National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development & Ganga Rejuvenation
Government of India

Hydrologic Status of Godavari River Basin

December 2024

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National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development & Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

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Centres for Mahanadi River Basin Management and Studies (cMahanadi)

The Center for Godavari River Basin Management and Studies (cGodavari) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by CSIR-NEERI and IIT Hyderabad, under the supervision of cGanga at IIT Kanpur, the center serves as a knowledge wing of the National River Conservation Directorate (NRCD). cGodavari is committed to restoring and conserving the Godavari River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.
www.cGodavari.org

Centres for Ganga River Basin Management and Studies (cGanga)

cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.

www.cganga.org

Acknowledgment

This report is a comprehensive outcome of the project jointly executed by CSIR-NEERI (Lead Institute) and IIT Hyderabad (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It is submitted to the National River Conservation Directorate (NRCD) in 2024. We gratefully acknowledge the individuals who provided information and photographs for this report.

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Preface

In an era of unprecedented environmental change, understanding our rivers and their ecosystems has never been more critical. This report aims to provide a comprehensive overview of our rivers, highlighting their importance, current health, and the challenges they face. As we explore the various facets of river systems, we aim to equip readers with the knowledge necessary to appreciate and protect these vital waterways.

Throughout the following pages, you will find an in-depth analysis of the principles and practices that support healthy river ecosystems. Our team of experts has meticulously compiled data, case studies, and testimonials to illustrate the significant impact of rivers on both natural environments and human communities. By sharing these insights, we hope to inspire and empower our readers to engage in river conservation efforts.

This report is not merely a collection of statistics and theories; it is a call to action. We urge all stakeholders to recognize the value of our rivers and to take proactive steps to ensure their preservation. Whether you are an environmental professional, a policy maker, or simply someone who cares about our planet, this guide is designed to support you in your efforts to protect our rivers.

We extend our heartfelt gratitude to the numerous contributors who have generously shared their stories and expertise. Their invaluable input has enriched this report, making it a beacon of knowledge and a practical resource for all who read it. It is our hope that this report will serve as a catalyst for positive environmental action, fostering a culture of stewardship that benefits both current and future generations.

As you delve into this overview of our rivers, we invite you to embrace the opportunities and challenges that lie ahead. Together, we can ensure that our rivers continue to thrive and sustain life for generations to come.

Centre for the Godavari River Basin
Management and Studies (cGodavari)
CSIR-NEERI, IIT Hyderabad

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Abbreviations and Acronyms

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
CWC	Central Water Commission
DEMs	Digital Elevation Models
ET	Evapotranspiration
FABDEM	Forest and Buildings removed Copernicus DEM
FLDAS	Famine Early Warning Systems Network Land Data Assimilation System
GIS	Geographic Information System
HFL	High Flood Level
IMD	India Meteorological Department
LULC	Land Use and Land Cover
NHP	National Hydrology Project
HMS	Hydro-Meteorological Site

1. Introduction

Hydrology is a vital scientific discipline that focuses on the occurrence, distribution, movement, and properties of water in the Earth's atmosphere and on its surface. As a branch of environmental science, hydrology examines the water cycle—encompassing processes such as precipitation, evaporation, infiltration, and runoff—and how these processes interact with various ecological and geological systems. Understanding hydrology is essential not only for predicting weather patterns and managing water resources but also for addressing pressing global challenges such as climate change, urbanization, and water scarcity.

The significance of hydrology extends beyond mere water management; it is intricately linked to public health, agriculture, and ecosystem sustainability. For instance, effective hydrological studies inform agricultural practices by optimizing irrigation techniques and enhancing crop yields while minimizing water waste. Furthermore, hydrologists play a crucial role in flood risk assessment and management, helping communities prepare for and mitigate the impacts of extreme weather events. As urban areas continue to expand, the need for sustainable water management practices becomes increasingly critical to ensure that both human populations and natural ecosystems can thrive.

Recent advancements in hydrological research have integrated modern technologies such as remote sensing and geographic information systems (GIS), enabling more precise monitoring and modeling of water resources. These tools allow scientists to analyze complex hydrological data and develop predictive models that can inform policy decisions and resource management strategies. As we face unprecedented environmental challenges, the role of hydrology in fostering a deeper understanding of our planet's water systems has never been more important. In hydrological modeling, the accuracy and reliability of predictions largely depend on the quality of input data. Key components include rainfall, evaporation, and discharge, each playing a crucial role in understanding water dynamics within a given watershed.

2. Digital Elevation Model (DEM)

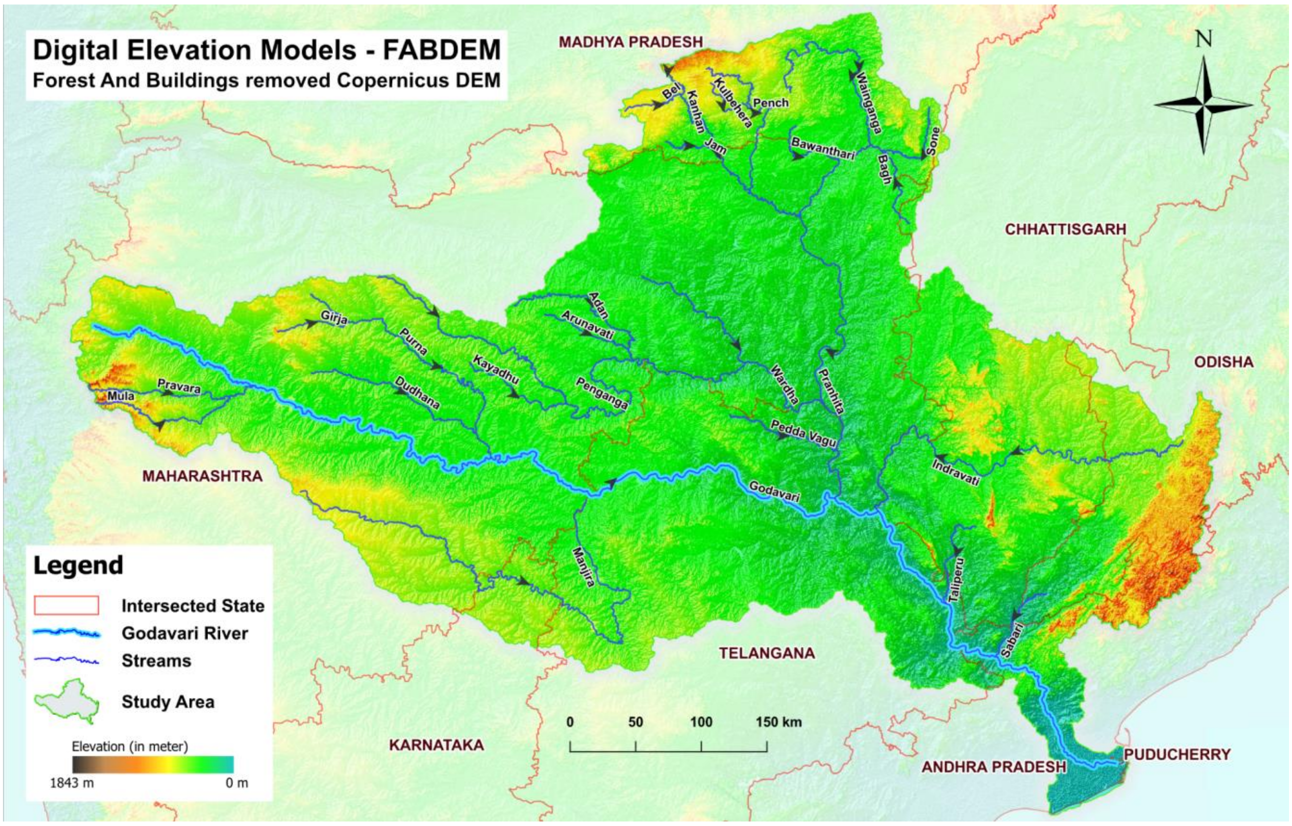

Figure 1 FABDEM (Forest and Buildings removed Copernicus DEM) with 30m resolution

Digital Elevation Models (DEMs) are essential for a wide range of geospatial analyses, providing detailed representations of the Earth's surface elevations. Among the notable datasets in this domain is the FABDEM (Forest and Buildings removed Copernicus DEM) shown in Figure 1, developed by researchers Jeffrey Neal and Laurence Hawker and published by the University of Bristol. Released on January 18, 2023, FABDEM is a global elevation dataset that specifically removes biases introduced by vegetation and structures, offering a clearer view of the terrain. With a total size of 296.7 GiB, it is available under a Non-Commercial Government Licence, facilitating access to high-resolution elevation data crucial for various applications such as topographic mapping, hydrological modeling, and environmental analysis[1].

FABDEM's data sources include satellite imagery and aerial surveys, ensuring high accuracy and reliability across its coverage. The dataset's resolution varies based on specific tiles downloaded, which are organized into multiple zip files covering different geographical extents. This modular structure allows users to select only the relevant portions of the dataset for their specific research needs, enhancing data management efficiency.

FABDEM's high-resolution elevation data offers significant practical applications and benefits for various stakeholders in the Godavari Basin. For water resource managers, it aids in identifying natural water storage areas, planning flood control measures, and understanding groundwater recharge zones. Urban planners can leverage the detailed terrain data to ensure safe development away from flood-prone zones, design efficient drainage systems, and align infrastructure planning with natural topography. Agricultural stakeholders, including farmers and planners, can utilize the data to determine suitable irrigation methods, implement soil conservation measures, and manage water availability effectively.

Despite its strengths, such as 30-meter resolution, removal of vegetation and building biases, and consistent basin-wide coverage, FABDEM has areas for improvement. These include ground truthing in densely vegetated regions, validating data in rapidly urbanizing areas, and integrating with real-time monitoring systems. To enhance its utility, future efforts should focus on technical advancements like automated validation systems, real-time flood monitoring integration, and user-friendly analysis tools. Additionally, stakeholder engagement through training programs, simplified visualization tools, and regular feedback sessions will ensure broader adoption and effective use of FABDEM's capabilities.

3. Land Use and Land Cover

Land use and land cover (LULC) data are essential for assessing the impact of human activities on hydrological processes. Changes in land use can significantly affect water runoff, infiltration rates, and overall watershed health. LULC data is typically derived from satellite imagery, aerial photography, and ground surveys.

