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

Waterbodies Atlas

November 2025

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Waterbodies Atlas Of Godavari River Basin

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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The Center for Godavari River Basin Management 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.

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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.

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Acknowledgment

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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)
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Abbreviations and Acronyms

Term	Acronym	Acronym	Term
Advanced Land Observing Satellite	ALOS	Normalized Difference Vegetation Index	NDVI
Advanced Wide Field Sensor	AWiFS	Normalized Difference Water Index	NDWI
Digital Elevation Model	DEM	Near Infrared	NIR
Environmental Systems Research Institute	ESRI	Panchromatic	PAN
Geospatial Decision Support System	GDSS	Remote Sensing	RS
Geographic Information System	GIS	Survey of India	SOI
Global Positioning System	GPS	Short Wave Infrared	SWIR
Indian Remote Sensing	IRS	Universal Transverse Mercator	UTM
Indian Space Research Organisation	ISRO	World Geodetic System	WGS
Light Detection and Ranging	LiDAR	Modified Normalized Difference Water Index	MNDWI
Linear Imaging Self Scanner	LISS	Multi-Spectral Instrument	MSI
Land Use Land Cover	LULC	Mean Sea Level	MSL

1. Introduction

The Godavari River Basin, spanning 312,812 square kilometers across seven Indian states (Maharashtra, Telangana, Andhra Pradesh, Chhattisgarh, Odisha, Madhya Pradesh, and Karnataka), represents one of the most complex and hydrologically significant watersheds in peninsular India (Central Water Commission 2019). As the country's second-longest river system (1,465 km) and the largest basin in the Deccan Peninsula, the Godavari supports a diverse array of waterbodies that are fundamental to the region's agricultural productivity, industrial development, urban water supply, and ecological sustainability. These waterbodies, ranging from massive multipurpose reservoirs to small village ponds, collectively form an intricate network that governs water availability, flood management, and groundwater recharge across nearly 10% of India's geographical area (Rao 1975).

The basin's waterbodies exhibit remarkable diversity in terms of origin, scale, functionality, and management regimes. Major reservoirs such as the Jayakwadi Dam (2,909 MCM capacity), Sriram Sagar Project (3,172 MCM), and the ambitious Polavaram Project (5,511 MCM) represent large-scale engineering interventions designed to harness the river's potential for irrigation, hydropower generation, and flood control (India-WRIS 2020). Natural lakes, including the ecologically significant Kolleru Lake Wildlife Sanctuary, provide critical habitat for over 100 migratory bird species and support regional biodiversity (Lakshmi et al. 2015). Traditional water harvesting structures, inherited from centuries of indigenous water management practices, continue to play vital roles in rural water security and groundwater augmentation. Agricultural runoff drains and irrigation channels form extensive networks exceeding 15,000 kilometers that facilitate water distribution while also serving as conduits for nutrient and sediment transport (Biggs et al. 2007).

The hydrological significance of these waterbodies extends far beyond their individual capacities. Collectively, they influence regional precipitation patterns through evapotranspiration, moderate extreme weather events, support diverse ecosystems, and provide livelihood opportunities for millions of people. The basin contains over 350 major and medium dams and barrages, the highest concentration among all Indian river basins which reflects both the region's water development intensity and the complexity of managing such an extensive network of artificial waterbodies (Central Water Commission 2014). This unprecedented development has transformed the basin's hydrology, with implications for downstream flow regimes, sediment transport, and ecological functioning that require systematic monitoring and adaptive management.

However, this extensive waterbody network faces unprecedented challenges from climate variability, increasing water demand, pollution, sedimentation, and encroachment. Seasonal variations in waterbody extent, ranging from minimum levels during pre-monsoon periods (March-May) to maximum inundation during post-monsoon seasons (October-December), significantly impact water availability and ecosystem dynamics. Understanding these temporal and spatial variations is crucial for sustainable water resource management, drought preparedness, flood mitigation, and long-term basin planning. Recent studies indicate that approximately 32% of traditional water storage structures show signs of abandonment or severe degradation, representing significant lost capacity that could be restored to enhance basin resilience (Ministry of Jal Shakti 2020).

