and lower Mahanadi River Basin (LMRB). Several tributaries including Seonath, Hasdeo, Mand, Ib, Ong, Tel etc are carrying water to the main river system of the basin. The UMRB encompasses 21.79 % of the total basin area, which includes 21.62 % in Chhattisgarh and 0.17 % in Maharashtra. The MMRB accounts for 41.24 % of the basin, comprising 31.03 % in Chhattisgarh, 9.76 % in Odisha and 0.45 % in Jharkhand. The LMRB occupies the remaining 36.97 %, with 36.55 % in Odisha and 0.42 % in Chhattisgarh.

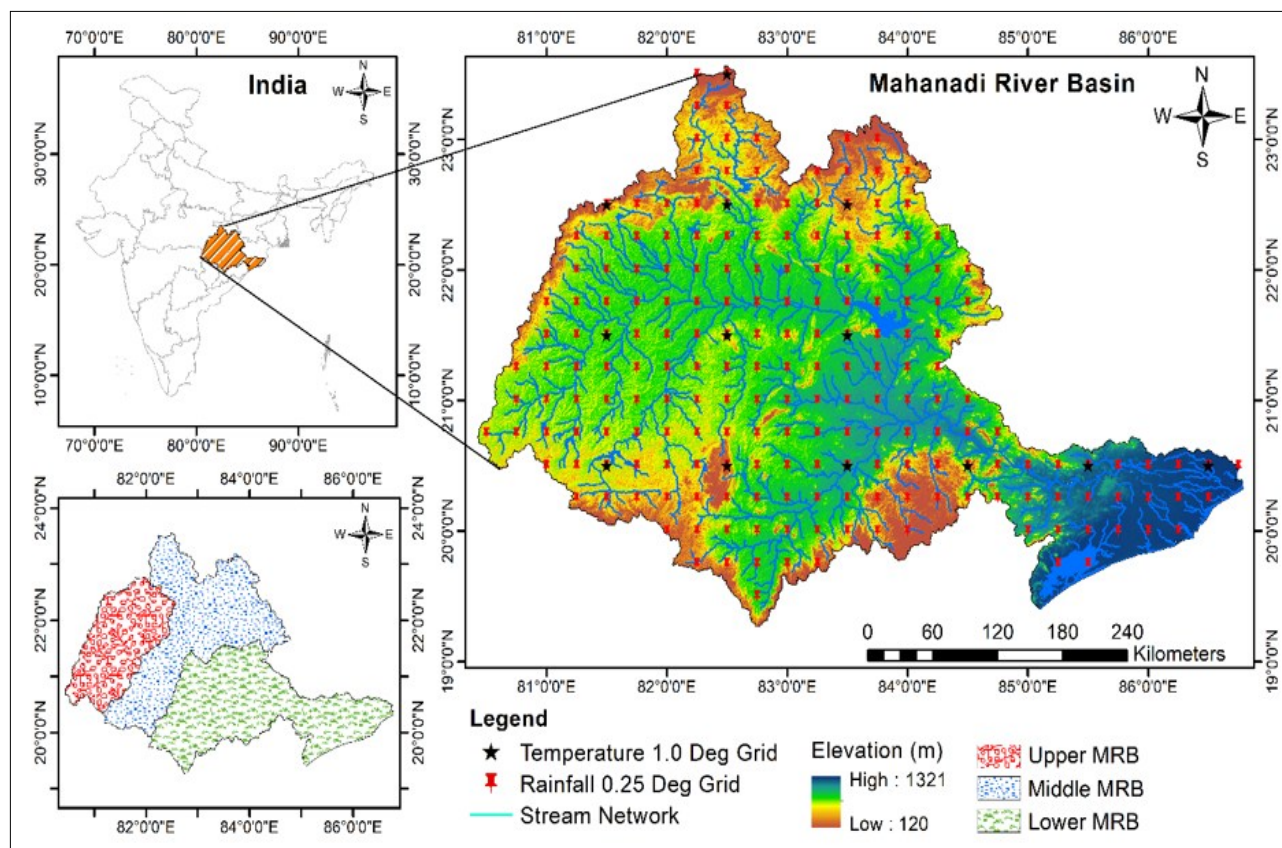


Fig. 1. Location map of the Mahanadi River Basin showing major sub-basins and the gauging stations (Source: Prepared using GIS software).