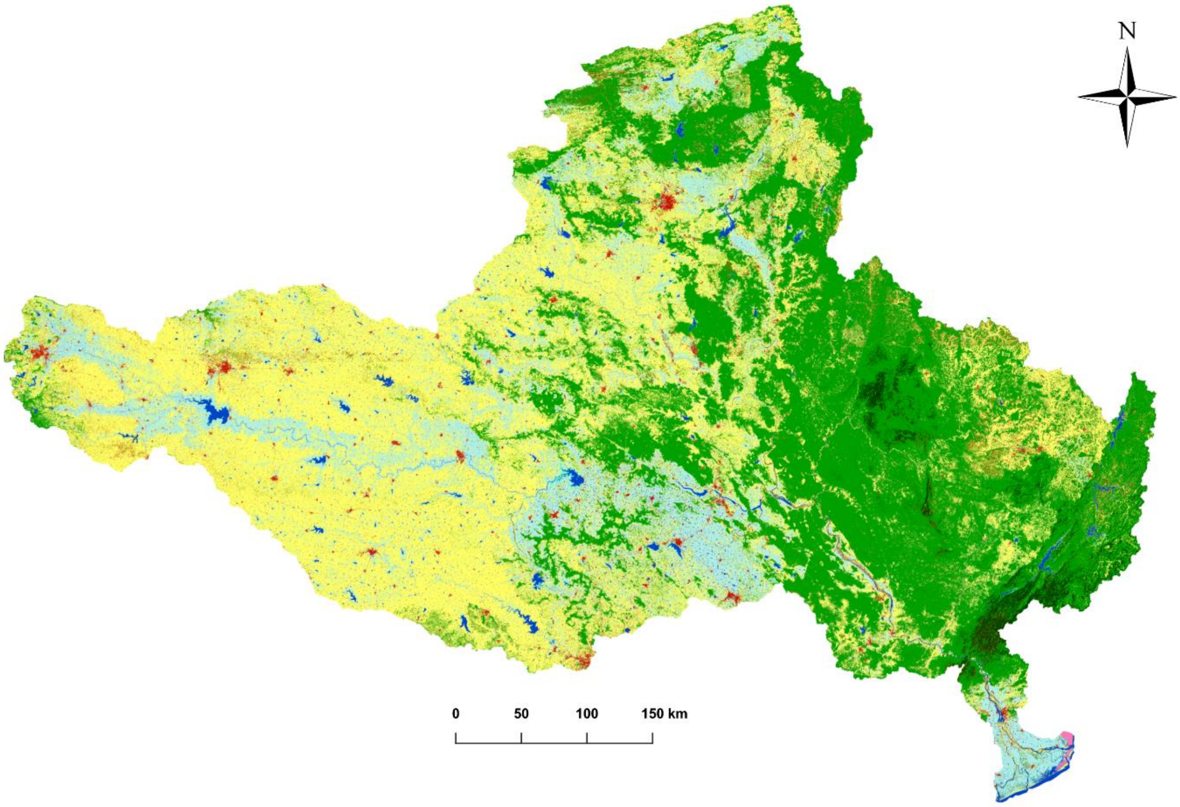

Figure 2 Land Use Land Cover of the Godavari Basin (2022)

Figure 2 shows GLC_FCS30D data for 2022, it is a novel global 30-meter land cover dynamics monitoring dataset that provides comprehensive insights into land cover dynamics from 1985 to 2022. It contains 35 land-cover subcategories with updates every five years prior to 2000 and annually thereafter. The dataset was developed using continuous change detection methods and the extensive Landsat imagery archives within the Google Earth Engine platform. Refined through spatiotemporal classification and temporal-consistency optimization, GLC_FCS30D achieves high-confidence accuracy, validated with over 84,000 global samples and attaining an overall accuracy of 80.88%. It reveals forest and cropland variations as dominant drivers of global land cover change over the past 37 years, with a net loss of approximately 2.5 million km² of forests and a net gain of around 1.3 million km² in cropland area. This dataset is valuable for climate change research and sustainable development analysi`s due to its diverse classification system, high spatial resolution, and extensive temporal coverage. It is also available in the Google Earth Engine Community catalog[2].

The landscape divides itself into three distinct regions:

- The Western Agricultural Zone

The western portion of the basin is dominated by yellow areas, indicating extensive rainfed cropland. This tells us that farmers in this region depend primarily on seasonal rainfall for their crops, making them particularly vulnerable to changes in precipitation patterns.

- The Central Transition Zone

  Moving eastward, we see a mix of agricultural land gradually giving way to forest cover. This transition zone, with its mosaic of land uses, serves as a critical buffer between intensive agriculture and dense forest areas.

- The Eastern Forest Belt

  The eastern section reveals extensive green areas representing various forest types, from open deciduous to dense evergreen forests. These forests play a crucial role in the basin's hydrology, acting as natural water towers that regulate water flow throughout the year

The map reveals several key insights about the basin's environmental health and human activities:

- Water Systems

  The presence of blue areas indicating water bodies and wetlands shows us the basin's natural water storage systems. These areas, including swamps, marshes, and flooded flats, act as natural sponges that help regulate water flow and prevent flooding.

- Agricultural Practices

  The distinction between rainfed and irrigated cropland helps us understand water demand patterns. Rainfed agriculture (shown in yellow) dominates much of the basin, while irrigated areas (shown in lighter shades) are strategically located near water sources.

- Urban Development

  Small red patches scattered throughout the map represent impervious surfaces and urban areas. While these areas appear small, their impact on local hydrology is significant, as they alter natural water infiltration patterns.

The current Land Use and Land Cover (LULC) data, while valuable, has critical gaps and uncertainties that need addressing to improve its accuracy and utility. Temporal resolution is a key limitation, as the 2022 data, though detailed, requires more frequent updates to capture rapid changes, particularly in urban expansion zones. Classification accuracy is another challenge, especially in mixed-use areas where distinguishing between land uses categories can be difficult, necessitating ground verification. Additionally, the data may not fully account for seasonal variations, particularly in agricultural regions where crop patterns change throughout the year.

Despite these limitations, LULC data offers significant applications for various stakeholders. Agricultural planners can use it to differentiate between rainfed and irrigated agriculture, aiding in water resource allocation and drought resilience strategies. Forest managers benefit from detailed forest classifications to monitor forest health, plan conservation efforts, and manage resources sustainably. Urban planners can identify urban areas and their interactions with other land uses, enabling sustainable urban expansion while protecting agricultural and forest lands.

To enhance the utility of LULC data, future improvements should focus on technical advancements, such as developing more sophisticated classification algorithms for better accuracy in mixed-use areas. Implementing regular monitoring systems to track land use changes at shorter intervals will help capture rapid transformations. Additionally, creating tools to integrate LULC data with other environmental datasets, such as rainfall, soil quality, and groundwater levels, will enable more comprehensive and actionable insights.

4. Stream Gauge and Discharge Data

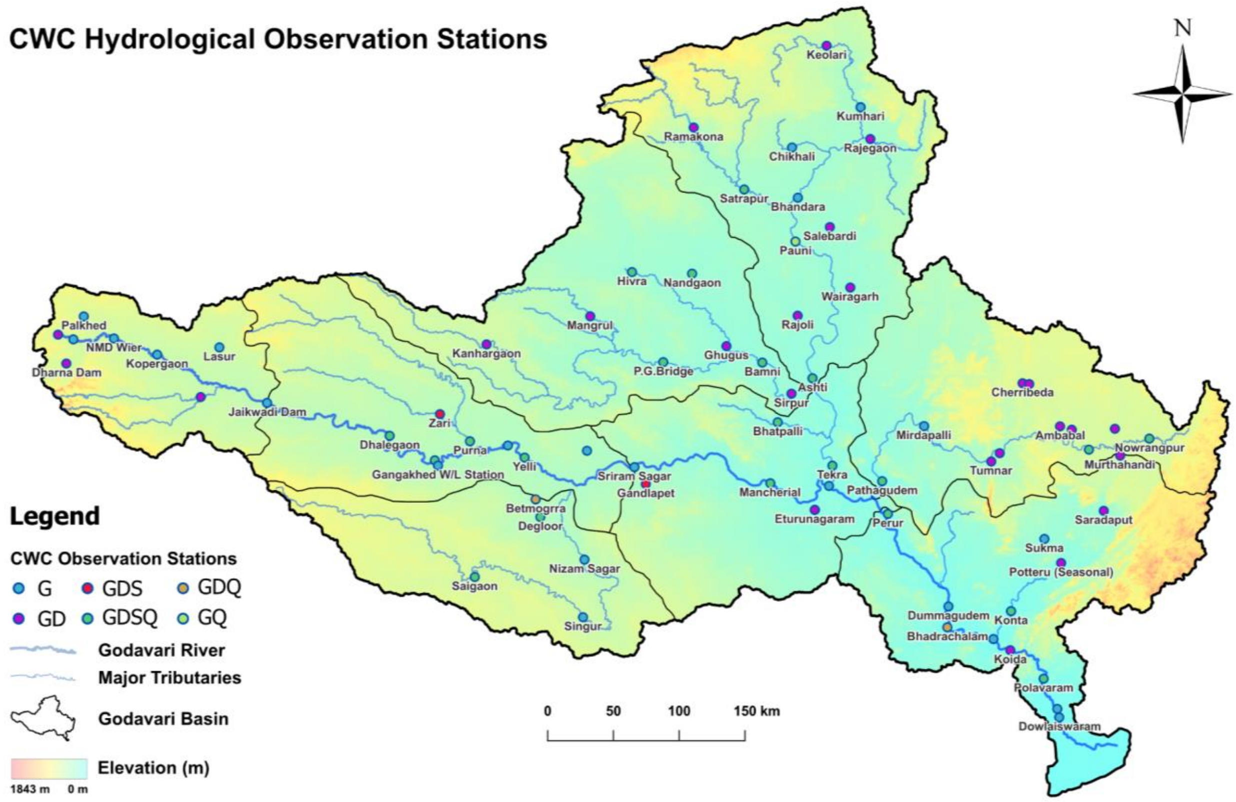

Figure 3 CWC Hydrological Observation Stations

The Godavari River Basin, one of the largest river basins in India, is monitored through a network of gauge stations maintained by the Central Water Commission (CWC). Figure 3 shows different CWC Hydrological Observation Stations. The basin river network comprises 48 gauge-discharge sites, which are crucial for collecting data on water levels and discharge rates. At 16 of these sites, sediment observations are also conducted, providing comprehensive insights into the river's hydrology and sediment transport dynamics. GDSQ refers to a type of hydro-meteorological site (HMS) used by the Central Water Commission (CWC) for collecting hydrological, meteorological, and water quality parameters. In this acronym, G stands for Gauge, D for Discharge, S for Sediment, and Q for Water Quality. The data collected is essential for managing water resources, flood forecasting, and understanding the ecological health of the river system.

The Godavari River, spanning approximately 1,465 km, flows through several states including Maharashtra, Telangana, and Andhra Pradesh, draining into the Bay of Bengal. The basin encompasses a total catchment area of about 312,812 square kilometers. Discharge data from both the mainstream Godavari and its tributaries, such as the Indravati and Penganga rivers, are vital for assessing water availability and planning irrigation and other water resource management strategies. Historical discharge data indicate significant variability influenced by seasonal monsoon rains, which contribute to peak discharge levels during the monsoon season.

