Larhyss Journal, ISSN 1112-3680, n°66, Jun 2026, pp. 217-234
© 2026 All rights reserved, Legal Deposit 1266-2002

SPATIO TEMPORAL ASSESSMENT OF LULC CHANGE IMPACTS ON BASIN HYDROLOGY IN THE INDIAN UPPER GODAVARI BASIN

PATIL G.[1*]***, KHERDE R.***[2]***, MEHTA D.J.***[3]

[1] Assistant Professor, Civil Engineering Department, Dr. D. Y. Patil Institute of Technology, Pimpri, 411018, India
[2] Assistant Professor, Civil Engineering Department, Dr. D. Y. Patil University, Ambi, Pune, 410506, India
[3] Assistant Professor, Civil Engineering Department, Dr. S. & S. S. Ghandhy Government Engineering College, Surat, Gujarat, 395001, India

(*) gauri.patil2310@gmail.com

Research Article – Available at http://larhyss.net/ojs/index.php/larhyss/index
Received September 5, 2025, Received in revised form April 22, 2026, Accepted April 24, 2026

ABSTRACT

This study investigates the spatiotemporal dynamics of land use and land cover (LULC) change and its implications for basin-scale hydrological behaviour in the Upper Godavari Basin, Maharashtra, India. Multi-temporal satellite-derived LULC datasets for 2018, 2021, and 2024 were analyzed to quantify changes in major land-cover classes and identify dominant transformation trends within the basin. The results reveal a consistent increase in built-up area accompanied by a gradual decline in cropland, indicating progressive urbanization and anthropogenic modification of the landscape. Minor variations were also observed in water bodies, tree cover, and range land. These land transformations are hydrologically significant, as the expansion of impervious surfaces reduces infiltration capacity and increases surface runoff, particularly during the monsoon period. Simultaneously, changes in vegetation cover influence evapotranspiration processes, soil moisture retention, and the overall water balance of the basin. The observed trends suggest a shift toward a more rapid hydrological response, with potential implications for flood generation, groundwater recharge, and seasonal water availability. The study highlights the importance of integrating LULC dynamics into basin-scale water resources planning and watershed management strategies. The findings provide a scientific basis for understanding how recent land transformations may influence hydrological processes in semi-arid river basins and support informed decision-making for sustainable water resource management in the Upper Godavari Basin.

Keywords: Basin scale hydrology, runoff generation, Evapotranspiration variability, Watershed response, Remote sensing applications, Geospatial analysis.

Abbreviation

LULC	Land Use Land Cover
ET	Evapotranspiration
GIS	Geographic Information System
DEM	Digital Elevation Model
IMD	India Meteorological Department
NRSC	National Remote Sensing Centre
ISRO	Indian Space Research Organisation
IGBP	International Geosphere–Biosphere Programme
WRIS	Water Resources Information System
SRTM	Shuttle Radar Topography Mission
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
GTOPO30	Global 30 Arc-Second Elevation Data Set
NBSS&LUP	National Bureau of Soil Survey and Land Use Planning
LAI	Leaf Area Index
MODIS	Moderate Resolution Imaging Spectroradiometer
GLDAS	Global Land Data Assimilation System
Tmin	Minimum Temperature
Tmax	Maximum Temperature
WRD	Water Resources Department
VIC	Variable Infiltration Capacity
HEC-HMS	Hydrologic Engineering Center–Hydrologic Modeling System
CMIP5	Coupled Model Intercomparison Project Phase 5
PET	Potential Evapotranspiration
SCS-CN	Soil Conservation Service Curve Number
ISPRS	International Society for Photogrammetry and Remote Sensing

INTRODUCTION

Human activities have emerged as a dominant force influencing environmental systems, significantly affecting land use and land cover (LULC) patterns and associated hydrological processes (Choukrani et al., 2018; Mfoutou and Diabangouaya, 2019; Riahi et al., 2020; Ezz, 2025; Chabokpour and Azamathulla, 2025). Globally, although the rate of net forest loss has shown a declining trend from approximately 7. 8 million hectares per year during 1990-2000 to 5.2 million hectares per year in 2000-2010 and further to 4.7 million hectares per year during 2010-2020 the impact of anthropogenic activities on land transformation remains substantial (Patil and Kherde, 2024; Woldearegay et al., 2026). In India, rapid population growth, urban expansion, and infrastructure development have led to significant changes in basin-scale land-use patterns, thereby altering the natural hydrological regime. Land use, land cover, and climate are two fundamental factors governing the hydrological behaviour of a region (Kouao et al., 2020; Doumounia et al., 2020). Even minor changes in LULC can influence surface energy balance, modify local climatic conditions, and affect precipitation and temperature patterns. These changes subsequently impact key hydrological processes such as evapotranspiration (ET) (Chibane and Al-Rahmani, 2015; Hamimed et al., 2017; Soro et al., 2018), groundwater recharge (Gaaloul, 2015; Bemmoussat et al., 2017; Remini, 2019; Qureshi et al., 2024), and surface runoff (Mistry et al., 2017; Yang et al., 2021; Atallah et al., 2024; Mehta and Yadav, 2024; Molavi, 2025). LULC changes also alter important physical characteristics of the land surface, including leaf area index, rooting depth, and surface roughness, thereby influencing the exchange of water, energy, and momentum between the land surface and atmosphere (Belloufi et al., 2016).