The basin experiences a tropical monsoon climate characterised by four distinct seasons, like hot summer (March–May), wet southwest monsoon (June–September), post-monsoon (October–December) and mild winter (January–February). The average annual rainfall varies between 1360 and 1463 mm, out of which 85–90 % is concentrated during the monsoon season. The average annual maximum temperature ranges from 32 °C to 40 °C, while minimum temperature varies from 8 °C to 22 °C. Agriculture is the dominant land use in the basin, covering approximately 54 % of the total area, followed by forest cover of around 30–32 %. Wastelands and fallow lands constitute about 6–8 %, while water bodies and natural wetlands account for approximately 4.5–5 % basin area. Kayitesi et al., revealed that the relationship between land use and land cover change and streamflow in tropical regions is generally weak and inconsistent (12). Das et al. reported that a marginal change in hydrologic variables such as evapotranspiration (ET), runoff and baseflow up to 0.09, 0.05 and 0.08 %, respectively in the Mahanadi basin due to change in land use and land cover (LULC) during 2005–25 (13). Dominantly, the soils of the basin are inceptisols and alfisols with texture ranging from clay to loam. Such soils support a variety of crops like rice, pulses, oilseeds and horticultural crops.

Data collection and preparation

A long-term (1980–2024) hydro-climatic dataset was used for this study. Gridded rainfall data at a spatial resolution of $0.25^\circ \times 0.25^\circ$ from the India Meteorological Department (IMD), Pune (14) and streamflow (discharge) data for 15 key gauging stations of Central Water Commission (CWC) in MRB were used in this study. The UMRB consists of Andhiyarkhore, Ghatora, Jondhra, Kotni, Simga sub-catchments; the MMRB consists of Bamnidhi, Baronda, Basantpur, Kurubhata, Rajim, Rampur sub-catchments and the LMRB consist of Kantamal, Kesinga, Salebhata, Tikarpara sub-catchments. The daily rainfall data over each sub-catchment area were averaged to generate mean areal rainfall. The streamflow data (m^3/s) were converted to runoff depth (mm) over the respective catchment area to ensure unit compatibility with rainfall for correlation and runoff coefficient calculation.

Pearson correlation

The strength of the linear relationship between annual rainfall and annual streamflow for each gauging station was assessed using the Pearson correlation coefficient (r), as shown in Eq. 1. The value of r ranges from -1 to +1, where values close to +1 indicate a strong positive linear relationship (15).

$$r = \frac{\sum_{i=1}^n (R_i - \bar{R})(S_i - \bar{S})}{\sqrt{\sum_{i=1}^n (R_i - \bar{R})^2 \sum_{i=1}^n (S_i - \bar{S})^2}} \quad \text{Eq.(1)}$$

where: R_i and S_i are the annual rainfall and streamflow for the i^{th} year, $\bar{R}$ and $\bar{S}$ are their respective means over the n -year period ($n=45$ years).

In this study, linear correlation has been used as a first-order approximation for large river basins. Linear models are widely used due to their simplicity and interpretability. While non-linear approaches may provide improved accuracy, they require detailed high-resolution datasets (e.g., soil moisture, reservoir operations etc) which are not consistently available for long-term analysis (6).

Regression model fitting

A simple linear regression model was fitted between annual rainfall and streamflow for each sub-catchment. The model is represented by Eq. 2. The coefficient of determination (R^2) was derived from this model to explain the proportion of variance in streamflow that is predictable from the rainfall (15). The R^2 values range from 0 to 1, with higher values indicating a better fit of the model to the data (16).

$$S = a + bR \quad \text{Eq.(2)}$$

where: S is the predicted streamflow (mm), R is the annual rainfall (mm), a is the regression intercept, b is the regression slope.

The formula for the coefficient of determination (R^2) is given by:

$$R^2 = \left[\frac{\sum_{i=1}^n (R_i - \bar{R})(S_i - \bar{S})}{\sqrt{\sum_{i=1}^n (R_i - \bar{R})^2} \sqrt{\sum_{i=1}^n (S_i - \bar{S})^2}} \right]^2 \quad \text{Eq.(3)}$$

Where: R_i = Annual rainfall for the i^{th} year, S_i = Annual streamflow for the i^{th} year, $\bar{R}$ = Mean annual rainfall over n years, $\bar{S}$ = Mean annual streamflow over n years, n = Total number of years (here, $n=45$).