Figure 4 shows the availability of discharge data from various gauge stations over a roughly 20-year period (2001-2022). The visualization uses a color-coded system:

- Green bars indicate periods when data was available
- Black bars indicate periods when data was missing or part of a "data mission"

The graph tracks 17 different stations, listed vertically (from Polavaram at the top to Ashu at the bottom). What's notable is that there are varying patterns of data availability across stations:

- Some stations like Polavaram show significant gaps (black sections)
- Others like Tekra show more consistent data collection (mostly green)
- Many stations show intermittent gaps, particularly in recent years (2018-2022)

Figure 5 is a bar graph showing the daily discharge measurements (in cumecs - m3/sec) for each gauge station. Some key observations:

- Polavaram shows the highest discharge rate at about 52,811 cumecs
- Peint shows the lowest recorded discharge at about 2,194 cumecs
- There's significant variation between stations, with some showing moderate discharge rates between 5,000-15,000 cumecs
- The data appears to represent maximum or peak discharge values for each station

Figure 4 Discharge data availability Godavari basin (source: India WRIS)

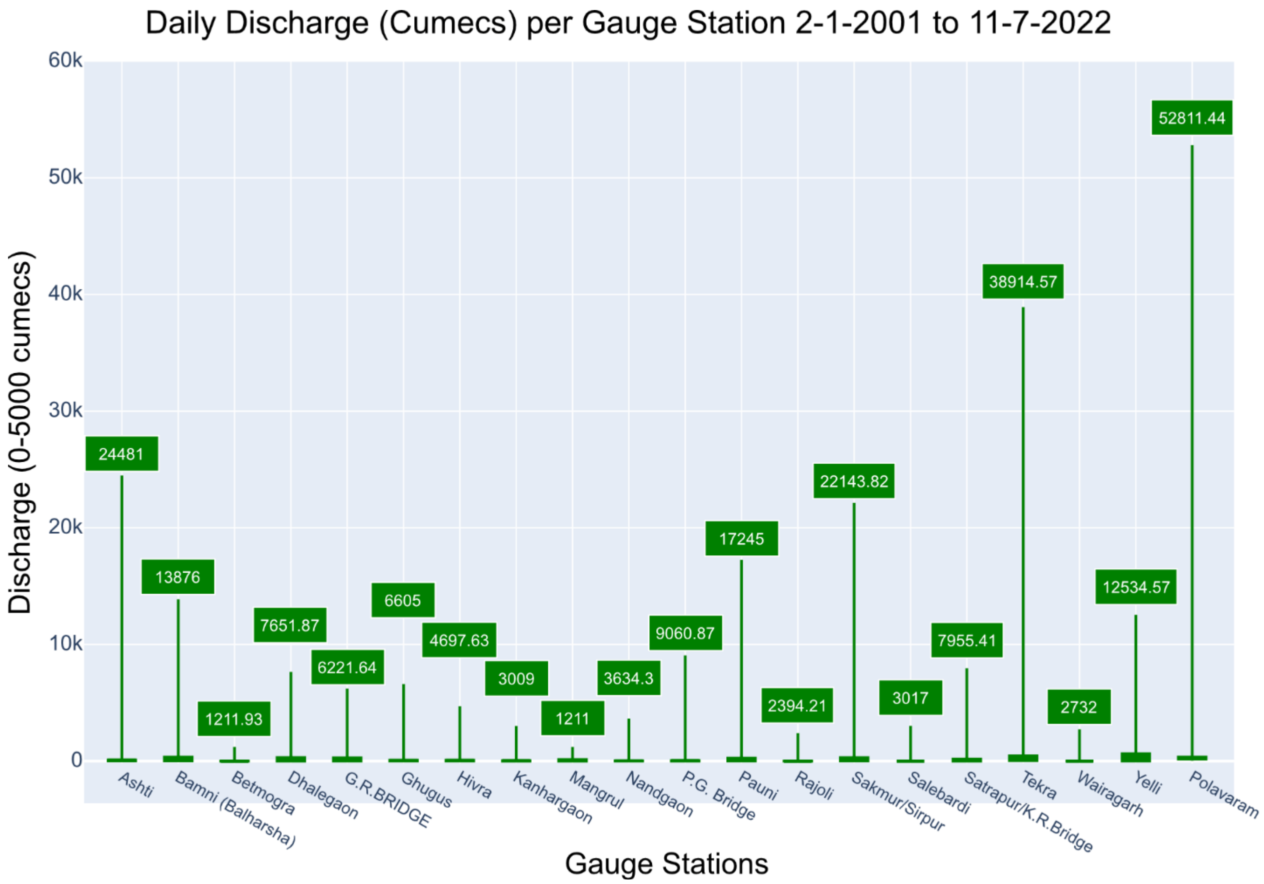

Figure 5 Daily discharge of gauge station (source: India WRIS)

High Flood Level (HFL) values are critical for flood risk management within the basin. The maximum observed flood discharge recorded at various gauge sites provides a benchmark for understanding potential flood scenarios. For instance, historical records indicate that extreme flood events can lead to discharges exceeding 20,000 m3/sec. Monitoring HFL values helps in designing infrastructure such as dams and levees to mitigate flood risks effectively.

Inter-basin transfers play a significant role in managing water resources across different river basins. In the context of the Godavari Basin, water transfers from tributaries to other basins are monitored to optimize resource allocation during periods of scarcity. This data is essential for understanding how changes in one basin may affect water availability in another, particularly during dry seasons when demand for water increases.

The frequency of data collection at gauge stations varies; however, continuous monitoring is typically prioritized during critical periods such as the monsoon season. The CWC collects daily discharge data at many sites while some locations may have ten-daily or monthly observations depending on their importance and historical trends. This systematic approach ensures timely updates on river conditions, enabling effective management responses to changing hydrological patterns.

5. Rainfall Data

Rainfall is one of the most significant variables in hydrology, as it directly influences surface runoff, groundwater recharge, and overall water availability. Accurate rainfall data is essential for effective water resource management and flood forecasting. Various methods are employed to collect and analyze rainfall data, including ground-based measurements from rain gauges and remote sensing technologies that provide spatially distributed precipitation estimates.

Recent studies have highlighted the importance of using high-resolution rainfall data for hydrological modeling. For instance, a predictive model that integrates rainfall forecasts with urban drainage systems has demonstrated improved performance when utilizing detailed rainfall inputs. Moreover, advancements in machine learning techniques have shown promise in enhancing rainfall-runoff modeling accuracy by effectively processing multiple meteorological datasets. These approaches underscore the necessity of precise rainfall data in hydrological assessments.

The India Meteorological Department (IMD) has released a valuable dataset: the New High Spatial Resolution (0.25° x 0.25°) Long Period (1901-2022) Daily Gridded Rainfall Data Set over India[3]. This dataset provides daily rainfall data at a very high spatial resolution, allowing for detailed analysis of rainfall patterns across India. The data, measured in millimeters (mm), spans 122 years, offering a comprehensive historical perspective. The dataset comprises 135x129 grid points, covering the region from 6.5°N, 66.5°E to 38.5°N, 100.0°E. Each yearly data file contains 365 or 366 records, accounting for non-leap and leap years, respectively. This dataset is a valuable resource for researchers, policymakers, and agricultural professionals to study climate variability, hydrological processes, and agricultural planning.

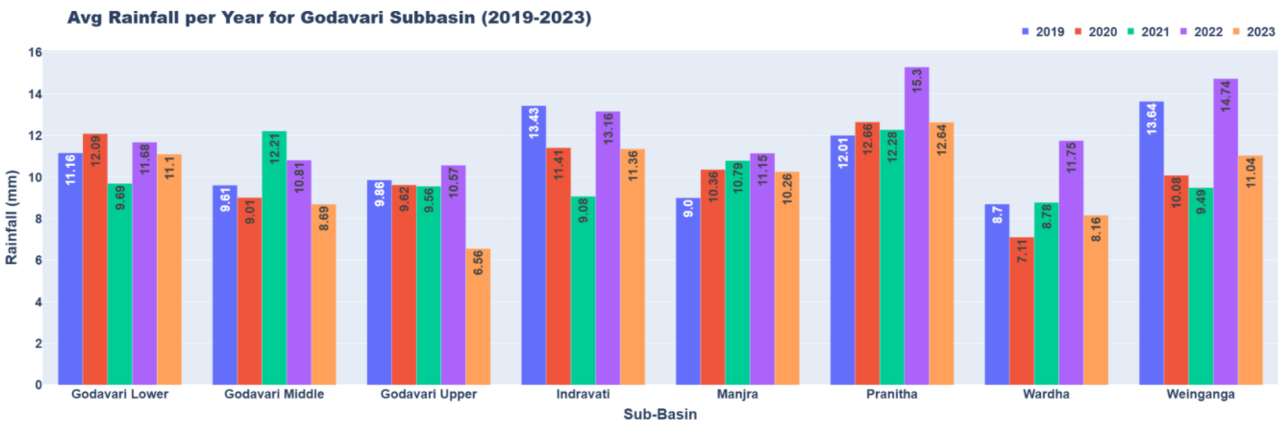

Figure 6 Average rainfall per year for the Godavari Subbasin (2019-2023)

Figure 6 shows fascinating patterns across the eight sub-basins of the Godavari:

The Weinganga sub-basin emerges as the region's water tower, consistently receiving the highest rainfall. The 2022 peak of 14.74 mm represents the maximum recorded across all sub-basins during our study period. Think of Weinganga as the basin's natural reservoir, playing a crucial role in maintaining water flow throughout the system.

The Pranitha sub-basin tells a different story—one of dramatic fluctuations. Its rainfall pattern resembles a roller coaster, ranging from 12.01 mm in 2019 to an impressive 15.3 mm in 2022, before declining sharply in 2023. These fluctuations create unique challenges for water management and agricultural planning