Urbanization-driven transformation of natural landscapes has been widely reported to increase runoff generation and reduce infiltration capacity (Faregh and Benkhaled, 2016; Hountondji et al., 2019; Ghitiri et al., 2021; Mah et al., 2023), thereby altering watershed response (Abdeddaim and Benkhaled, 2016; Luo and Shao, 2022; Bentalha, 2023). Consequently, understanding the influence of LULC dynamics on hydrological processes has become essential for effective water resources planning and management (Paulo-Monteiro and Costa-Manuel, 2004; Argaz, 2018; Jayasena et al., 2021; Mehta et al., 2022; Long et al., 2023). Several studies have emphasized the need to analyze the relationship between land cover transitions and hydrological components such as runoff, evapotranspiration, and groundwater recharge across different spatial and temporal scales (Bhardwaj et al., 2020; Hengade and Eldho, 2019; Hengade et al., 2018; Saraf and Regulwar, 2018). Such assessments are crucial for developing sustainable watershed management strategies, particularly in rapidly transforming river basins. Recent advancements in remote sensing and geographic information systems (GIS) have facilitated improved monitoring and analysis of LULC dynamics using multi-temporal satellite datasets. These tools enable consistent evaluation of land transformation patterns and provide valuable insights into their implications for basin-scale hydrological behaviour (Mahapatra et al., 2020; Moskovkin et al., 2018; Vand et al., 2018). However, despite the availability of such techniques, there remains a need for updated assessments focusing on recent LULC transitions and their hydrological implications in many Indian river basins. The Upper Godavari Basin in Maharashtra represents a region undergoing significant land transformation due to increasing urbanization and changing land use practices. While previous studies have examined hydrological responses in the Godavari Basin, limited attention has been given to recent spatiotemporal LULC changes and their implications for basin-scale hydrological behaviour(Deepthi et al., 2020; Kherde et al., 2024). Therefore, a comprehensive assessment of recent land use transitions using multi-temporal satellite data is required to better understand their impact on hydrological processes. In this context, the present study aims to analyze spatiotemporal LULC changes in the Upper Godavari Basin and to interpret their implications for basin hydrology. The findings of this study are expected to contribute to improved understanding of land-water interactions and to support informed decision-making for sustainable water resource management and watershed planning in the region.

STUDY AREA

The study area comprises the Upper Godavari watershed, defined as the catchment of the Godavari River from its origin near Trimbakeshwar in the Western Ghats (Nashik district, Maharashtra) to the Paithan section (Biswas et al., 2019; Koneti et al., 2018). Fig. 1 illustrates the geographical extent of the Godavari Basin in India along with the delineation of the Upper Godavari Basin as a sub-basin within the larger Godavari River system. The Upper Godavari region lies within the geographical bounds of 73°E - 75. 75°E longitude and 19°N - 20. 75°N latitude. The basin covers an area of 21,774 km² (Jayakwadi catchment) and represents a headwater to plateau transition zone, where steep western escarpments grade into the Deccan Plateau. The climate is tropical monsoon, with rainfall concentrated during June to September, producing strong seasonal runoff peaks and pronounced low flow periods in the dry season. Land use is dominated by agriculture and expanding built-up areas in the plateau, while forest and shrubland patches occur in higher elevation and protected zones, making the basin appropriate for evaluating spatiotemporal LULC-driven changes in runoff, evapotranspiration, and base flow.

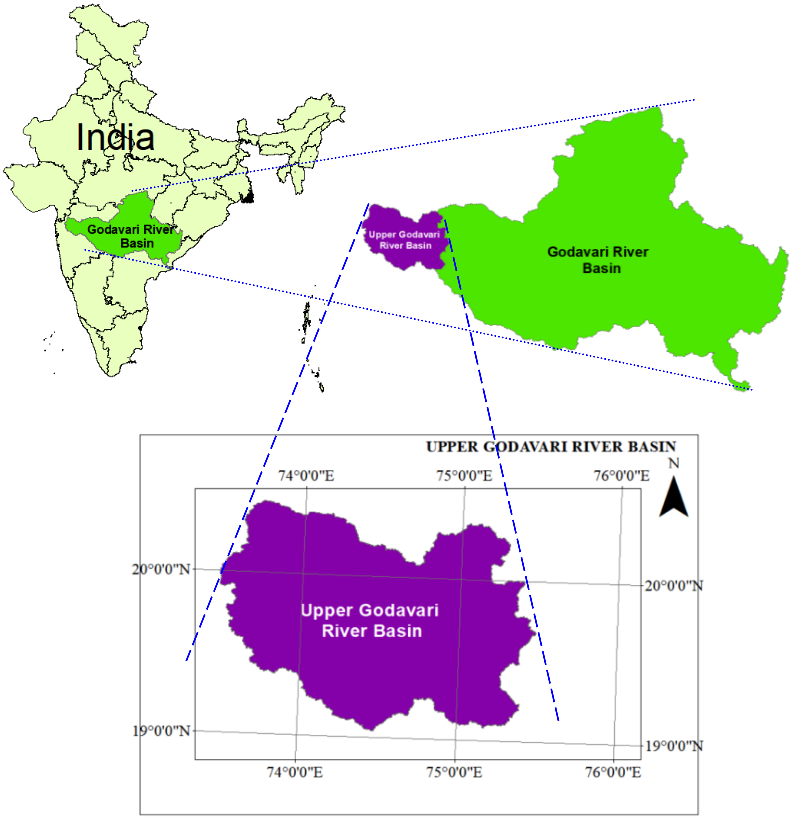


Figure 1: Spatial location and boundary of the Upper Godavari Basin in Maharashtra, India (Deepthi et al., 2020)

METHODOLOGY

The overall methodology adopted in this study is presented in Fig. 2, which illustrates the systematic workflow followed for hydrological assessment of the Upper Godavari Basin. The approach integrates geospatial analysis (Gohil et al., 2024a; 2024b), LULC change detection, and hydrological interpretation to evaluate basin-scale responses. The study begins with project initiation, where the objectives and scope of the hydrological analysis are defined. This is followed by data collection, which includes acquiring India Meteorological Department (IMD) rainfall data, Digital Elevation Model (DEM), Land Use/Land Cover (LULC) maps, and soil data required for analysis. Subsequently, basin delineation is performed using DEM and boundary datasets to define the spatial extent of the study area. The collected LULC data are then processed through clipping, projection, and classification under the LULC data processing stage to ensure consistency and accuracy. The processed datasets are further used for LULC change detection, where temporal variations in land use patterns are identified and quantified. This is followed by spatial analysis, which examines the distribution and variability of LULC classes across the basin. In the next stage, hydrological interpretation is carried out to understand key processes such as runoff generation, evapotranspiration (ET), infiltration, and groundwater recharge. Based on these interpretations, a basin-scale assessment is conducted to evaluate the hydrological response of the basin, particularly under monsoon and seasonal conditions. Finally, the study proceeds to results and discussion, where the findings are analyzed in detail, followed by the conclusion, which summarizes key outcomes and provides recommendations for sustainable water resource management.