Runoff coefficient

The mean annual runoff coefficient (C) for each sub-catchment was calculated as the ratio of mean annual streamflow depth (mm) to the mean annual rainfall depth (mm) over the study period, as shown in Eq. 4. This coefficient, ranging from 0 to 1 (or 0 % to 100 %), represents the long-term efficiency of a catchment in converting rainfall into runoff (11).

$$C = \frac{\text{Mean annual streamflow (mm)}}{\text{Mean annual rainfall (mm)}} \quad \text{Eq.(4)}$$

Results and Discussion

Spatial variability of rainfall and streamflow

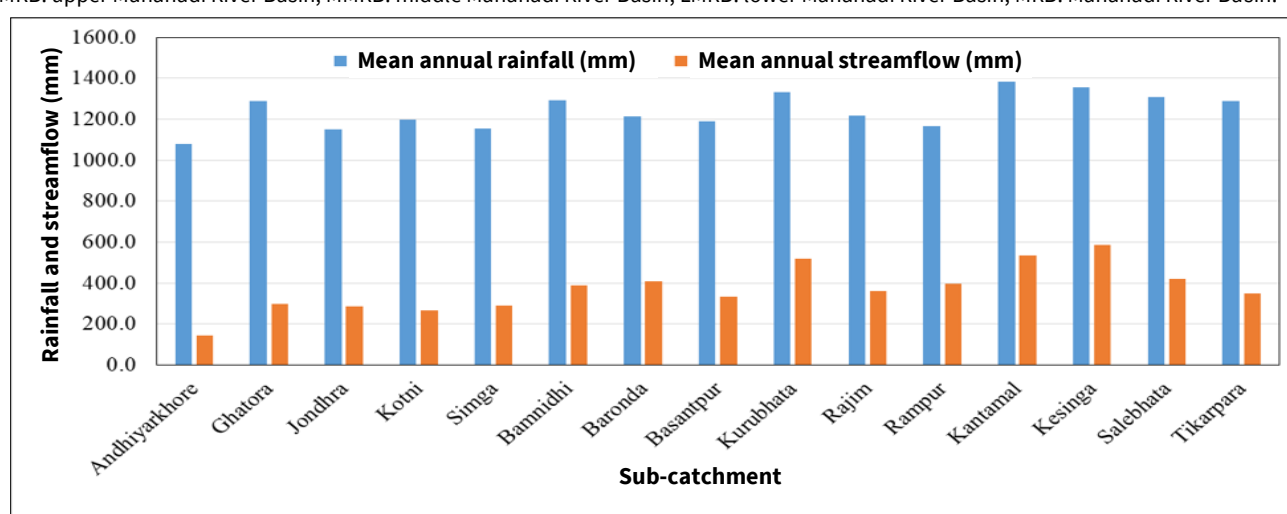
The analysis of normal annual rainfall and streamflow across the 15 sub-catchments of the Mahanadi river basin reveals distinct spatial patterns over the 45 year period, as shown in Fig. 2. The mean annual rainfall varies from 1077.43 mm at sub-catchment Andhiyarkhore to 1384.92 mm at sub-catchment Kantamal in UMRB and LMRB, respectively (Fig. 2). It indicates the orographic effects as well as the distance from the moisture source in the Bay of Bengal, generally showing higher precipitation in the lower parts of the basin. The corresponding mean annual streamflow has even greater variation, ranging from a low flow of 144.44 mm at Andhiyarkhore to a high flow of 585.70 mm at Kesinga in the LMRB (Fig. 2).

Aggregating to the sub-basin scale, the mean annual rainfall was found to be 1174.19 mm for UMRB, 1235.53 mm for MMRB and 1334.49 mm for LMRB, as presented in Table 1. The mean annual streamflow followed a different pattern, with sub-basin averages of 257.00 mm (UMRB), 401.21 mm (MMRB) and 472.81 mm (LMRB). The notably low streamflow in the UMRB relative to its rainfall is a critical finding, suggesting significant hydrological modifications and losses in the middle reaches, likely due to the pervasive influence of the Hirakud dam and other reservoirs, which impound water for irrigation, thereby reducing downstream flow (9, 17). The LMRB, receiving the highest rainfall and accumulating flow from the entire upper catchment, exhibits the highest streamflow volume.