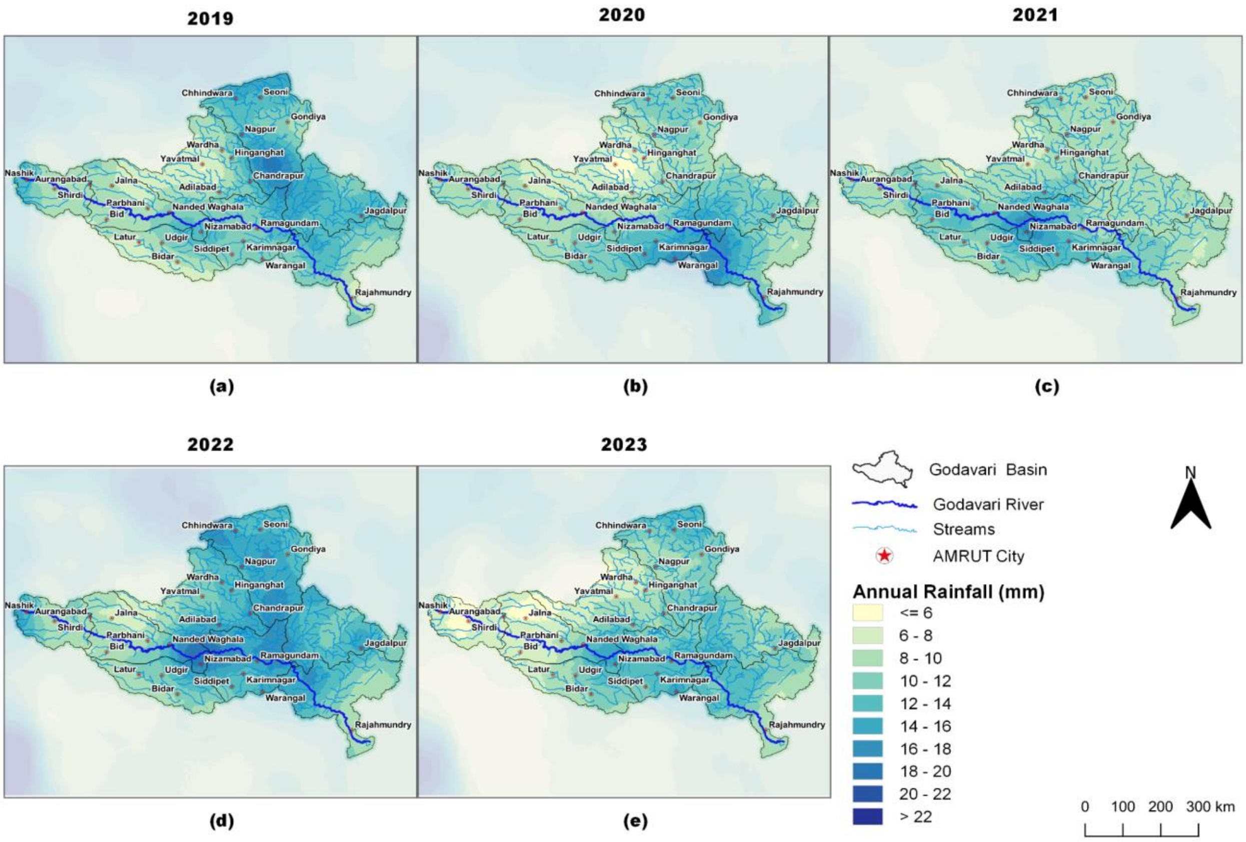

Figure 7 Annual Rainfall (mm) of the Godavari Basin (2019-2023)

Figure 7 shows annual rainfall patterns in the Godavari Basin from 2019-2023, there's a clear spatial variation in rainfall distribution:

Higher Rainfall Areas:

- The central and northeastern parts of the basin consistently show higher rainfall (dark blue regions)
- These areas receive annual rainfall of >18-22mm or more
- This higher rainfall zone appears to be concentrated around the middle portion of the Godavari River and its tributaries
- The pattern remains relatively consistent across all five years, though with some slight variations in intensity

Lower Rainfall Areas:

- The western and northwestern portions of the basin receive significantly less rainfall (light green regions)
- These areas typically receive around 6-10mm of annual rainfall

- This creates a notable rainfall gradient from west to east in the basin
- The western edge consistently shows the lowest rainfall amounts across all years

This rainfall pattern variation could be attributed to several factors:

1. Topographical features affecting rainfall distribution
2. Distance from the coast and moisture sources
3. Regional atmospheric circulation patterns
4. Orographic effects from local terrain

Looking ahead, there are significant opportunities to enhance the utility of the current dataset through targeted improvements and stakeholder-specific actions. Data enhancement opportunities include integrating real-time rainfall data to support immediate decision-making and establishing a network of ground-truth stations to validate and calibrate satellite-based measurements, ensuring greater accuracy and reliability.

For stakeholders, tailored approaches are essential to maximize the dataset's value. Farmers in the agricultural sector would benefit from seasonal forecasting tools that integrate historical rainfall patterns, enabling informed cropping decisions. Urban planners, particularly in AMRUT cities, require detailed water budgeting tools that account for changing rainfall patterns to support sustainable urban development. Water management authorities need advanced early warning systems for both floods and droughts, leveraging observed trends to improve preparedness and response. By addressing these recommendations, the dataset can become a more powerful tool for informed decision-making across sectors

6. Evaporation and Water Loss Data

Evaporation metrics are crucial for understanding water loss within the Godavari Basin, a region characterized by its diverse hydrological dynamics. These metrics quantify the rate at which water is converted from liquid to vapor, significantly influencing local water availability and ecosystem health. The Godavari Basin experiences variations in evaporation due to climatic factors, vegetation cover, and land use practices. Accurate measurement of evaporation is essential for effective water resource management, particularly in the context of climate change and increasing water demands. The integration of remote sensing technologies and ground-based observations can enhance the reliability of evaporation data, providing insights into seasonal patterns and long-term trends that are vital for sustainable management strategies.

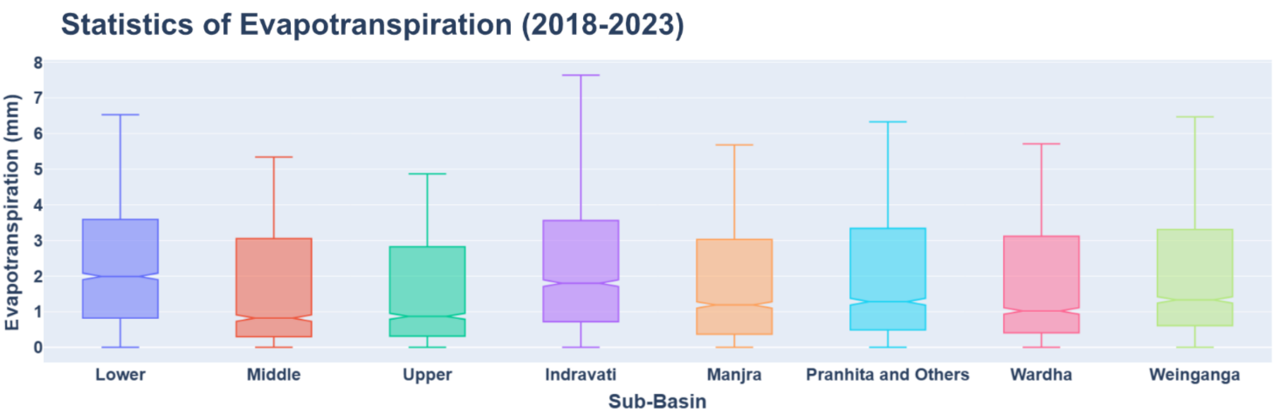

Figure 8 evapotranspiration of Godavari Sub-basin (2018-2023) (source: India WRIS)

The analysis of evapotranspiration (ET) patterns in the Godavari Basin from 2018 to 2023 reveals significant spatial and temporal variations across its sub-basins shown in Figure 8 and Figure 9. The Indravati sub-basin exhibits the highest variability in ET rates, ranging from near 0 to approximately 7.5 mm, reflecting complex interactions between climate, vegetation, and topography. In contrast, the Upper and Middle sub-basins show more moderate and stable ET patterns, typically ranging between 0.5 and 4 mm. Temporal trends highlight consistent seasonal cycles, with peak ET values occurring during summer months, particularly in the Lower basin, where ET regularly reaches 6 mm. These patterns align with monsoon cycles and agricultural seasons, providing critical insights for irrigation planning and water management.

Despite the comprehensive monitoring network combining ground-based measurements and remote sensing, data uncertainties persist due to instrumental limitations during cloud cover, temporal gaps in ground stations, and spatial variability within sub-basins. To address these challenges, technical enhancements such as additional ground-based monitoring stations, advanced remote sensing technologies, and standardized quality control procedures are recommended. Stakeholder engagement is equally crucial, with a focus on establishing communication channels with agricultural communities, creating user-friendly data visualization tools, and developing capacity-building programs for local water management authorities.

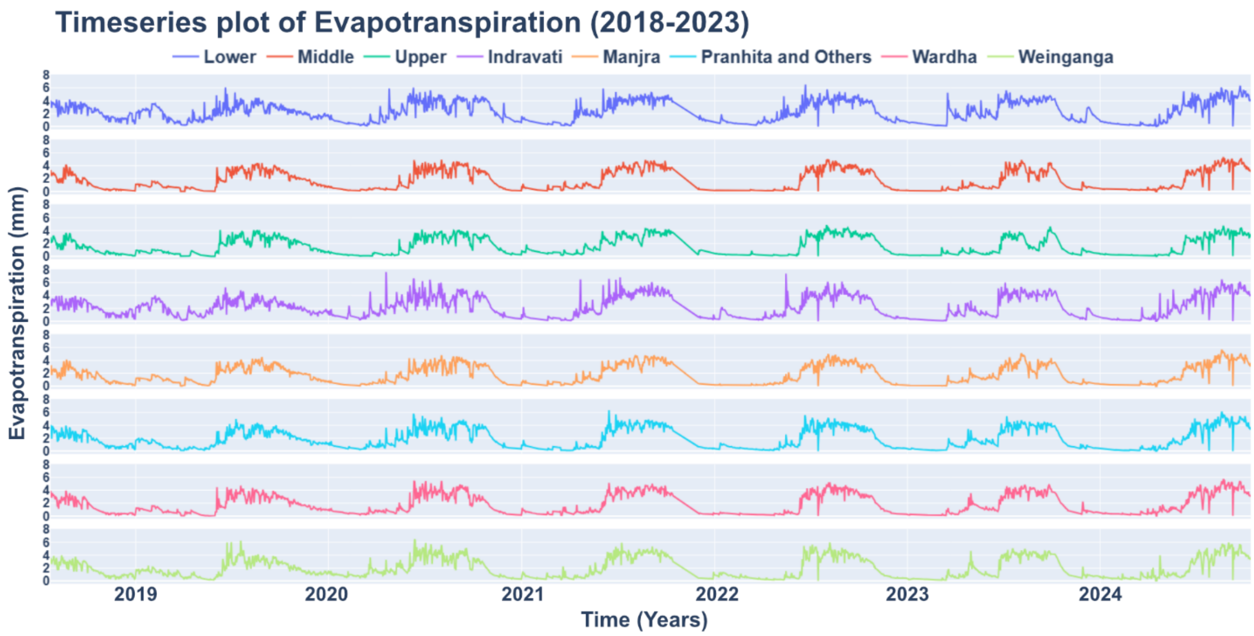

Figure 9 Time Series data of evapotranspiration (2018-2023)

Looking ahead, short-term priorities include addressing data gaps, enhancing real-time data sharing, and implementing quality control measures. Long-term strategies should focus on developing integrated hydrological modeling systems, establishing basin-wide early warning systems for extreme events, and creating a comprehensive stakeholder engagement platform. These efforts will improve the accuracy and utility of ET data, supporting sustainable water resource management in the Godavari Basin.

7. Groundwater Data

Groundwater monitoring in the Godavari Basin is essential for understanding the region's hydrological dynamics and ensuring sustainable water resource management. The basin, which has experienced increasing reliance on groundwater due to declining surface water availability, necessitates a comprehensive monitoring framework. This framework includes the establishment of a network of observation wells that provide critical data on groundwater levels, quality, and abstraction rates. By employing advanced technologies such as remote sensing and geospatial analysis, researchers can enhance the efficiency of groundwater monitoring systems. These efforts are crucial for assessing groundwater sustainability, identifying potential aquifer recharge zones, and managing water resources effectively amidst changing climatic conditions.