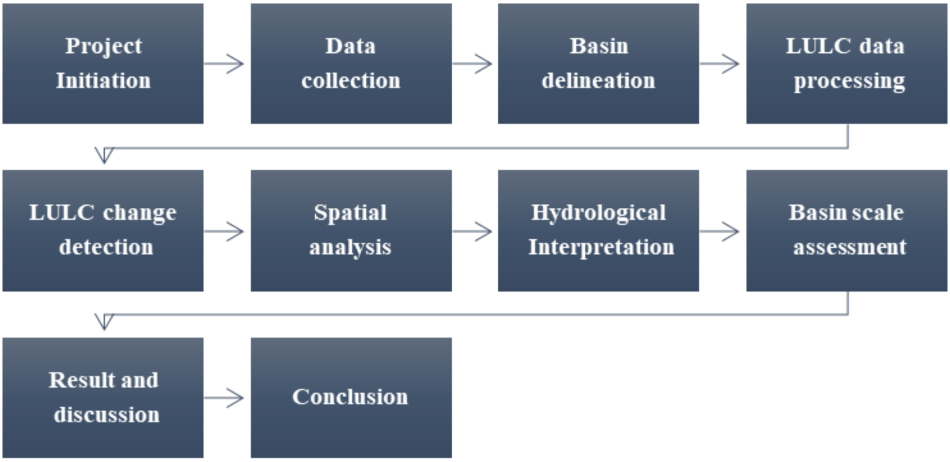


Figure 2: Methodological workflow for hydrological assessment of the upper Godavari basin

Basin delineation and topographic analysis

The Upper Godavari Basin was delineated using digital elevation data and watershed boundary information obtained from the India WRIS. Elevation and slope characteristics were derived from DEM datasets such as the Shuttle Radar Topography Mission (SRTM) or Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) to understand the basin's physiographic characteristics. These topographic parameters play an important role in influencing runoff generation, flow direction, and drainage characteristics within the basin.

Satellite-based LULC data preparation and processing

Multi-temporal LULC datasets for selected benchmark years (2018, 2021, and 2024) were obtained from satellite-based sources such as the National Remote Sensing Centre/ Indian Space Research Organisation (NRSC/ISRO). All datasets were harmonized to a common classification scheme and processed to ensure consistency in spatial resolution, projection, and extent. The datasets were clipped to the basin boundary and reclassified into major land use categories, including water bodies, tree cover, cropland, built-up area, rangeland, flooded vegetation, and bare ground. Class-wise spatial distribution maps were generated for each year, and areal statistics were extracted to quantify the extent of each land cover category within the basin.

Spatiotemporal LULC change analysis

To evaluate the hydrological impacts of land use land cover (LULC) dynamics, multi-temporal LULC maps of the Upper Godavari Basin are prepared for selected benchmark years. All LULC datasets are harmonized to a common classification framework (preferably IGBP compatible or a consistent national LULC scheme) and processed to a uniform projection and spatial resolution to ensure temporal comparability. Class-wise areal statistics are derived for each year, and changes are quantified to characterize the magnitude, direction, and spatial distribution of LULC transitions over time. LULC change detection is performed by computing, for each land cover class, the area (km^2) in each benchmark year, the absolute change (km^2) between time periods, and the percentage change (%) relative to total basin area. The change in area of class i between years t_1 and t_2 is calculated as:

Area change:

$$\Delta A_i = A_{i,t_2} - A_{i,t_1} \tag{1}$$

% change:

$$\Delta A_i(\%) = 100\,\frac{A_{i,t_2} - A_{i,t_1}}{A_{\text{basin}}} \tag{2}$$

This spatiotemporal analysis enables identification of hydrologically relevant transitions such as forest to agriculture, agriculture to built-up, shrub and grassland to cropland, and water body expansion or contraction, which are later linked to changes in runoff generation, evapotranspiration, and base flow response.

Spatiotemporal assessment of LULC impacts on basin hydrology

The final stage of the methodology quantifies and maps the hydrological response to LULC change. For each LULC scenario, basin-averaged values of runoff, ET, and base flow are compared. Hydrological change between two LULC years is expressed as:

Hydrological change:

$$\Delta Q = Q_{t_2} - Q_{t_1} \tag{3}$$

% change:

$$\Delta Q(\%) = 100\,\frac{Q_{t_2} - Q_{t_1}}{Q_{t_1}} \tag{4}$$

Similar expressions are used for ET and base flow. Grid-wise outputs are mapped to identify zones of increased runoff generation, areas of reduced ET due to vegetation loss, and regions with altered base flow contribution. This grid-level mapping forms the spatial component, while multi-year LULC scenarios form the temporal component, together constituting the spatiotemporal assessment. A basin water balance consistency check may be performed using the relationship among precipitation, runoff, ET, and change in storage. This improves methodological robustness and supports the interpretation of scenario-wise hydrological differences. The hydrological assessment of the Upper Godavari Basin was carried out using a comprehensive set of geospatial and hydro-meteorological datasets, as summarized in (Table 1).