Table 1. Sub-catchment and sub-basin wise mean rainfall and streamflow

Sub-basin	Sub-catchments	Mean annual rainfall (mm)	Mean annual streamflow (mm)
UMRB	Andhiyarkhore	1077.43	144.44
	Ghatora	1289.05	299.00
	Jondhra	1151.73	285.48
	Kotni	1198.83	266.92
	Simga	1153.92	289.15
Sub-basin Avg.		1174.19	257.00
MMRB	Bamnidhi	1293.96	388.73
	Baronda	1213.40	407.04
	Basantpur	1189.86	334.57
	Kurubhata	1331.00	519.39
	Rajim	1218.80	362.13
	Rampur	1166.15	395.41
Sub-basin Avg.		1235.53	401.21
LMRB	Kantamal	1384.92	536.51
	Kesinga	1356.15	585.70
	Salebhata	1308.16	419.06
	Tikarpara	1288.72	349.95
Sub-basin Avg.		1334.49	472.81
Entire MRB		1241.47	372.23

UMRB: upper Mahanadi River Basin; MMRB: middle Mahanadi River Basin; LMRB: lower Mahanadi River Basin; MRB: Mahanadi River Basin.

**Fig. 2.** Sub-catchment wise rainfall and streamflow of Mahanadi River Basin.

Rainfall-streamflow correlation

This analysis indicates a strong positive linear relationship between rainfall and streamflow for the MRB. Still, with large sub-catchment and sub-basin wise spatial variability (Fig. 3). The average value of the correlation coefficient for the entire basin is $r = 0.78$, indicating that a large proportion of precipitation is converted to river discharge. However, this correlation varies considerably at the sub-catchment scale, ranging from a moderate $r = 0.56$ at Andhiyarkhore and Ghatora to a very strong $r = 0.92$ at Kesinga. Regulated catchments such as Andhiyarkhore and Ghatora, influenced by upstream reservoirs like Ravishankar Sagar Dam and Dudhawa Dam, showing relatively lower rainfall-streamflow correlations ($r = 0.56$). In contrast, less regulated catchments like Kesinga exhibit much stronger correlations ($r = 0.92$), indicating that reservoir storage and controlled releases dampen and delay runoff response, thereby weakening the direct rainfall-streamflow linkage. Uncertainty in analysis may arise from gridded rainfall errors, discharge measurement inaccuracies and spatial averaging. These uncertainties can influence correlation and regression estimates, although long-term datasets help minimise their effects.

This spatial variability becomes clearer at the sub-basin scale. The rainfall-streamflow linkage was the strongest in LMRB with an average correlation coefficient of $r = 0.83$. It represents a highly efficient rainfall-runoff response and a small variations in rainfall is immediately reflected in river discharge. The MMRB

presents an average rainfall-streamflow correlation of $r = 0.77$, which is slightly lower than that of LMRB. The UMRB has shown the lowest average correlation ($r = 0.75$) among the three sub-basins. The very low correlations at Andhiyarkhore and Ghatora are a direct consequence of their location downstream of major reservoirs like Ravishankar Sagar. These dams regulate flow by storing monsoon runoff and releasing it during dry periods for irrigation, thereby decoupling the timing and volume of streamflow from immediate rainfall events (9). The undulating topography and significant forest cover (30–32 %) in the UMRB also promote infiltration and groundwater recharge, which attenuates the surface runoff response and weakens the direct correlation (18). The observed weakening of the rainfall-streamflow correlation in the upper and middle reaches due to dam regulation is consistent with the work of previous researchers, who reported significant hydrologic alteration in the MRB due to river valley projects (8).

Regression model fitting

The linear regression analysis provides further insight into the predictive power of rainfall for estimating streamflow across the sub-catchments. The coefficient of determination (R^2) values depicted in Fig. 4 follow a similar trend to that obtained during the correlation analysis. Kesinga and Kantamal sub-catchments in the LMRB with high values of R^2 (0.84 and 0.82, respectively) have more than 80 % of their annual streamflow variability explained by rainfall alone through a simple linear model. This indicates that rainfall is