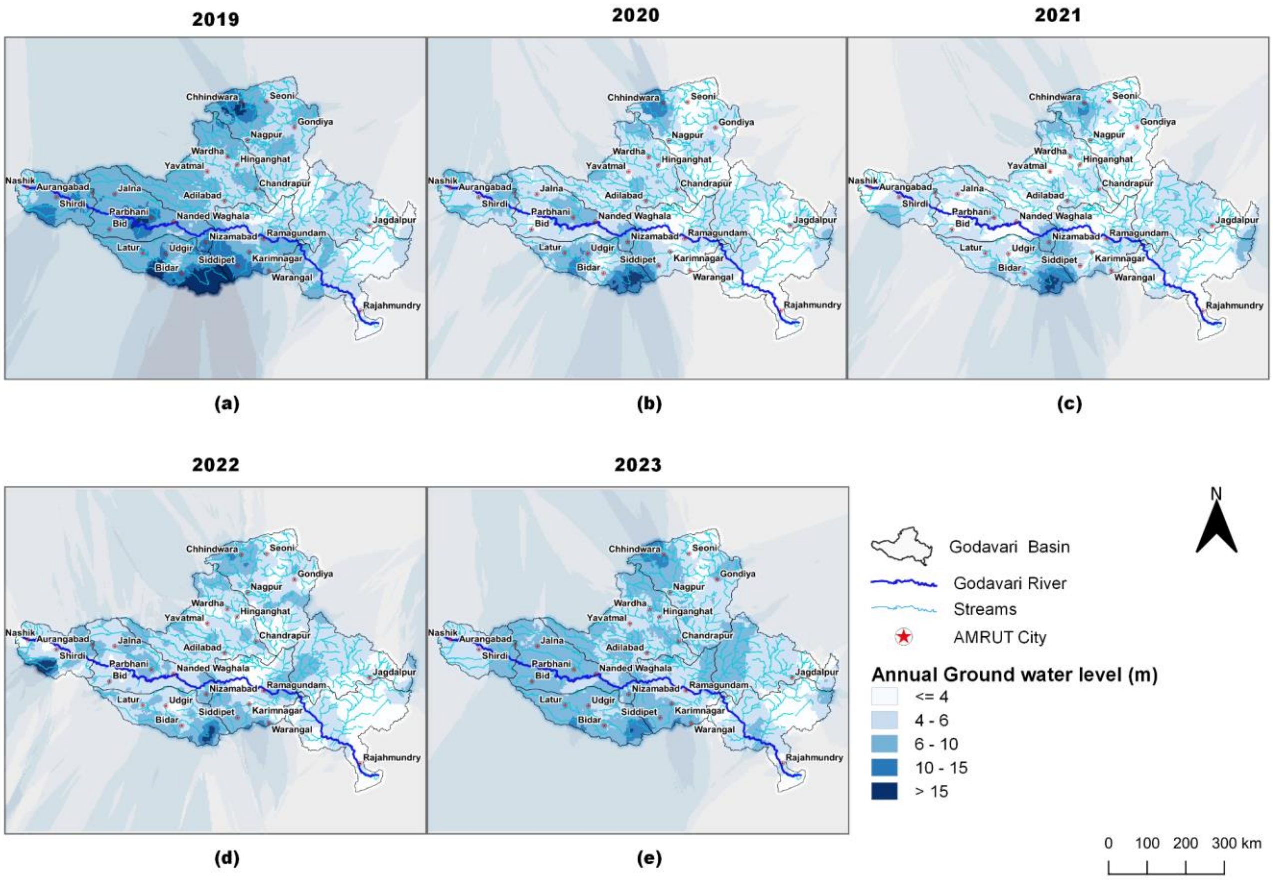

Figure 10 Annual Ground water level (m) of the Godavari Basin (2019-2023)

Figure 10 in comparison to the previous rainfall map, there's an interesting inverse relationship between rainfall and groundwater levels in certain parts of the Godavari Basin:

Western Region:

- Despite receiving lower rainfall (6-10mm annually), this region shows higher groundwater levels (>15m in some areas)
- This paradox can be explained by:
    1. The terrain being more suitable for groundwater storage
    2. Better aquifer conditions that allow water retention

3. Possibly flatter topography that enables better water percolation
4. Slower groundwater movement due to favourable geological conditions

Central and Eastern Regions:

- Despite receiving higher rainfall (18-22mm annually), these areas show lower groundwater levels (4-10m)
- This can be attributed to:
    1. Hilly terrain with steep slopes
    2. Rapid surface water runoff due to the topography
    3. Less opportunity for water to percolate into the ground
    4. Harder rock formations that may limit groundwater storage

The temporal pattern from 2019-2023 shows this relationship remains relatively consistent, though with some variations in intensity. This highlights how groundwater availability isn't solely dependent on rainfall, but is significantly influenced by:

- Local geology
- Topography
- Soil characteristics
- Land use patterns
- Slope gradient

This understanding is crucial for water resource management and planning in different parts of the basin, as areas with high rainfall may not necessarily have better groundwater resources.

The current monitoring infrastructure includes observation wells, manual piezometers, and automated data loggers strategically placed along the Godavari River and its tributaries. However, data reliability is affected by spatial gaps in remote areas, inconsistent collection frequencies, varying measurement techniques, and limited real-time monitoring integration. To address these limitations, technical improvements such as additional monitoring wells, automated real-time systems, satellite-based techniques, and standardized protocols are recommended. Policy measures, including zone-specific management strategies, conservation incentives, stricter monitoring in depleted areas, and sustainable extraction guidelines, are also essential.

Stakeholder engagement is critical, with agricultural communities, urban water authorities, industrial users, and environmental groups relying on groundwater data. Enhancing communication through user-friendly visualization platforms, regular workshops, local knowledge integration, and early warning systems will improve accessibility and utility. Short-term priorities include addressing data gaps, enhancing real-time monitoring, and improving data sharing. Long-term strategies should focus on integrated groundwater modeling, artificial recharge projects, drought management plans, and climate change impact monitoring. These efforts will ensure sustainable groundwater management in the Godavari Basin.

8. Soil Moisture

Soil moisture is a vital component of the hydrological cycle in the Godavari Basin, significantly impacting vegetation health, agricultural productivity, and groundwater recharge. It serves as an essential indicator for monitoring drought conditions and forecasting floods.

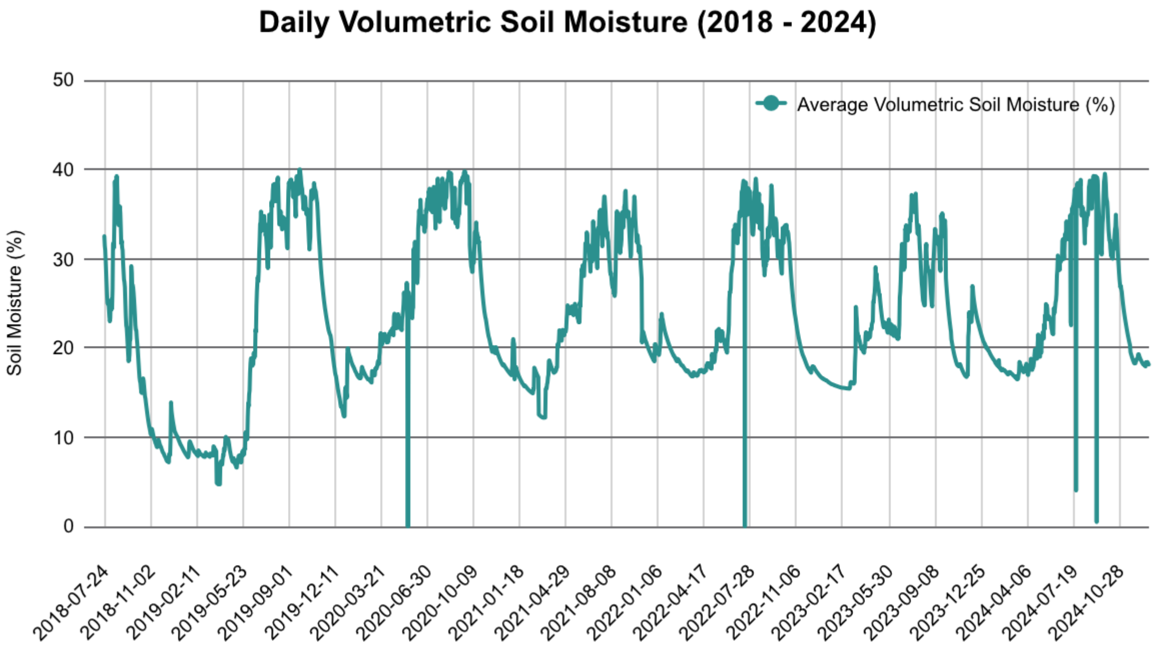

Figure 11 Daily Volumetric Soil Moisture (2018 - 2024)

Looking at the daily volumetric soil moisture data from 2018 to 2024 (Figure 11), we can observe distinct cyclical patterns that tell an important story. The moisture levels fluctuate dramatically between nearly 0% and 40%, with clear seasonal patterns. These variations align perfectly with the basin's monsoonal characteristics, where approximately 95% of the annual water load occurs during the rainy season. Think of it as the basin's yearly breathing pattern – inhaling moisture during monsoons and gradually exhaling it during dry periods.

The subbasin analysis (Figure 12) adds another layer of understanding by showing horizontal variation across different regions. The Lower subbasin maintains relatively high moisture levels at 24.8%, while the Upper region shows lower levels at 20.07%. This spatial variation likely results from differences in topography, soil composition, and local climate patterns.

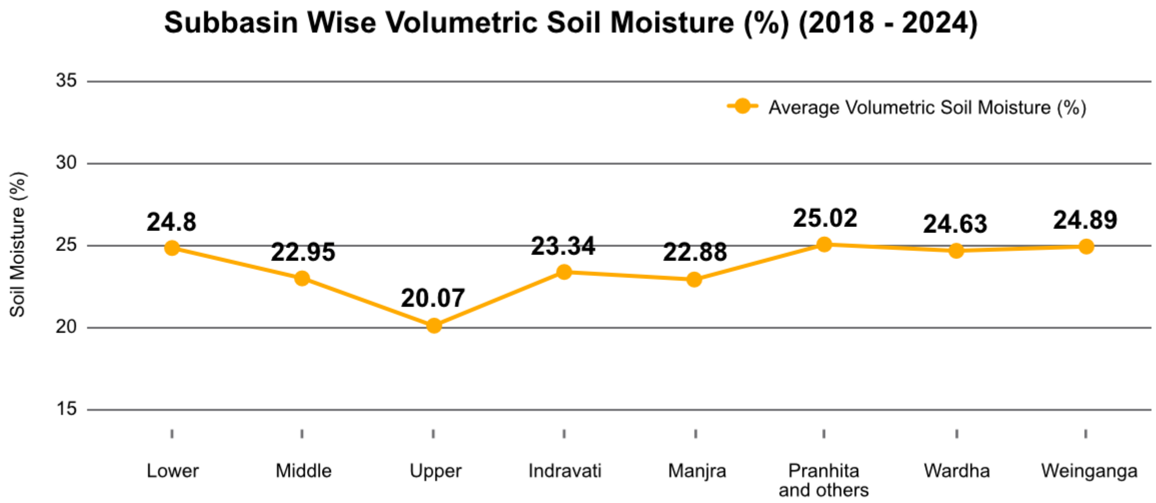

Figure 12 Subbasin Wise Volumetric Soil Moisture (%) (2018 - 2024)

FLDAS, or the Famine Early Warning Systems Network Land Data Assimilation System, is a vital resource that provides timely and accurate land surface information to support decision-making in agriculture, water management, and disaster response. It integrates various data sources, including satellite observations and ground-based measurements, to generate high-resolution estimates of soil moisture, temperature, and other relevant variables. FLDAS employs sophisticated algorithms to assimilate this data into a consistent framework, allowing for real-time monitoring of land surface conditions[4].