This Waterbodies Atlas represents a comprehensive effort to systematically document, map, and analyze all significant waterbodies within the Godavari River Basin using advanced remote sensing technologies, high-resolution satellite imagery, and ground-based validation techniques. The atlas provides detailed information about the location, extent, seasonal variation, and functional characteristics of reservoirs, lakes, ponds, wetlands, water harvesting structures, and agricultural drainage systems. By integrating data from multiple sources including Cartosat-2/3 (0.6-1.0 m resolution), Sentinel-2 MSI (10 m resolution), Survey of India toposheets (1:50,000 scale), drone surveys, LiDAR mapping, and Smart Cities programme datasets, this study establishes a robust spatial database that supports evidence-based water resource management and policy formulation (ISRO 2021; Patle et al. 2019).

The primary objectives of this waterbodies atlas include: (1) comprehensive inventory and mapping of all waterbodies across the 8 sub-basins and 466 watersheds comprising the Godavari Basin; (2) quantitative assessment of seasonal variations in waterbody extent and storage capacity through pre-monsoon and post-monsoon analysis; (3) development of a standardized classification system and attribute database for different waterbody types compatible with national water resource information systems; (4) identification of abandoned or degraded water harvesting structures requiring restoration, with assessment of restoration potential and priority ranking; (5) analysis of connectivity between different waterbody categories and their role in basin-wide hydrological processes; and (6) establishment of a framework for continuous monitoring and adaptive management of the basin's water resources utilizing automated change detection and stakeholder engagement mechanisms.

2. Data sources and methodology

The comprehensive mapping and analysis of waterbodies across the Godavari River Basin employs a multi-source approach that integrates cutting-edge remote sensing technologies with established cartographic methods. This methodological framework ensures accurate detection, delineation, and characterization of waterbodies across diverse physiographic landscapes, from the steep Western Ghats at elevations over 1000 meters down to the flat deltaic plains near sea level along the Bay of Bengal. The methodology follows international best practices for water resource mapping while adapting techniques to address the specific challenges of tropical monsoon environments and complex land-water interfaces characteristic of the Indian subcontinent (Pekel et al. 2016). Data sorces employed in the report are summarized in Table 1.

2.1 Primary data sources

2.1.1 High-Resolution Satellite Imagery

Sentinel-2A imagery forms the backbone of waterbody mapping across the basin. The Sentinel-2A provides high-resolution (10-meter for visible and NIR bands) optical imagery with a revisit time of 5 days, enabling detailed monitoring of seasonal waterbody variations across the entire basin area (ESA 2022) (Figure 1). The 13 spectral bands of Sentinel-2A, particularly the red (Band 4: 665 nm), near-infrared (Band 8: 842 nm), green (Band 3: 560 nm), and short-wave infrared (Band 11: 1610 nm; Band

12: 2190 nm) bands, facilitate accurate water detection through spectral indices such as the Normalized Difference Water Index (NDWI) (McFEETERS 1996; Xu 2006). The high temporal resolution is crucial for capturing ephemeral waterbodies and documenting rapid changes during monsoon onset and recession periods.