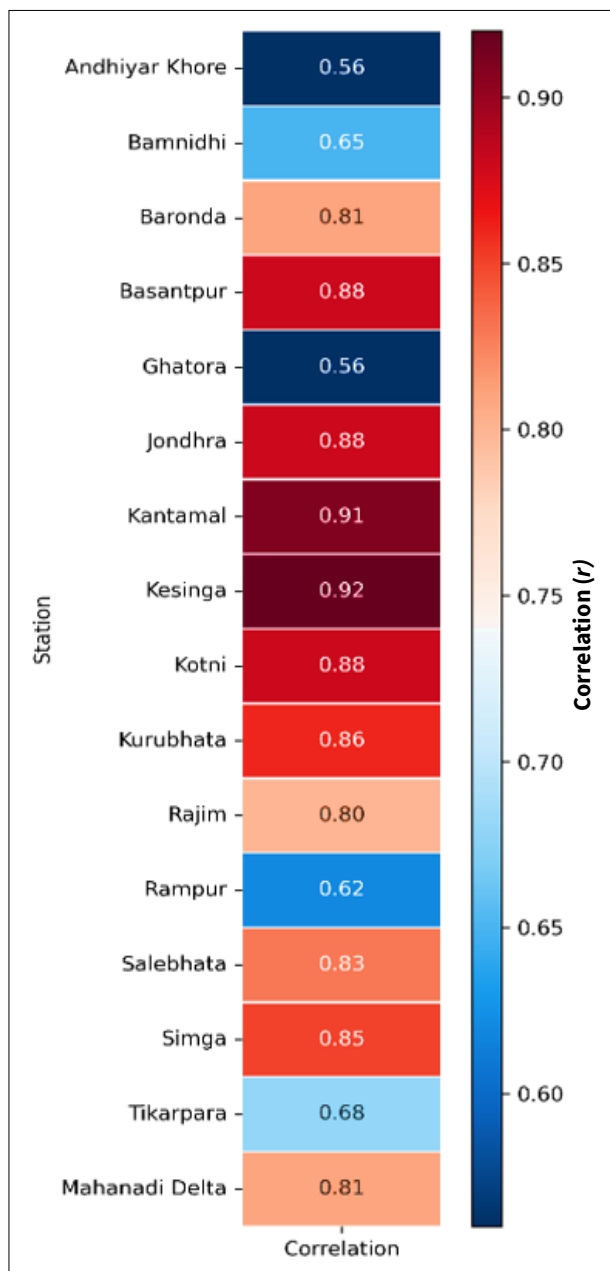


Fig. 3. Heat map of Pearson correlation coefficient (r) between annual rainfall and streamflow.

dependable predictor of streamflow within catchment area. Similarly, stations such as Basantpur ($R^2 = 0.78$) and Kurubhata ($R^2 = 0.73$) within the MMRB also showed a strong model performance. However, the predictive power drops significantly in sub-catchments affected by heavy regulation, such as Andhiyarkhore ($R^2 = 0.31$) and Ghatora ($R^2 = 0.32$) in the UMRB and Rampur ($R^2 = 0.39$) in the MMRB. The low R^2 values here confirm that factors other than rainfall, primarily dam operations dominate the streamflow regime, making simple rainfall-runoff models insufficient for accurate prediction (9).

A detailed examination of the scatter plots and fitted trend lines (Fig. 4) reveals nuances beyond the R^2 values. The slopes of the regression lines (the 'b' coefficient from Eq. 2) visually represent the runoff generation efficiency. Steeper slopes are observed in high-runoff sub-catchments like Kesinga and Kantamal (LMRB), indicating a greater volume of streamflow generated per unit increase in rainfall. In contrast, flatter slopes characterise regulated catchments like Andhiyarkhore and Ghatora. Furthermore, the scatter plots for highly regulated sub-catchments exhibit more

variation of data points around the trend line, indicating higher prediction uncertainty. For example, at Tikarpara in the LMRB, the scatter is quite high due to the complex interplay of upstream rainfall, reservoir operations and channel processes. Conversely, the tight clustering of points along the trend line for Jondhra and Basantpur signifies a more deterministic and predictable rainfall-runoff relationship.

Dynamics of the runoff coefficient

The runoff coefficient (C) provides a direct measure of catchment efficiency to generate runoff and shows remarkable spatial heterogeneity, ranging from 0.13 at Andhiyarkhore (UMRB) to 0.43 at Kesinga (LMRB), as depicted in Fig. 5.

The upper sub-basin (UMRB) has the lowest runoff coefficients, with a sub-basin average of $C = 0.22$. This means only about 22 % of the annual rainfall becomes measurable streamflow. This is attributed due to the combined effect of reservoir storage, significant evapotranspiration losses from forests and agriculture (7, 19) and infiltration into the groundwater system in the plateau area (16). The MMRB, while showing a higher average runoff coefficient of $C = 0.32$, reflects the impact of water regulation primarily from the Hirakud dam, which reduces the downstream flow. Also, some contrasting results are also observed at Kurubhata and Rampur gauging points with $C = 0.39$ and 0.34 , respectively, which may be because of local topography, land use and their strategic location relative to the position of the dam.