Table 1: Input datasets and sources for hydrological assessment of the upper Godavari basin

Sr. No.	Dataset	Source	Spatial Resolution	Period Used
1	Basin boundary (Upper Godavari)	India WRIS	Vector boundary	Latest available
2	Digital Elevation Model	SRTM / ASTER / GTOPO30	30 m / 90 m / ~1 km (as used)	Static
3	Soil texture and soil properties	NBSS&LUP	Polygon/raster soil map	Static
4	LULC maps (multi-temporal)	NRSC / ISRO / satellite imagery	e. g., 30 m / 56 m (sensor dependent)	year wise

5	Leaf Area Index (LAI)	MODIS LAI	500 m / 8-day aggregated monthly	LULC years / climatology
6	Vegetation biophysical parameters	GLDAS / literature / standard	Class based	Static / monthly
7	Daily precipitation	IMD gridded rainfall	0. 25° or 0. 5° daily	Simulation period
8	Daily T_{min} and T_{max}	IMD gridded temperature	1. 0° daily (or available product)	Simulation period
9	Observed discharge	WRD Maharashtra	Daily	Calibration validation period
10	Reservoir reference	basin reports	Point/location data	Static

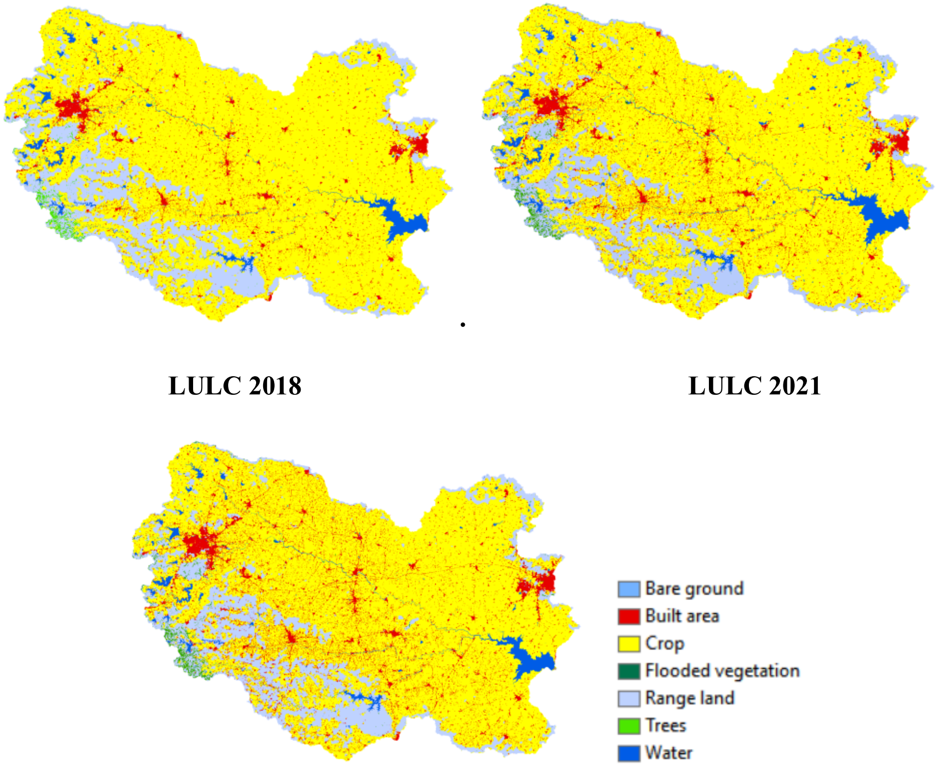
Basin-scale hydrological interpretation

The combined spatial and temporal analysis of LULC changes was used to infer basin-scale hydrological response. Particular emphasis was placed on understanding how recent land transformation trends influence runoff generation, evapotranspiration behaviour, and delayed flow contribution. Seasonal variability was also considered, as intense monsoon rainfall interacting with modified land surfaces can significantly alter hydrological response. The analysis provides insights into how land use changes may influence flood potential, groundwater recharge, and overall water balance within the basin.

RESULTS AND DISCUSSION

Spatiotemporal LULC change in the upper Godavari basin

To quantify land use land cover dynamics, multi-temporal LULC maps for 2018, 2021, and 2024 were compared. Table 2 presents the temporal variation in the distribution of LULC classes within the Upper Godavari Basin for the years 2018, 2021, and 2024. Table 3 summarizes the changes in LULC classes across different time intervals. Fig. 3 illustrates the spatial distribution of Land Use Land Cover (LULC) classes in the Upper Godavari Basin for the years 2018, 2021, and 2024. The maps clearly depict the temporal changes in land-use patterns across the basin.



LULC 2018 **LULC 2021**

LULC 2024

Figure 3: Temporal variation in spatial patterns of land use/land cover (LULC) in the Upper Godavari Basin (2018–2024)

Table 2: Temporal distribution of land use land cover (LULC) classes in the upper Godavari basin (2018–2024)

Sr. No.	LULC Class	2018 (%)	2021 (%)	2024 (%)
1	Water	2. 397	3. 338	2. 424
2	Trees	0. 569	0. 651	0. 701
3	Flooded vegetation	0. 004	0. 0097	0. 0034
4	Crop	76. 79	75. 47	73. 17
5	Built area	5. 03	6. 75	8. 65
6	Bare ground	0. 0059	0. 0026	0. 0065
7	Range land	15. 23	13. 84	15. 05
	Total	100	100	100

Table 3: Change in LULC percentages in the upper Godavari basin.