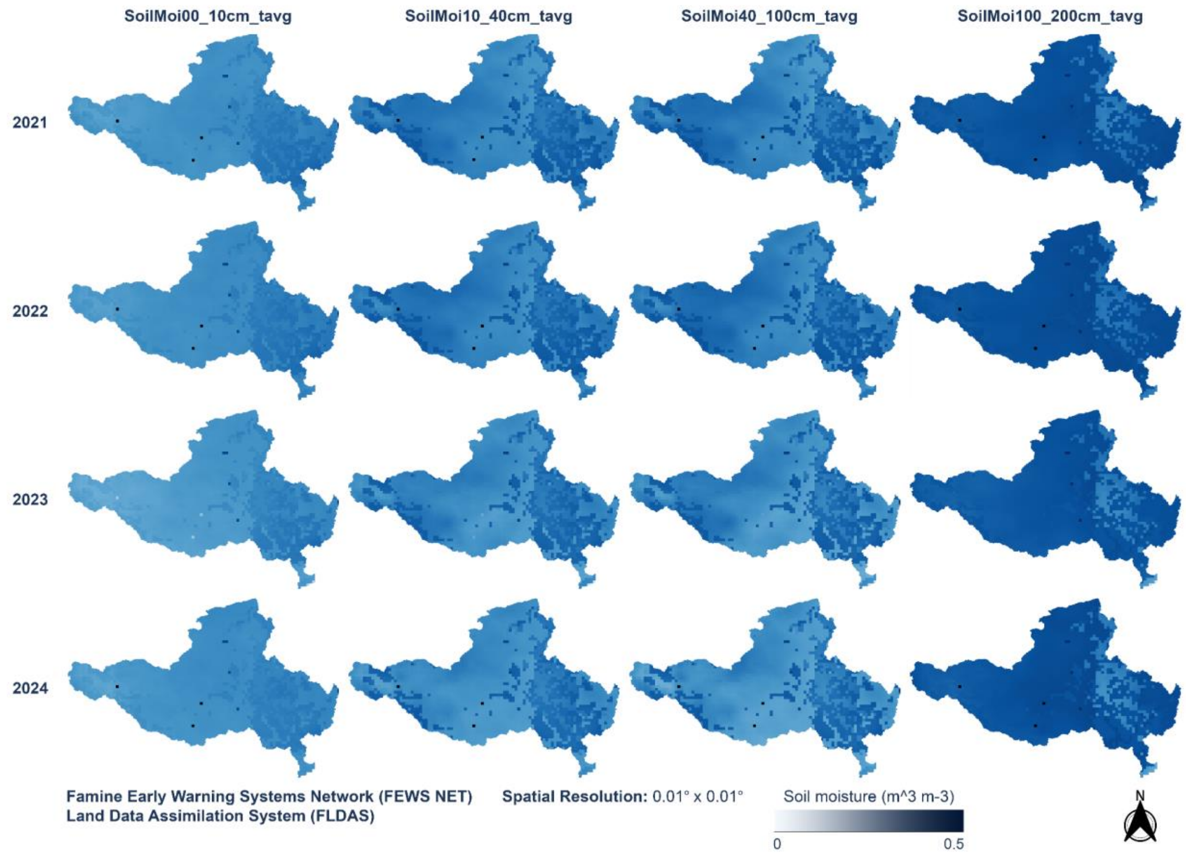

Figure 13 Soil Moisture of the Godavari Basin (2021-2024)

Particularly noteworthy is the depth-based analysis of soil moisture from 2021 to 2024, which illustrates how water content varies at different depths (10cm, 40cm, 100cm, and 200cm). The moisture content generally increases with depth, as indicated by progressively darker blue colors on the soil moisture maps. This information is crucial for understanding the dynamics of soil moisture and its implications for agricultural productivity and water resource management. This vertical variation is crucial because:

- The 10cm layer (surface) shows the most variability, directly responding to rainfall and evaporation
- The 40 cm and 100 cm layers represent the critical root zone for many crops
- The 200cm layer maintains more stable moisture levels, acting as a long-term water reservoir security.

The analysis of soil moisture in the Godavari Basin provides valuable insights into its complex dynamics, but several data gaps and areas for improvement remain. Key areas requiring further investigation include the relationship between extreme weather events and soil moisture, long-term climate change impacts on moisture patterns, and the influence of land use changes on soil moisture retention. Additionally, the average monthly precipitation of 915.6mm needs to be better correlated with soil moisture at different depths to enhance understanding and predictive capabilities.

To make this data actionable for stakeholders, practical applications must be prioritized. Farmers can use depth-based moisture information to optimize irrigation practices, while agricultural planners can identify suitable crops for different sub-basins. Conservation agencies can leverage the data to target soil erosion prevention efforts more effectively, particularly in areas where erosion averages 4.34 tons per hectare annually.

Moving forward, future research should focus on implementing advanced monitoring systems to capture rapid moisture changes, developing integrated models that connect surface and subsurface water movements, and creating user-friendly interfaces for stakeholders to access and interpret the data. Establishing regular feedback mechanisms with local communities will ensure that the data addresses their specific needs. This comprehensive understanding of soil moisture dynamics in the Godavari Basin is essential for managing this critical resource, balancing agricultural productivity with environmental sustainability.

9. Sediment Load Analysis

Sedimentation is the deposition of sediments, leading to the formation of sedimentary rock, and broadly applies to the range of processes involved. It is the process where suspended particles settle out of a fluid due to gravity or other forces. In geology, *sedimentation* refers to the deposition of sediments, particularly the mechanical deposition of sediment particles from suspension in air or water, which leads to the formation of depositional landforms and sedimentary rocks. Siltation, on the other hand, is a type of water pollution caused by an increased concentration of suspended sediments, specifically fine particles like silt or clay, in water bodies. *Siltation* often results from soil erosion or sediment spills, frequently due to human activities such as construction, agriculture, or mining. While *sedimentation* can occur in any fluid medium, siltation refers specifically to sediment accumulation in water bodies.

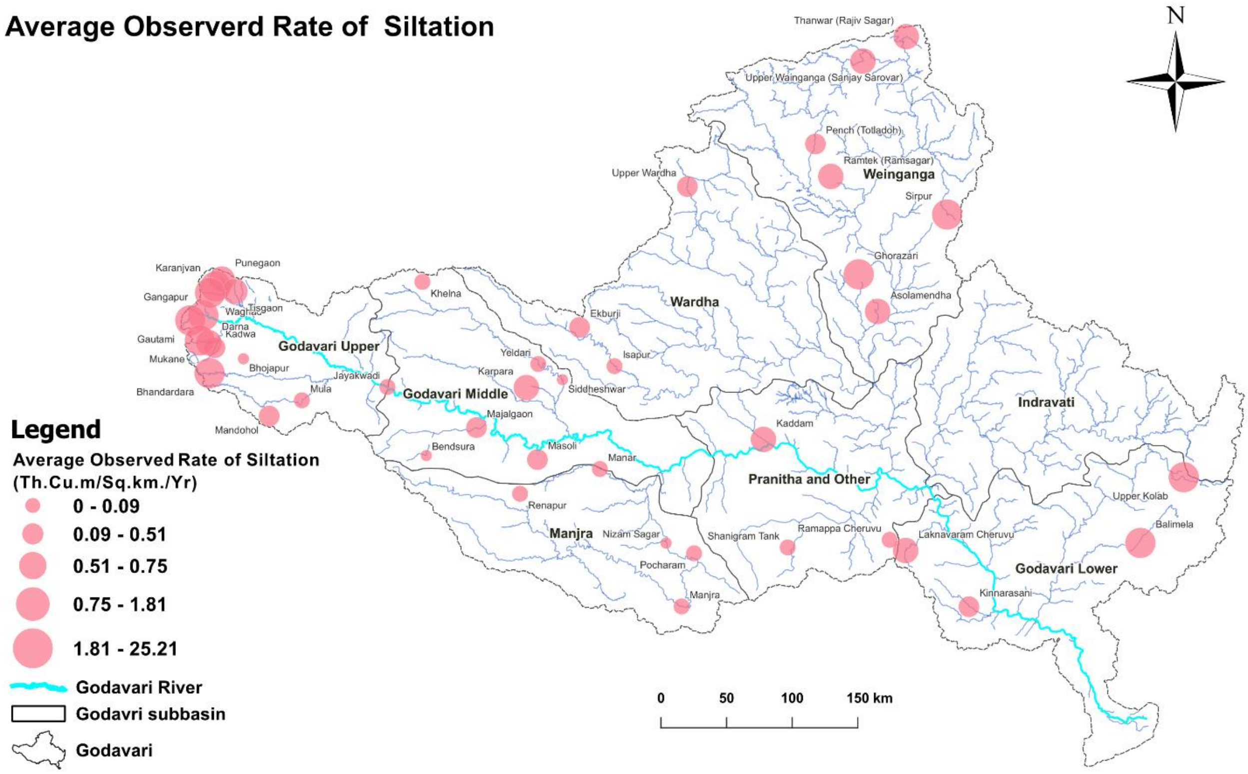

Figure 14 Average observed rate of siltation

The siltation data is collected from India WRIS. Figure 14 showcases a particularly concerning concentration of high siltation rates in the Godavari Upper region, where rates reach between 1.81 and 25.21 thousand cubic meters per square kilometer per year. The spatial distribution of siltation is notably pronounced around critical reservoirs such as Mula and Jayakwadi, indicating severe sediment accumulation in these areas. This pattern suggests intensive erosion processes in the upper catchment areas, which has significant implications for reservoir management and water resource planning[5].

The temporal analysis of sediment load in the Godavari River system presents a striking transformation over the past five decades. The river has experienced a dramatic reduction in sediment load, declining from 150 megatons during the 1970-1979 period to merely 47 megatons in the 2010-2019 timeframe. This significant decrease of nearly 69% in sediment load carries substantial implications for both the river system's health and its interaction with the Bay of Bengal. While traditional assumptions might link such changes to rainfall patterns, the data reveals a more nuanced story. Despite a slight increase in rainfall across the basin, precipitation changes alone cannot explain the magnitude of sediment load reduction [6].

The significance of this data lies in its revelation of human activities, particularly dam construction, as a primary driver of sediment load changes. The high siltation rates observed in major reservoirs have effectively created sediment traps, substantially reducing the natural flow of sediments to the Bay of Bengal. This finding represents a critical data point for understanding human impact on river systems and planning future water resource management strategies.