Conversely, the lower sub-basin (LMRB) demonstrated the highest runoff coefficients (Fig. 6), with an average of $C = 0.35$. This is due to flow accumulation from all parts of the basin, lower deep percolation due to high water table, significant base flow, low dam regulation which promotes higher surface runoff generation (20, 21). This high runoff generation capacity is consistent with CWC reports that classify the Mahanadi delta as highly vulnerable to floods (15). The station at Tikarpara, shows a lower coefficient ($C = 0.27$) than the entire LMRB, likely due to channel storage and the immense regulating effect of all upstream reservoirs and barrages.

The relatively lower runoff coefficients observed in the UMRB can be partly attributed to dense forest cover and permeable soils that enhance infiltration and subsurface flow pathways. In contrast, anthropogenic withdrawals such as reservoir storage, irrigation abstraction and regulated releases significantly alter the natural flow regime by modifying both the timing and magnitude of streamflow. Large reservoirs like Hirakud, Ravishankar Sagar and Dudhawa dams intercept monsoonal runoff and redistribute water for irrigation and other uses, thereby reducing immediate downstream discharge and weakening rainfall-streamflow linkage (12, 13). Therefore, the observed spatial variability in streamflow and runoff coefficients is a combined outcome of inherent basin characteristics and human interventions and these components must be evaluated separately for more accurate hydrological interpretation and water resource management.

The findings of this study align with and build upon previous research in the Mahanadi and neighbouring basins. The estimated runoff coefficients, which show lower values in the forested and dam-regulated upper basin, are in broad agreement with the range of values and their controlling factors discussed in recent literature (11, 22). The higher runoff coefficients and