Sr. No.	LULC Class	Change (2018–2021) (%)	Change (2021–2024) (%)	Change (2018–2024) (%)
1	Water	+0. 941	-0. 915	+0. 0277
2	Trees	+0. 083	+0. 0498	+0. 1328
3	Flooded vegetation	+0. 006	-0. 0063	-0. 0006
4	Crop	-1. 385	-2. 241	-3. 626
5	Built area	+1. 747	+1. 898	+3. 645
6	Bare ground	-0. 0024	+0. 0039	+0. 00144
7	Range land	-1. 390	+1. 2097	-0. 1802

The land use land cover (LULC) analysis of the Upper Godavari Basin reveals measurable changes in landscape composition during the study period. The results show that cropland remained the dominant land use category in all assessment years; however, its overall proportion gradually declined, while built-up area increased significantly, indicating progressive urbanization and anthropogenic land transformation. Minor fluctuations were also observed in water bodies, tree cover, flooded vegetation, bare ground, and range land. Table 2 shows that cropland remained the dominant LULC class in the Upper Godavari Basin during 2018, 2021, and 2024, although its percentage declined from 76. 79% in 2018 to 73. 17% in 2024. In contrast, the built-up area increased substantially from 5. 03% to 8. 65%, indicating progressive urban expansion and anthropogenic land transformation. Water bodies showed only a marginal net increase over the study period, while tree cover exhibited a slight positive change. Range land fluctuated during the intermediate period but remained close to its initial proportion by 2024. Table 3 further indicates that the largest net increase during 2018–2024 occurred in built-up area (+3. 644872561%), whereas the largest net decrease was observed in cropland (-3. 625896310%). These changes suggest that agricultural land has likely been converted into urban and infrastructure-related land uses in several parts of the basin. Such transitions are hydrologically significant because increasing built-up area tends to reduce infiltration and enhance runoff, while declining cropland and vegetation alter evapotranspiration and soil water retention characteristics. Water bodies showed a modest rise from 2. 40% in 2018 to 3. 34% in 2021, followed by a decline to 2. 42% in 2024, indicating temporal variation in reservoir storage, tanks, and seasonal surface water spread. Tree cover increased slightly from 0. 57% in 2018 to 0. 70% in 2024, whereas flooded vegetation remained negligible and fluctuated only marginally. Rangeland decreased from 15. 23% in 2018 to 13. 84% in 2021, then recovered to 15. 05% in 2024, suggesting localized transitions between open land, agricultural use, and other categories. Bare ground occupied a very small proportion throughout the study period and did not contribute substantially to basin-scale LULC dynamics. Overall, the LULC transitions indicate a clear tendency toward land conversion from cropland and open land to built-up surfaces, especially in the later phase of the study period. These changes are hydrologically important because they directly affect infiltration capacity, surface roughness, soil moisture retention, evapotranspiration, and runoff generation. Expansion of impervious surfaces tends to reduce infiltration and enhance overland flow, while a reduction in vegetation cover lowers interception and transpiration, thereby altering the basin-scale hydrological balance.

Basin-scale hydrological response under different LULC scenarios

To isolate the hydrological influence of LULC change, the Variable Infiltration Capacity (VIC) model was simulated under multiple LULC scenarios while maintaining the same meteorological forcing across all runs. Therefore, differences in simulated runoff, evapotranspiration (ET), and base flow are attributable primarily to changes in land cover characteristics, vegetation properties, and land surface parameters rather than climatic variability. This scenario-based approach allows the effect of progressive land transformation on basin hydrology to be evaluated more explicitly. The results demonstrate that changes in land cover modify the partitioning of precipitation into surface runoff, evapotranspiration, and subsurface flow, thereby influencing the overall hydrological regime of the Upper Godavari Basin. The observed increase in runoff under recent LULC scenarios is consistent with findings reported by other researchers, who reported increased runoff generation associated with urban expansion in the Godavari Basin.

Runoff response

The scenario analysis indicates that simulated runoff varies significantly under different LULC conditions, as shown in Figure 3. The most recent LULC scenario produced a comparatively higher runoff response than the baseline scenario, suggesting that recent land cover changes have increased the tendency of the basin to generate surface runoff. This increase in runoff can be associated with three major factors: the expansion of built-up land, the reduction in vegetative cover, and the resulting decline in surface permeability. Built-up surfaces reduce infiltration opportunity and promote rapid hydrological response during rainfall events. Similarly, loss of natural vegetation lowers interception storage and weakens the ability of the land surface to delay and absorb rainfall input. The increase in runoff is particularly pronounced during the **monsoon season** when intense precipitation interacts with modified land surface conditions. Under such circumstances, reduced infiltration and storage capacity lead to enhanced overland flow generation. Thus, the results suggest that recent LULC change has shifted parts of the basin toward a more runoff-dominated hydrological response.

Evapotranspiration response

The simulated evapotranspiration exhibits a declining tendency under LULC scenarios characterized by vegetation loss and expansion of built-up area. Areas with reduced forest, shrubland, or dense vegetative cover generate lower ET due to declines in canopy interception, root water uptake, and transpiration. Where natural or semi-natural vegetation is converted into cropland or urban land, the ability of the land surface to return water to the atmosphere becomes limited. Consequently, a greater fraction of rainfall remains available for runoff generation or short-term soil storage. The reduction in evapotranspiration, therefore, complements the runoff increase observed under recent LULC conditions. This decline in ET has important water balance implications at the basin scale. Lower atmospheric water loss may initially appear beneficial for water availability; however, in hydrological terms, it often reflects the degradation of vegetative buffering capacity and contributes to more rapid and concentrated surface flow during the rainy season.