However, it's important to acknowledge the existing data gaps and uncertainties in our understanding. While we have robust measurements of siltation rates and sediment loads, there remains a need for more detailed studies on the ecological implications of these changes and their long-term effects on delta formation and coastal processes. Future improvements in monitoring should focus on developing more comprehensive datasets that include seasonal variations and the impact of extreme weather events on sedimentation patterns.

Stakeholder engagement emerges as a crucial component in addressing these challenges. The findings highlight the need for collaborative approaches involving irrigation departments, environmental agencies, and local communities in developing sustainable solutions. The data presents clear evidence that management strategies must balance the benefits of water storage through dams with the need to maintain natural sediment transport processes. Future reports should continue to emphasize these stakeholder perspectives and needs, ensuring that technical findings are translated into actionable policies that serve both environmental and human requirements.

This analysis underscores the critical importance of integrated river basin management approaches that consider both the spatial distribution of sedimentation and its temporal changes. The findings provide a strong foundation for developing targeted interventions in high-siltation areas while also highlighting the need for basin-wide management strategies that can address the complex interplay between human activities and natural processes in the Godavari River Basin.

10. Hydrologic data Insights

The comprehensive analysis of the Godavari River Basin reveals a complex interplay of natural processes and human activities, highlighting the need for integrated and sustainable resource management. Several key takeaways emerge from the preceding sections:

- **Land Use Dynamics:** The basin's landscape is a mosaic of agricultural zones, forests, and urban areas. The transition zone between agriculture and forests is crucial for maintaining ecological balance. While the 2022 LULC data provides valuable insights, its utility can be enhanced through more frequent updates, improved classification accuracy, and integration with other environmental datasets. This will enable more informed decision-making in agriculture, forestry, and urban planning.
- **Hydrological Monitoring Gaps:** While the CWC's network of gauge stations provides essential data on water levels and discharge, significant gaps in data availability, both spatially and temporally, pose a challenge. The inconsistent data collection frequency and the presence of "data missions" necessitate a more robust and consistent monitoring strategy. Addressing these gaps is crucial for accurate flood forecasting, water resource assessment, and effective drought management. The reliance on peak discharge data, while informative, should be supplemented with more frequent measurements to better understand flow dynamics.
- **Rainfall Variability and its Implications:** The spatial and temporal variability of rainfall across the basin is significant. The Weinganga sub-basin acts as a crucial water tower, while the Pranitha sub-basin exhibits dramatic rainfall fluctuations. Integrating real-time rainfall data, establishing ground-truth stations, and developing seasonal forecasting tools will empower farmers, urban planners, and water management authorities to make informed decisions.
- **Evapotranspiration Dynamics:** The analysis of ET patterns reveals significant spatial and temporal variations, with the Indravati sub-basin showing the highest variability. Addressing data uncertainties through enhanced monitoring networks and stakeholder engagement is essential for improving irrigation planning and water management.
- **Groundwater Paradox:** The inverse relationship between rainfall and groundwater levels in certain areas underscores the influence of local geology, topography, and land use on groundwater availability. Technical improvements in monitoring infrastructure, coupled with policy measures and stakeholder engagement, are crucial for sustainable groundwater management.
- **Soil Moisture Dynamics:** The cyclical patterns of soil moisture, influenced by the monsoon season, highlight the importance of understanding depth-based variations. Integrating soil moisture data with other environmental parameters and developing user-friendly tools will benefit farmers, agricultural planners, and conservation agencies.
- **Siltation and Sediment Load Reduction:** The high siltation rates in the upper Godavari region, particularly around reservoirs, and the dramatic reduction in sediment load over the past decades point to the significant impact of dam construction. Further research on the ecological implications of these changes and enhanced stakeholder engagement are crucial for developing sustainable river basin management strategies.

11. Application

These applications illustrate the critical role of hydrology in addressing diverse water-related challenges both in India and globally, emphasizing its importance for sustainable development and environmental management.

Disaster-Related Applications of Hydrology:

- Flood Management and Risk Assessment: Flood management practices vary across different countries, with India's National Hydrology Project (NHP) focusing on enhancing flood control through improved data acquisition and decision support systems, utilizing real-time monitoring of hydrological parameters to predict floods and optimize reservoir operations in vulnerable areas, while in the United States, hydrological applications are extensively used for flood risk assessment through advanced modeling techniques, with studies demonstrating that the integration of hydrological models with geographic information systems (GIS) leads to more effective floodplain mapping and risk management strategies[7,8].
- **Drought Monitoring Systems:** In Africa, hydrology is applied to develop drought monitoring systems that utilize satellite data to assess soil moisture and rainfall deficits. These systems provide early warnings for drought conditions, aiding in food security planning and resource allocation[9].
- **Climate Change Impact Studies:** Australian researchers utilize hydrological models to study the impacts of climate change on water resources. These studies help predict changes in streamflow patterns and inform adaptive management strategies for water conservation[10].

Water Resource Management and Planning:

- **Groundwater Management:** In India, hydrology is crucial for sustainable groundwater management. The NHP supports the establishment of hydro-informatics centers that facilitate groundwater monitoring and modeling, helping to assess aquifer recharge and depletion rates effectively[11].
- **Irrigation Planning:** Hydrological studies are essential for optimizing irrigation practices in Indian agriculture. By analyzing rainfall patterns and soil moisture levels, hydrologists can recommend efficient irrigation schedules, which are vital for improving crop yields and conserving water resources[12].
- **Urban Water Supply Systems:** In rapidly urbanizing regions of India, hydrology helps design efficient water supply systems. By modeling urban runoff and demand, planners can develop infrastructure that meets the growing needs of urban populations while minimizing flooding risks[13].
- **Hydropower Generation Optimization:** In countries like Norway, hydrology is crucial for optimizing hydropower generation. Hydrological models help predict water inflows into reservoirs, enabling better planning for energy production while balancing ecological needs[14].

Other Applications of Hydrology:

- **Water Quality Assessment:** The application of hydrology in monitoring water quality is significant in India, where pollution poses a major threat to water resources. Hydrological models are employed to track pollutant transport in rivers and lakes, aiding in the formulation of policies for water quality management[15].

- **Wetland Restoration:** Hydrology plays a vital role in wetland restoration projects across Europe. By understanding the hydrological dynamics of wetland ecosystems, scientists can design restoration efforts that improve biodiversity and ecosystem services[16].

12. Conclusion

In conclusion, this comprehensive analysis of the Godavari River basin, incorporating diverse perspectives from topography and land use/land cover to rainfall patterns, hydrology, groundwater, and soil moisture, provides valuable insights into the complex interplay of natural and human-induced factors impacting this vital resource. The availability of high-resolution data, including FABDEM, topography, reveals unprecedented details of the basin's characteristics, informing decisions related to water resource management, urban planning, and environmental protection. The study underscores the intricate relationship between natural systems and human activities, highlighting the need for sustainable development and effective resource management strategies. Analysis of rainfall patterns emphasizes the importance of adaptive management in the face of changing conditions, while the assessment of hydrological processes and groundwater dynamics points to both challenges and opportunities for improved monitoring and stakeholder engagement. Furthermore, the examination of soil moisture reinforces the complex interplay between surface conditions, depth, and seasonal variations, crucial for balancing agricultural productivity and environmental sustainability. Critically, the analysis of sediment load reveals the influence of both natural and anthropogenic factors, further emphasizing the need for integrated water resource management. While the report offers robust findings, it also acknowledges data limitations and calls for more comprehensive data collection and further research to reduce uncertainties and enhance our understanding of this complex system. Ultimately, the study emphasizes the critical role of stakeholder engagement in addressing the multifaceted challenges related to water resource management in the Godavari River basin, paving the way for more informed and sustainable practices.

13. Recommendation

To enhance the effectiveness of hydrology data management and improve water resource management across India, the following recommendations are proposed for government organizations:

1. **Establishment of Comprehensive Monitoring Networks**

   Action: Develop and modernize hydromet monitoring systems across all states to ensure real-time data acquisition for meteorology, streamflow, groundwater, and water quality.

   Justification: Comprehensive monitoring networks will provide timely and accurate data essential for effective decision-making in water resource management and disaster preparedness.

2. **Integration of Advanced Technologies**

   Action: Utilize advanced technologies such as remote sensing, Geographic Information Systems (GIS), and cloud computing to enhance data collection, analysis, and visualization.

   Justification: The integration of these technologies will improve the accuracy of hydrological models and facilitate better access to water information for stakeholders.

3. **Development of Decision Support Systems (DSS)**

   Action: Create interactive analytical tools and decision support platforms that integrate various datasets for flood forecasting, reservoir operations, and water resources accounting.

   Justification: DSS will enable policymakers to simulate different management scenarios, enhancing the planning and operational efficiency of water resources.

4. **Capacity Building and Training Programs**

   Action: Implement extensive training programs for water resource professionals to enhance their skills in hydrological modeling, data analysis, and the use of modern technologies.

   Justification: Building capacity within institutions will ensure that personnel are equipped to manage complex hydrological data effectively and make informed decisions.

5. **Public Engagement and Education Initiatives**

   Action: Launch educational programs aimed at increasing public awareness about the importance of hydrology and sustainable water management practices.

   Justification: Engaging communities will foster a culture of conservation and responsible water use, which is crucial for addressing challenges related to water scarcity and ecosystem sustainability.

6. **Standardization of Data Collection Protocols**

Action: Establish standardized protocols for data collection, storage, and sharing among various agencies involved in water resource management.

Justification: Standardization will facilitate better integration of data from different sources, improving the overall quality and accessibility of hydrological information.

7. **Strengthening Water Informatics Centers**

   Action: Enhance the capabilities of National Water Informatics Centre (NWIC) to serve as a central repository for water-related data across India.

   Justification: A robust NWIC will ensure comprehensive data management, making it easier for stakeholders to access reliable information for planning and decision-making.

8. **Collaboration with Research Institutions**

   Action: Foster partnerships with academic and research institutions to leverage expertise in hydrological research and innovative solutions.

   Justification: Collaborations can lead to advancements in hydrological science that inform better management practices and policy development.

By implementing these recommendations, Indian government organizations can significantly enhance their capacity to manage water resources effectively, address challenges posed by climate change, urbanization, and ensure sustainable development across various sectors reliant on hydrology.