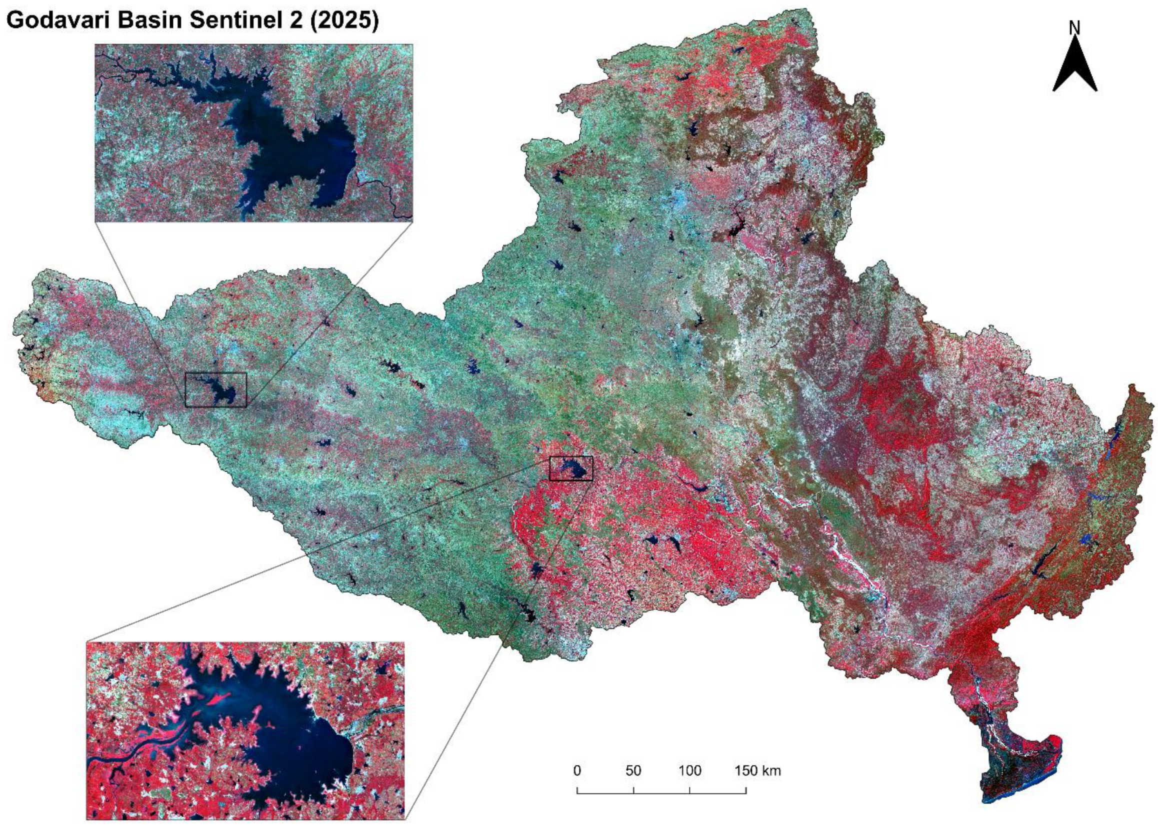

Figure 1: Sentinel-2 False Color Composite of Godavari Basin (NIR-Red-Green rendering) highlighting vegetation in red tones, water bodies in dark blue/black, and urban/bare areas in cyan and pink

2.1.2 Survey of India Toposheets

Survey of India (SOI) topographic maps at 1:50,000 scale provide authoritative reference data for waterbody location, historical extent, and traditional nomenclature (Survey of India 2020). These maps, derived from systematic ground surveys and aerial photography conducted primarily between 1960-2000, serve as essential baseline data for assessing long-term changes in waterbody distribution and extent. The toposheets offer valuable information about traditional names (often in regional languages), administrative boundaries, associated infrastructure including canals and control structures, and contour information critical for watershed delineation and catchment area calculation. The systematic grid-based coverage following the International Map of the World specification ensures comprehensive spatial reference across the entire basin with consistent cartographic standards. Digital versions of these toposheets, georeferenced to WGS84 datum and UTM Zone 44N projection, facilitate direct integration with satellite imagery and GIS analysis workflows.

2.1.3 Water transition Datasets

To capture the dynamics of surface water variability, seasonal persistence, and long-term transitions across the Godavari River Basin, the Global Surface Water (GSW) dataset developed by the Joint Research Centre (JRC), European Commission, was employed as a complementary data source (Pekel et al. 2016). This dataset provides globally consistent, multi-temporal information on surface water presence, absence, and transitions derived from over three decades of Landsat imagery (1984–2021). The water transition layer characterizes changes in surface water occurrence between baseline and recent periods, categorizing pixels into classes such as permanent water loss, new permanent water, seasonal-to-permanent transitions, and permanent-to-seasonal changes. These transition classes are particularly relevant for identifying long-term hydrological alterations driven by climatic variability, reservoir construction, river regulation, and land-use change within the basin. This allows differentiation between:

- **Permanent waterbodies** (water present throughout the year),
- **Seasonal waterbodies** (water present for part of the year), and
- **Ephemeral or intermittent features**, which are especially prevalent in semi-arid sub-basins and monsoon-fed tributaries of the Godavari.

In the context of the Godavari River Basin, characterized by strong monsoonal forcing and pronounced wet–dry season contrasts, these datasets provide critical insights into hydrological resilience, seasonal storage capacity, and vulnerability of small and medium waterbodies. The transition layer was used to support interpretation of Sentinel-2–derived water extents, enabling distinction between persistent hydrological features and short-lived monsoon-induced inundation. All GSW layers were accessed and processed within the GEE environment, ensuring spatial consistency with Sentinel-2–based outputs. The datasets were resampled to match the working spatial resolution and clipped to the basin boundary. While Sentinel-2 imagery provided high-resolution snapshots of contemporary waterbody extents, the JRC water transition products offered a long-term temporal context, strengthening the atlas by linking present-day observations with historical surface water dynamics.