Base flow response

Compared with runoff and evapotranspiration, the simulated base flow shows relatively moderate changes under different LULC scenarios. Nevertheless, noticeable localized increases and decreases are observed in some sub-basins, depending on the nature of land cover transitions and local physiographic conditions. Base flow response is influenced by several interacting factors, including infiltration opportunity, soil water retention, land management practices, soil–vegetation interactions, and the presence of reservoirs, tanks, and irrigation structures. In areas where the extent increases, delayed water release and localized recharge may enhance a base flow-like response. In contrast, urbanized zones with low infiltration potential may suppress groundwater recharge and reduce the groundwater contribution to stream flow. Hence, unlike runoff, which shows a relatively clear increasing trend, base flow response is more spatially heterogeneous and depends strongly on local hydrogeological and land cover controls. Fig. 4 illustrates basin-averaged hydrological components simulated under different LULC scenarios. The results indicate that runoff increased from 332 mm to 371 mm, whereas evapotranspiration declined from 612 mm to 584 mm.

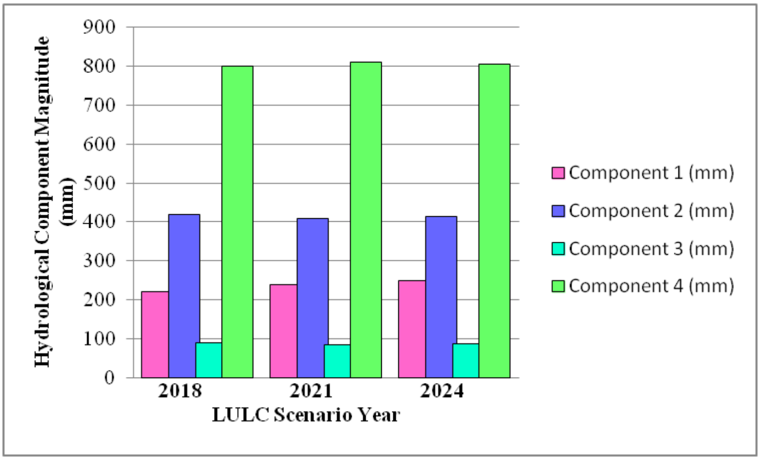


Figure 4: Basin-scale hydrological response under different LULC scenarios.

The basin's averaged annual hydrological components indicate a progressive shift in water balance partitioning under recent LULC conditions. While precipitation was held constant across all scenarios, simulated runoff increased from 332 mm under baseline conditions to 371 mm in the recent LULC scenario, whereas evapotranspiration decreased from 612 mm to 584 mm. Base flow exhibited a comparatively moderate decline from 86 mm to 77 mm, suggesting that the dominant hydrological effect of recent land transformation is an increase in rapid surface response rather than a strong basin-wide change in delayed subsurface flow. During the non-monsoon period, the relative importance of soil moisture storage, groundwater release, and base flow contribution becomes more evident. Thus, LULC change affects not only the annual water balance but also the seasonal timing and magnitude of hydrological response. Seasonal comparison shows that the hydrological influence of LULC change is strongest during the monsoon period. Runoff increased from 300 mm under baseline conditions to 340 mm in the recent LULC scenario during the monsoon season, while monsoon ET declined from 540 mm to 513 mm. In contrast, non-monsoon changes were comparatively smaller, indicating that land cover effects become most visible when intense rainfall interacts with reduced infiltration opportunity and diminished vegetative buffering.

Water balance consistency and interpretation

A water balance consistency assessment was carried out to verify the physical realism of the VIC model outputs under different LULC scenarios. The total rainfall input was compared with the simulated outputs, namely runoff, evapotranspiration, base flow, and change in storage. The basin water balance can be represented as (Mehta and Yadav, 2022):

$$\mathrm{P} = \mathrm{Q} + \mathrm{ET} + \Delta S \tag{5}$$

P = precipitation input,

Q = runoff and base flow components,

ET= evapotranspiration,

ΔS= change in basin water storage, primarily soil moisture storage.

Small residuals in water balance closure may occur due to variations in soil moisture storage between the beginning and end of the simulation period. Inclusion of the storage term improves closure and confirms that the simulated hydrological fluxes are physically consistent. Overall, the results demonstrate that LULC change has a measurable impact on the hydrological regime of the Upper Godavari Basin, particularly through increased runoff generation and reduced evapotranspiration under scenarios characterized by vegetation loss and anthropogenic land conversion. These findings are significant for basin-scale water resources planning, reservoir operation, land use regulation, and watershed management in the catchment. The water balance assessment indicates satisfactory closure across all LULC scenarios, with closure residuals remaining within 1–2 mm. This supports the internal consistency of the estimated hydrological partitioning and confirms that the observed increase in runoff under recent LULC conditions is primarily accompanied by reduced evapotranspiration and a modest reduction in base flow contribution.

CONCLUSION

This study presents a comprehensive assessment of spatiotemporal land use/land cover (LULC) changes in the Upper Godavari Basin and their implications for basin-scale hydrological behaviour. The analysis of multi-temporal satellite datasets for the years 2018, 2021, and 2024 reveals a clear trend of land transformation characterized by a significant increase in built-up area and a corresponding decline in cropland. These changes reflect ongoing urbanization and increasing anthropogenic pressure on land resources within the basin. The observed LULC transitions are hydrologically significant, as they influence the fundamental processes governing the basin water balance. Expansion of built-up area contributes to reduced infiltration capacity and enhanced surface runoff generation, particularly during the monsoon season. Simultaneously, changes in vegetation cover affect evapotranspiration processes, soil moisture retention, and the overall distribution of water within the basin. The combined effect of these changes suggests a shift toward a more rapid hydrological response, with potential implications for increased flood susceptibility and altered seasonal water availability. In addition, the reduction in permeable surfaces and modification of land cover characteristics may influence groundwater recharge and base flow contribution, which are critical for sustaining river flows during dry periods. The study highlights that land use dynamics not only affect the magnitude of hydrological components but also their temporal distribution, particularly in monsoon-dominated environments. Overall, the findings emphasize the importance of integrating LULC change analysis into basin-scale water resources planning and watershed management. Understanding the interaction between land transformation and hydrological processes is essential for developing effective strategies to manage increasing water stress, mitigate flood risks, and ensure sustainable utilization of water resources in the Upper Godavari Basin. The approach adopted in this study provides a practical framework for evaluating land-water interactions using spatial data, and it can be extended to other river basins experiencing similar land use transitions.