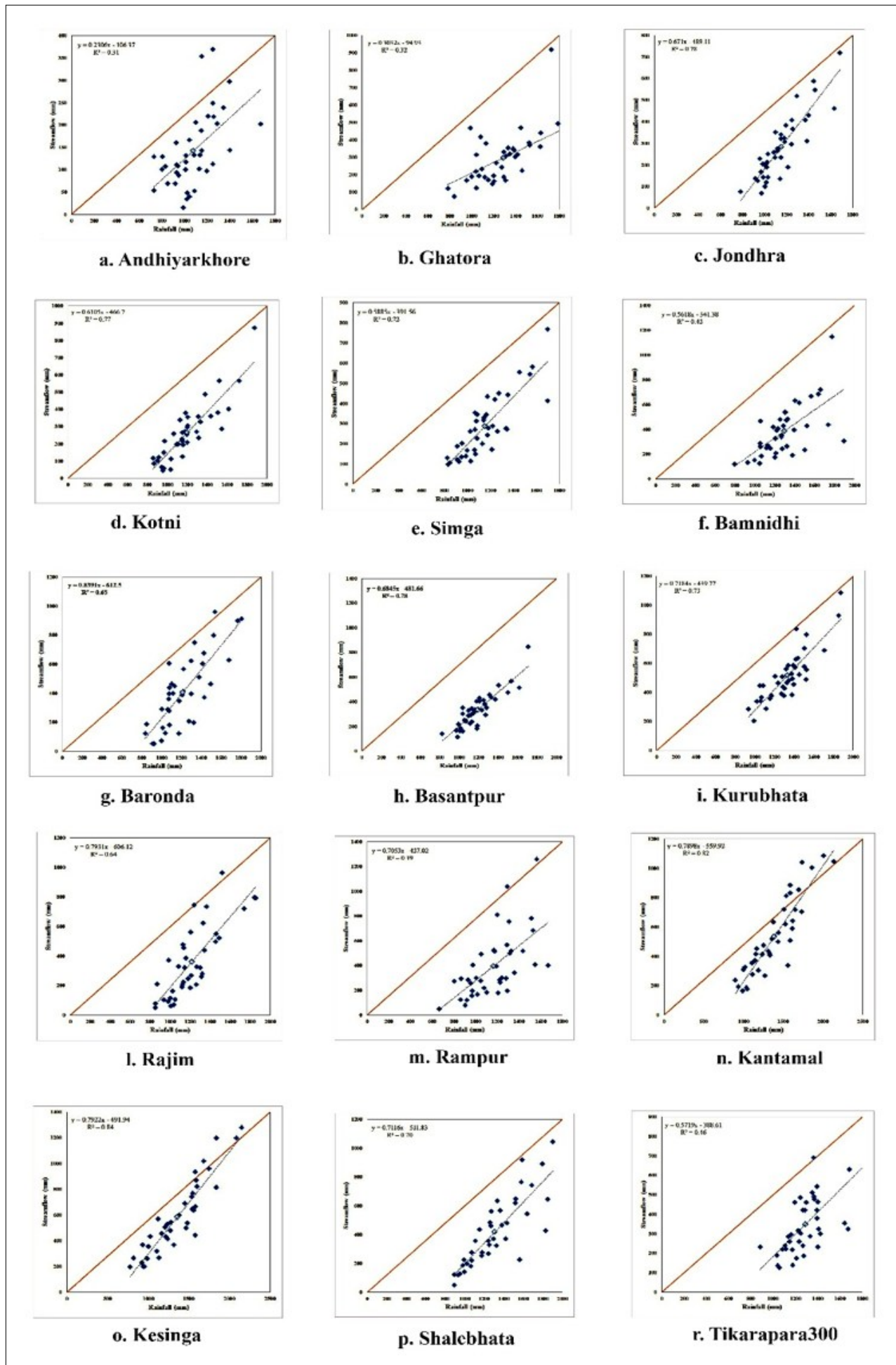


Fig. 4. Scatter plots and linear regression models for annual rainfall and streamflow across the 15 sub-catchments of the Mahanadi River Basin.

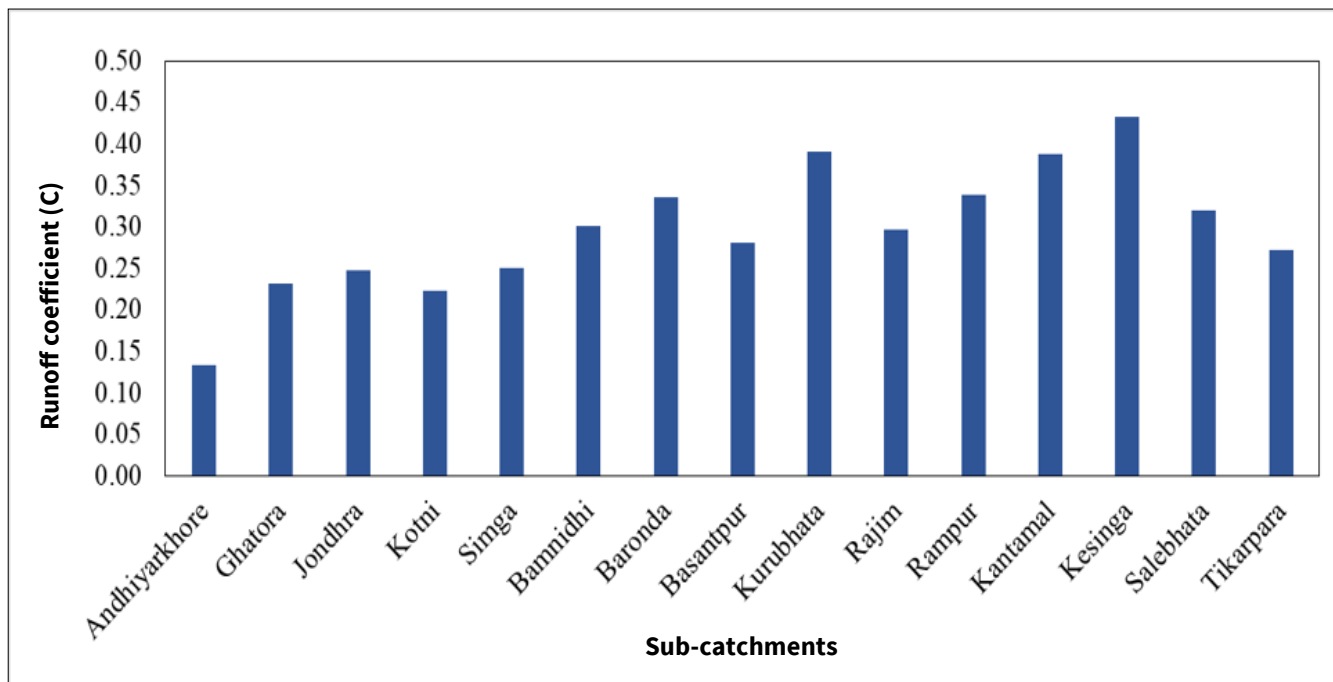


Fig. 5. Runoff coefficient (C) across the 15 sub-catchments of the Mahanadi River Basin.