Table 1. Datasets employed for the development of the Waterbodies Atlas of the Godavari River Basin

Dataset	Source	Sensor / Product	Spatial Resolution	Temporal Coverage / Acquisition Period	Data Format
Multispectral satellite imagery	USGS Earth Explorer / Copernicus Open Access Hub	Sentinel-2A MSI (Level-1C / Surface Reflectance)	10 m (Visible & NIR), 20 m (SWIR)	2024 (multi-season, cloud-free composites)	.tiff
Toposheets	Survey of India (SOI)	1:50,000 scale Toposheets	~1–2 m cartographic accuracy	1960–2000	PDF (georeferenced)
Surface water transition maps	Joint Research Centre (JRC), European Commission	Global Surface Water – Transitions	30 m	1984–2021	tiff

2.2 Data Preprocessing

Satellite imageries were sourced exclusively from Sentinel-2A MSI Level-1C products (ESA 2022) and processed within the GEE environment to ensure both radiometric consistency and geometric precision. Preprocessing steps followed standard protocols widely adopted in remote-sensing applications. Radiometric refinement included conversion of Top-of-Atmosphere (TOA) reflectance to surface reflectance using the GEE-integrated Sen2Cor-based atmospheric correction (COPERNICUS/S2_SR), ensuring minimization of atmospheric scattering and absorption artifacts. Additional harmonization steps such as band resampling and scale-factor adjustments were applied to maintain uniform spectral quality across all scenes. Cloud and shadow contamination was addressed using automated masking algorithms. Specifically, the SCL (Scene Classification Layer) and QA60 bitmask were used to identify clouds, cirrus, and cloud shadows. These automated masks were further refined through visual inspection to ensure that mixed or partially contaminated pixels were removed from the analysis. Only pixels with high-confidence clear-sky labels were retained. Geometric accuracy was inherently maintained through the Sentinel-2A orthorectified product.

2.3 Methodology

2.3.1 Water Body Extraction and Delineation

Surface waterbodies across the Godavari River Basin were delineated using multispectral Sentinel-2 imagery through application of the Normalized Difference Water Index (NDWI). NDWI exploits the contrasting spectral response of water and terrestrial surfaces in the green and near-infrared (NIR) bands and is expressed as:

$$NDWI = \frac{(Green - NIR)}{(Green + NIR)}$$

NDWI has been widely demonstrated as an effective and computationally efficient indicator for open surface water detection, particularly for basin-scale assessments where consistency and repeatability are critical (McFEETERS 1996). Cloud-free Sentinel-2 image composites were generated for the analysis period using median compositing to minimize atmospheric effects and residual cloud contamination. The resulting NDWI surface represents a continuous probability gradient of surface water presence, with higher positive values indicating stronger water signatures.