Acknowledgments

The authors gratefully acknowledge the India Meteorological Department (IMD) for providing gridded rainfall and temperature datasets and the relevant agencies (NBSS&LUP and NRSC/ISRO) for soil and LULC datasets used in this study. The authors also thank the reviewers and editors for their constructive comments, which improved the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

ABDEDDAIM H., BENKHALED A. (2016). Influence of the hydrographic network on hydrologic response "in northeast watersheds of Algeria”, Larhyss Journal, No 27, pp. 313-335. (In French)

ARGAZ A. (2018). 1D model application for integrated water resources planning and evaluation: case study of Souss river basin, Morocco, Larhyss Journal, No 36, pp. 217-229.

ATALLAH M., DJELLOULI F., HAZZEB A. (2024). Rainfall-runoff modeling using the HEC-HMS model for the Mekerra wadi watershed (N-W Algeria), Larhyss Journal, No 57, pp. 187-208.

BELLOUFI Y., BRIMA A., ATMANI R., MOUMMI N., AISSAOUI F. (2016). Theoretical and experimental study of air refresh by a geothermal heat exchanger air/ground, Larhyss Journal, No 25, pp. 121-137. (In French)

BEMMOUSSAT A., ADJIM M., BENSAOULA F (2017). Use of the ZYGOS model for the estimation of groundwater recharge in Sikkak watershed (Northen west of Algeria), Larhyss Journal, No 30, pp. 105-119. (In French)

BENTALHA C. (2023). Evaluation of the hydraulic and hydrology performance of the green roof by using SWMM, Larhyss Journal, No 53, pp. 61-72.

BHARDWAJ K., SHAH D., AADHAR S., MISHRA V. (2020). Propagation of meteorological to hydrological droughts in India, Journal of Geophysical Research: Atmospheres, Vol. 125, No 22, pp. 1-13.

BISWAS B., JADHAV R.S., TIKONE N. (2019). Rainfall distribution and trend analysis for Upper Godavari Basin, India, from 100 years record (1911–2010), Journal of the Indian Society of Remote Sensing, Vol. 47, No 10, pp. 1781-1792.

CHABOKPOUR J., AZAMATHULLA H.M.D. (2025). Multi-scale CFD analysis of erosion dynamics in heterogeneous rockfill structures implications for sustainable hydraulic engineering design, Larhyss Journal, No 61, pp. 217-239.

CHIBANE B., ALI-RAHMANI S.E. (2015). Hydrological based model to estimate groundwater recharge, real- evapotranspiration and runoff in semi-arid area, Larhyss Journal, No 23, pp. 231-242.

CHOUKRANI G., HAMIMSA A., SAIDI M.E., BABQIQI A. (2018). Diagnosis and future projection of climate change in arid zone. case of Marrakech-Safi region (Morocco), Larhyss Journal, No 36, pp. 49-63. (In French)

DEEPTHI B., SUNIL A., NAIR S.C., MIRAJKAR A.B. (2020). Ranking of CMIP5-based general circulation models using compromise programming and TOPSIS for precipitation: A case study of Upper Godavari Basin, India, International Journal of Big Data Mining for Global Warming, Vol. 2, No 2, pp. 1-16.

DOUMOUNIA A., ZEBA A., DAMIBA L., ZOUGMORE F., NIKIEMA M. (2020). Climate variability analysis in the Nouhao sub-basin in eastern center of Burkina Faso, Larhyss Journal, No 41, pp. 57-69.

EZZ H. (2025). Unexpected flooding in Mersa Matruh, Egypt - Investigating causes, hydrological analysis, and flood risk assessment, Larhyss Journal, No 61, pp. 371-399.

FAREGH W., BENKHALED A. (2016). GIS based SCS-CN method for estimating runoff in Sigus watershed, Larhyss Journal, No 27, pp. 257-276. (In French)

GAALOUL N. (2015). Modeling of underground flows in unsaturated porous medium: application to artificial recharge by treated wastewater - Korba coastal water table (cap-bon, Tunisia), Larhyss Journal, No 21, pp. 181-190. (In French)

GITHIRI G., SIETCHIPING R., ROMERO C., (2021). UN-habitat urban-rural linkages program and pilot projects, Larhyss Journal, No 47, pp. 7-23.

GOHIL, M., MEHTA, D., SHAIKH, M. (2024a). An integration of geospatial and fuzzy-logic techniques for multi-hazard mapping, Results in Engineering, Vol. 21, Paper ID 101758.

GOHIL, M., MEHTA, D., SHAIKH, M. (2024). An integration of geospatial and fuzzy-logic techniques for flood-hazard mapping, Journal of Earth System Science, Vol. 133, Issue 2, Article No. 80.

HAMIMED A., ZAAGANE M., OUALID A.T., TEFFAHI M., BAKHTIAR D. (2017). Monitoring daily actual evapotranspiration and surface water status over an agricultural area in western Algeria using remote sensing data, Larhyss Journal, No 29, pp. 45-59.

HENGADE N., ELDHO T.I. (2019). Relative impact of recent climate and land cover changes in the Godavari River Basin, India, Journal of Earth System Science, Vol. 128, No 4, pp. 1-17.

HENGADE N., ELDHO T.I., GHOSH S. (2018). Climate change impact assessment of a river basin using CMIP5 climate models and the VIC hydrological model, Hydrological Sciences Journal, Vol. 63, No 4, pp. 596-614.