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15. Appendices

15.1. Supplementary Data Tables

Table 1 Information of hydrologic data

S.No.	Data Type	Data Source	Resolution	Deliverables
1	FABDEM	https://data.bris.ac.uk/data/dataset/s5hqmjcdj8yo2ibzi9b4ew3sn	Resolution: 30-meter	GeoTIFF
2	GLC_FCS30D Global Land Cover Change	https://doi.org/10.5281/zenodo.8239305	Resolution: 30-meter, Yearly (2012 to 2022)	GeoTIFF
3	Discharge	India WRIS	Unit:m^3 (cumecs), Daily (2001 to 2022)	Data (Excel file)
4	Rainfall (India)	IMD Pune	0.25x0.25 degree, 135x129 grid points, Unit:mm, Daily (1901 to 2022)	NetCDF file
5	Evaporation Transpiration	India WRIS	Unit:mm, Daily (2018 to 2024)	Data (Excel file), pdf
6	Groundwater Level	data.gov.in, India WRIS	Yearly (2018 to 2024)	.shp, Data (Excel file)
7	Groundwater Quality	India WRIS	Yearly (2018 to 2024)	Data (Excel file)
8	Soil Moisture	India-WRIS, FLDAS	Yearly (2018 to 2024)	Data (Excel file), Raster
9	Sedimentation	India-WRIS	Yearly (1975 to 2018)	Data (Excel file)

Table 2 The fine classification system containing 35 land-cover sub-categories

LC id	Classification System	Color	
10	Rainfed cropland	(255,255,100)	
11	Herbaceous cover cropland	(255,255,100)	
12	Tree or shrub cover (Orchard) cropland	(255,255,0)	
20	Irrigated cropland	(170,240,240)	
51	Open evergreen broadleaved forest	(76,115,0)	
52	Closed evergreen broadleaved forest	(0,100,0)	
61	Open deciduous broadleaved forest (0.15<fc<0.4)	(170,200,0)	
62	Closed deciduous broadleaved forest (fc>0.4)	(0,160,0)	
71	Open evergreen needle-leaved forest (0.15< fc <0.4)	(0,80,0)	
72	Closed evergreen needle-leaved forest (fc>0.4)	(0,60,0)	
81	Open deciduous needle-leaved forest (0.15<fc<0.4)	(40,100,0)	
82	Closed deciduous needle-leaved forest (fc>0.4)	(40,80,0)	
91	Open mixed leaf forest (broadleaved and needle-leaved)	(160,180,50)	
92	Closed mixed leaf forest (broadleaved and needle-leaved)	(120,130,0)	
120	Shrubland	(150,100,0)	
121	Evergreen shrubland	(150,75,0)	
122	Deciduous shrubland	(150,100,0)	
130	Grassland	(255,180,50)	
140	Lichens and mosses	(255,220,210)	
150	Sparse vegetation (fc<0.15)	(255,235,175)	
152	Sparse shrubland (fc<0.15)	(255,210,120)	
153	Sparse herbaceous (fc<0.15)	(255,235,175)	
181	Swamp	(0,168,132)	
182	Marsh	(115,255,223)	
183	Flooded flat	(158,187,215)	
184	Saline	(130,130,130)	
185	Mangrove	(245,122,182)	
186	Salt marsh	(102,205,171)	

187	Tidal flat	(68,79,137)	
190	Impervious surfaces	(195,20,0)	
200	Bare areas	(255,245,215)	
201	Consolidated bare areas	(220,220,220)	
202	Unconsolidated bare areas	(255,245,215)	
210	Water body	(0,70,200)	
220	Permanent ice and snow	(255,255,255)	
0, 250	Filled value	(255,255,255)	

Table 3 Live storage status of Godavari Reservoirs (DEC 2024)

NAME OF RESERVOIR	STATE	IRR. (CCA) IN TH. HA	HYDEL IN MW	FRL (MTS.)	LIVE CAP. AT FRL (BCM)	LATEST DATE AVAILABLE	LEVEL (MTS)	LIVE STORAGE (BCM)	% OF LIVE CAP AT FRL
DONKARAYI	AP	0	25	316.08	0.376	2024-12-05	315.5	0.36	96
SRIRAM SAGAR	TG	411	27	332.54	2.3	2024-12-05	332.54	2.28	99
LOWER MANAIR	TG	199	60	280.42	0.621	2024-12-05	280.26	0.621	100
NIZAM SAGAR	TG	93.619	10	428.24	0.482	2024-12-05	428.22	0.482	100
SINGUR	TG	16.187	15	523.6	0.822	2024-12-05	523.36	0.822	100
KADDAM(K.N.R.)	TG	27.732	0	213.36	0.137	2024-12-05	211.88	0.137	100
SANJAY SAROVAR(BHIMGARH)	MP	12.646	3.45	519.38	0.508	2024-12-05	518.5	0.368	72
JAYAKWADI(PAITHAN)	MAH	227	0	463.91	2.171	2024-12-05	463.72	2.111	97
ISAPUR	MAH	104	0	441	0.965	2024-12-05	440.84	0.948	98
MULA	MAH	139	0	552.3	0.609	2024-12-05	551.87	0.586	96
YELDARI	MAH	78	0	461.77	0.809	2024-12-05	461.71	0.803	99
PENCH(TOTLADOH)	MAH	127	160	490	1.091	2024-12-05	488.93	0.935	86
UPPER WARDHA	MAH	70	0	342.5	0.564	2024-12-05	341.81	0.503	89
BHANDARDARA	MAH	63.74	46	744.91	0.304	2024-12-05	744.54	0.3	99
DARNA DAM	MAH	87	0	571.5	0.202	2024-12-05	571.24	0.195	97
BALIMELA	ORI	0	360	462.08	2.676	2024-12-05	458.3	2.009	75
MACHKUND(JALAPUT)	ORI	0	115	838.16	0.893	2024-12-05	837.04	0.786	88
UPPER KOLAB	ORI	89	320	858	0.935	2024-12-05	854.8	0.636	68
UPPER INDRAVATI	ORI	128	600	642	1.456	2024-11-28	634.52	0.707	49

Table 4 List of Reservoir with Sediment Studies

Reservoir Name	**River**	**Year of Present Survey**	**Cumulative Loss of Gross Capacity (MCM)**	**% Cumulative Loss of Gross Capacity**	**Average Observed rate of siltation (Th.Cu.m/Sq.km./Yr)**
Asolamendha	Pathari	1918	--	--	--
Asolamendha	Pathari	1987	27.02	29.07	1.592
Asolamendha	Pathari	1994	29.97	32.24	1.713
Balimela	Machhkund-Sileru	1972	--	--	--
Balimela	Machhkund-Sileru	1999	282.5	7.83	2.132
Balimela	Machhkund-Sileru	2003	--	--	2.132
Bendsura	Bendsura	1955	--	--	--
Bendsura	Bendsura	1981	3.541	26.99	0.723
Bendsura	Bendsura	1990	5.218	39.77	0.989
Bendsura	Bendsura	1995	5.241	39.95	0.024
Bhandardara	Pravara	2004	--	--	--
Bhandardara	Pravara	2015	27.437	9.02236107	2.532
Bhojapur	Mahalungi	2017	0.36	3.52250489	0.052
Darna	Darna	2015	31.251	14.21081351	0.781
Donkarai	Sileru	2003	--	--	--

Ekburji	Chandrabhaga	2016	2.53	21.14	0.647
Gangapur	Godavari	1965	--	--	--
Gangapur	Godavari	1997	48.89	23.01	4.275
Gautami	Godavari	2014	8.306	15.7	25.212
Ghorazari	Bokardoh	2015	19.202	44.49	2.302
Isapur	Penganga	2003	28.63	3.08	0.308
Itiadoh Dam	Gadhavi/Garvi	2007	-0.42	-0.13	--
Jayakwadi	Godavari	1976	--	--	--
Jayakwadi	Godavari	1999	249.801	8.59	0.499
Jayakwadi	Godavari	2003	--	--	0.499
Jolaput (Machhkund)	Machhkund	2002	-61.68	-6.91	--
Kaddam	Kaddam	1958	--	--	--
Kaddam	Kaddam	1977	46.251	37.17	0.916
Kaddam	Kaddam	2008	--	--	0.916
Kadwa	Kadwa	2016	2.331	4.4	0.561
Karanjvan	Kadwa	1974	--	--	--
Karanjvan	Kadwa	2008	16.96	9.66	2.011
Karpara	Karpara/Kapra R	2014	8.192	32.9	0.759
Khelna	Khelna	1964	--	--	--
Khelna	Khelna	1985	0.702	5.57	0.207

Kinnarasani	Kinnarasani	2010	30.71	15.61	0.524
Laknavaram Cheruvu	Lakhamvaram	1909	--	--	--
Laknavaram Cheruvu	Lakhamvaram	1975	18.84	31.18	1.065
Majalgaon	Sindfana	1987	--	--	--
Majalgaon	Sindfana	2007	--	--	0.52
Majalgaon	Sindfana	2010	45.92	10.11	0.52
Manar	Manar	1969	--	--	--
Manar	Manar	1999	18.726	13.54	0.394
Mandohol	Mandohal Odha	2015	3.48	39.64	0.719
Manjra	Manjira	1966	--	--	--
Manjra	Manjira	1977	18.74	36.79	0.102
Masoli	Machill N	2014	5.7	21.02	0.634
Mukane	Unduhol	2015	60.45	29.49	22.213
Mula	Mula	1972	--	--	--
Mula	Mula	2004	--	--	0.507
Mula	Mula	2008	41.57	5.63	0.507
Mula	Mula	2015	--	--	0.507
Nizam Sagar	Manjara	1930	--	--	--
Nizam Sagar	Manjara	1967	438.27	52.1	0.546
Nizam Sagar	Manjara	1975	477.48	56.76	0.226

Nizam Sagar	Manjara	1992	508.66	60.47	0.085
Pench (Totladoh)	Pench	2009	72.95	6.68	0.632
Pocharam	Aliaru	1922	--	--	--
Pocharam	Aliaru	1978	3.783	22.45	0.1
Punegaon	Unanda R	2014	1.4	7.97	1.769
Ramappa Cheruvu	Manair	1919	--	--	--
Ramappa Cheruvu	Manair	1975	2.66	3.23	0.258
Ramappa Cheruvu	Manair	2007	--	--	0.258
Ramtek (Ramsagar)	Sur	1914	--	--	--
Ramtek (Ramsagar)	Sur	1987	14.78	12.61	0.953
Renapur	Rena	2014	1.93	11.77	0.507
Shanigram Tank	Siddipet	1891	--	--	--
Shanigram Tank	Siddipet	1972	2.95	10.14	0.113
Siddheshwar	Purna	2007	1.69	2.09	0.087
Sirpur	Bagh	2007	33.36	17.33	2.204
Tembhapuri	Nagjhari Nadi	2018	-1.28	-6.52	--
Thanwar (Rajiv Sagar)	Thanwar	2005	8.46	6.12599566	0.922
Tisgaon	Parashari R	2014	1.983	15.54	1.363
Upper Indravati	Indravati	2007	-28.14	-1.93	--
Upper Kolab	Kolab	1986	--	--	--

Upper Kolab	Kolab	2011	141.05	11.61	3.461
Upper Wainganga (Sanjay Sarovar)	Wainganga	2003	15.83	3.86418005	0.986
Upper Wardha	Wardha	1993	--	--	--
Upper Wardha	Wardha	2011	47.49	5.91	0.613
Waghad	Kolvan	1978	--	--	--
Waghad	Kolvan	2011	7.38	9.83	1.88
Yeldari	Purna	1968	--	--	--
Yeldari	Purna	1983	84.94	9.09	0.773
Yeldari	Purna	2005	--	--	0.426
Yeldari	Purna	2011	134.34	14.38	0.241