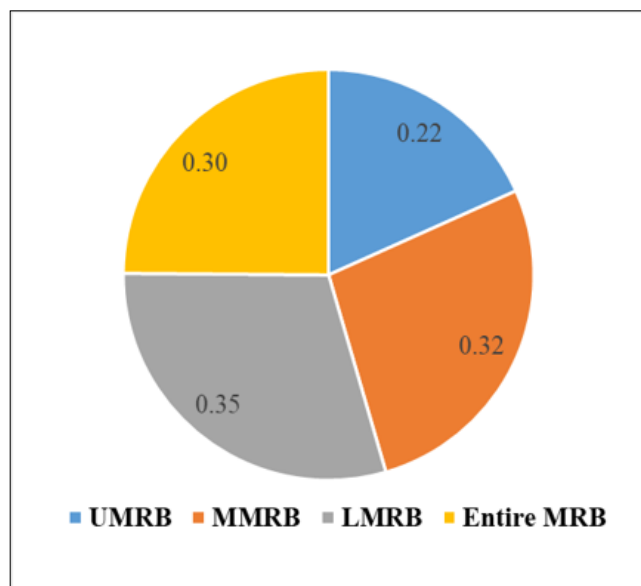


Fig. 6. Average runoff coefficient of upper Mahanadi River Basin (UMRB), middle Mahanadi River Basin (MMRB), lower Mahanadi River Basin (LMRB) and the entire Mahanadi River Basin (MRB).

stronger correlations in the lower basin corroborate the findings of previous researchers, who identified the Mahanadi delta as highly susceptible to flooding due to its efficient runoff generation and conveyance (20). A recent study in the Kesinga sub-catchment of the Mahanadi basin also highlighted the applicability of machine learning models for discharge prediction, underscoring the importance of the robust relationships we observed in this key area (23).

Our study, by providing a detailed, sub-catchment scale quantification across the entire MRB, offers a more granular and updated validation of these spatial patterns, reinforcing the critical role of anthropogenic interventions and physiography in modulating basin hydrology.

Conclusion

This study provides a comprehensive and explicit assessment of rainfall–streamflow dynamics of the Mahanadi River Basin (MRB), highlighting the dominant role of rainfall in governing streamflow while emphasising strong spatial variability across sub-catchments. The analysis confirms a significant positive relationship between rainfall and streamflow at the basin scale, with the strength of this relationship increasing from the upper Mahanadi River Basin (UMRB) to the lower Mahanadi River Basin (LMRB). The lower basin exhibits the highest hydrological responsiveness due to cumulative flow contributions, higher water tables and reduced regulation, whereas the upper and middle basins show weakened rainfall–streamflow linkage due to the combined effects of natural losses and extensive anthropogenic interventions such as reservoir regulation and irrigation withdrawals.

The runoff coefficient further reinforces this spatial heterogeneity, with lower values in the UMRB ($C = 0.22$) indicating significant losses through infiltration, evapotranspiration and storage and higher values in the LMRB ($C = 0.35$) reflecting efficient runoff generation and increased flood susceptibility. The relatively low predictive performance of rainfall-based regression models in regulated sub-catchments highlights the growing influence of non-climatic controls, particularly dam regulations on streamflow variability. Overall, the study demonstrates that basin hydrology is shaped by a complex interaction of physiographic characteristics, human that varies across the sub-basins of the MRB.

Based on these findings, several key recommendations are proposed. In the UMRB, efforts should focus on enhancing water-use efficiency through micro-irrigation, strengthening watershed management practices and promoting groundwater recharge to improve water availability. In the middle Mahanadi River Basin (MMRB), optimisation of reservoir operations using real-time data and integrated basin planning is essential to balance irrigation demand with downstream flow requirements. In the LMRB, priority should be given to flood management strategies, including

improved drainage systems, floodplain zoning and adoption of submergence-resilient agricultural practices. Across the entire basin, there is a need to incorporate climate change considerations into water resource planning, strengthen hydro-meteorological monitoring networks and adopt integrated modelling approaches that account for both natural hydrological processes and anthropogenic influences. Furthermore, future studies should explicitly separate natural losses from human-induced withdrawals to improve the accuracy of hydrological assessments and support sustainable water management in the MRB.

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Authors' contributions

SLR contributed to conceptualisation, methodology, coding, formal analysis, data curation, visualisation and writing the original draft. APS contributed to methodology, supervision, investigation and writing, review and editing. JCP contributed to validation, investigation and writing, review and editing. DMD contributed to conceptualisation, methodology, validation and writing, review and editing. SKR and PPJ contributed to resources, data curation and writing, review and editing. PKB contributed to data analysis and editing. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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