HOUNTONDJI B., CODO F.P., AHOUMENOU Y., SINTONDJI L.O., AHOUANSOU M. (2019). Infiltration of waters and deposits in the retention of the mini-dam of Wourowourokou in northern Benin, Larhyss Journal, No 39, pp. 201-214. (In French)

KHERDE R.V., MEHTA D.J., MORE K.C., SAWANT P.H. (2024). Dynamic watershed modelling: HEC-HMS analysis of a tropical watershed, Larhyss Journal, Vol. 60, No 1, pp. 87-111.

KONETI S., SUNKARA S.L., ROY P.S. (2018). Hydrological modeling with respect to impact of land-use and land-cover change on the runoff dynamics in Godavari River Basin using the HEC-HMS model, ISPRS International Journal of Geo-Information, Vol. 7, No 6, pp. 1-21.

KOUAO J.M., KOUASSI A.M., DEKOULA S.C., ASSEUFI B.D. (2020). Analysis of the climate regionalization of the ivory coast in a changing climate context, Larhyss Journal, No 41, pp. 233-259. (In French)

LONG A., MOKHTAR M., HALIM S., AHMED F. (2023). Fostering inclusive watershed management through Multihelix engagement model on micro hydropower electrification in Sabah, Malaysia, Larhyss Journal, No 56, pp. 7-24.

LUO Z., SHAO Q. (2022). A modified hydrologic model for examining the capability of global gridded PET products in improving hydrological simulation accuracy of surface runoff, streamflow and baseflow, Journal of Hydrology, Vol. 610, No 1, pp. 1-15.

MAH D.Y.S., DAYANG NUR HUWAIDA A.S., TEO F.Y. (2023). Investigation of historical extreme rainfall on permeable road in a commercial centre, Larhyss Journal, No 53, pp. 165-182.

MAHAPATRA S., JHA M.K., BISWAL S., SENAPATI D. (2020). Assessing variability of infiltration characteristics and reliability of infiltration models in a tropical sub-humid region of India, Scientific Reports, Vol. 10, No 1, pp. 1-18.

MEHTA, D., YADAV, S.M. (2022). Temporal analysis of rainfall and drought characteristics over Jalore District of SW Rajasthan, Water Practice & Technology, Vol. 17, Issue 1, pp. 254-267.

MEHTA, D., PRAJAPATI, K., ISLAM, M.N. (2022). Watershed delineation and land use land cover (LULC) study of Purna River in India, In India II: Climate Change Impacts, Mitigation and Adaptation in Developing Countries, Cham: Springer International Publishing, pp. 169-181.

MEHTA D., YADAV S. (2024). Rainfall runoff modelling using HEC-HMS model: case study of Purna river basin, Larhyss Journal, No 59, pp. 101-118.

MFOUTOU W., DIABANGOUAYA D.B. (2019). Bank erosion on the Mfilou river on Brazzaville, Larhyss Journal, No 39, pp. 299-311. (In French)

MISTRY A., LODHA P., PRAKASH I., MEHMOOD K. (2017). Estimation of direct runoff for Purna River sub-basin using SCS-CN method, Dangs District, Gujarat, International Journal of Advance Engineering and Research Development, Vol. 4, No 4, pp. 581-593.

MOLAVI A. (2025). Application of intelligent autocorrelated models for runoff simulation a case study of the Iranian Samiyan and Doostbighlou rivers, Larhyss Journal, No 64, pp. 7-32.

MOSKOVKIN V.M., SERKINA O.V., LESOVIK R.V., MITROKHIN A.A., DOBRYDINA I.M. (2018). Trends in studying urban runoff: A retrospective analysis, Amazonia Investiga, Vol. 7, No 14, pp. 228-239.

PATIL G., KHERDE R. (2024). Hydrological modeling of a river basin using Monte Carlo simulation techniques, Trends in Sciences, Vol. 21, No 6, pp. 1-16.

QURESHI H.U., ABBAS I., SHAH S.M.H., TEO F.Y. (2024). Hydrologic evaluation of monthly and annual groundwater recharge dynamics for a sustainable groundwater resources management in Quetta city, Pakistan, Larhyss Journal, No 60, pp. 27-53.

REMINI B. (2019). The Oasis of El Guerrara (Algeria): irrigation and recharge of the aquifers ensured by the floods, Larhyss Journal, No 40, pp. 135-163. (In French)

RIAHI R., BELAID H., HATIRA A., BACCOUCHE S. (2020). Contribution to the study of runoff and erosion of low slope homogeneous hydrological units of a watershed of the middle valley of Medjerda (Tunisia), Larhyss Journal, No 43, pp. 119-137.

SARAF V.R., REGULWAR D.G. (2018). Impact of climate change on runoff generation in the Upper Godavari River Basin, India, Journal of Hazardous, Toxic, and Radioactive Waste, Vol. 22, No 4, pp. 1-9.

SORO G.E., NOUFE D., GOULA BI T.A. (2018). Sensitivity analysis of a global hydrological model to the estimates of average rainfall and potential evapotranspiration: application to the Marahoue basin in Cote d'Ivoire, Larhyss Journal, No 23, pp. 115-168. (In French)

VAND A.S., SIHAG P., SINGH B., ZAND M. (2018). Comparative evaluation of infiltration models, KSCE Journal of Civil Engineering, Vol. 22, No 10, pp. 4173-4184.

WOLDEAREGAY M., WOLDU Z., MASRESHA G., SAMUEL Y. (2026). Land use/land cover change dynamics of moist evergreen Afromontane Forest, Southern Ethiopia: Implications for conservation, Scientific African, Vol. 31, No 1, pp. 1-15.

YANG Y., YANG Y., XIA. (2021). Hydrological cycle and water resources in a changing world: A review, Geography and Sustainability, Vol. 2, No 2, pp. 115-122.