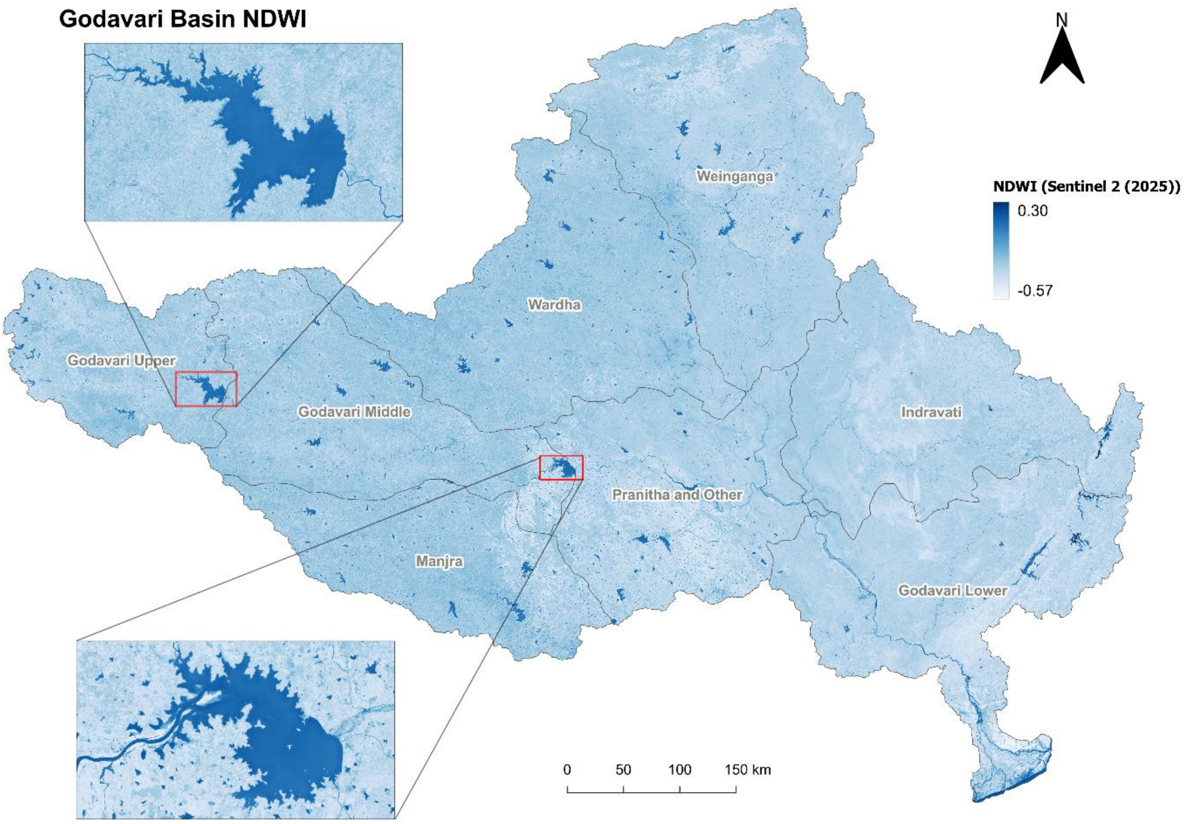

Figure 2: Basin-wide NDWI analysis showing spatial variability of water detection values across the Godavari River Basin derived from Sentinel-2A imagery.

A basin-wide NDWI map (Figure 2) was used to visualize spatial patterns of surface water distribution, enabling identification of major rivers, reservoirs, lakes, tanks, ponds, and wetlands. Higher NDWI values correspond to deeper or more permanent waterbodies, while moderate NDWI values indicate shallow, turbid, or vegetation-influenced water features. Negative NDWI values represent non-water surfaces such as built-up areas, bare soil, and dense vegetation. Waterbody extraction was carried out by applying empirically derived NDWI thresholds, refined through visual interpretation and comparison with known reservoir extents and ancillary reference data. This approach ensured reliable discrimination of surface water while avoiding over-classification in agricultural or moisture-affected areas. Post-classification refinement included removal of isolated pixels and smoothing of boundaries to generate spatially coherent waterbody features suitable for atlas-scale representation.

2.3.2 Waterbody Dynamics and Seasonal Characteristics

To assess the long-term persistence and seasonal behavior of surface waterbodies, the study utilized the Global Surface Water – Transition dataset developed by the Joint Research Centre (JRC) (Pekel et al. 2016). This dataset provides spatially explicit information on changes in surface water occurrence derived from multi-decadal Landsat observations and is widely recognized as a robust reference for surface water dynamics.

The JRC water transition layer classifies pixels based on changes in water presence between historical and recent periods, distinguishing categories such as:

- Persistent permanent water,

- New permanent water,
- Permanent-to-seasonal transitions,
- Seasonal-to-permanent transitions, and
- Loss of permanent or seasonal water.

Permanent waterbodies (dark blue) are concentrated in major reservoirs, regulated river reaches, and deltaic channels. Areas classified as new permanent water reflect expansion of storage infrastructure, particularly in the middle basin where irrigation development has intensified. Extensive seasonal water patterns dominate tank systems and floodplain depressions, emphasizing the monsoon-driven nature of surface water availability in the basin.

Transition zones between permanent and seasonal states indicate hydrological instability, potentially linked to siltation, changing reservoir operation, altered inflow regimes, or climatic variability. In the delta region, mixed transition signals reflect the combined influence of river discharge regulation, backwater effects, and coastal processes. Sentinel-2 NDWI-derived contemporary water extents were used to contextualize and validate transition classes, ensuring that present-day mapping reflects both current conditions and longer-term hydrological behavior. This integrated approach strengthens the atlas by moving beyond static waterbody inventories toward an understanding of water persistence, vulnerability, and transformation over time.

3. Waterbodies Atlas of the Godavari River Basin

3.1 Present status: Location and spread of waterbodies

The spatial mapping of waterbodies across the Godavari River Basin reveals a highly heterogeneous yet structured distribution shaped by physiography, climate, and long-term water management practices (Figure 3). Analysis of multi-season Sentinel-2 imagery indicates the presence of 19,146 mapped waterbodies exceeding 0.5 ha, distributed across eight sub-basins (Central Water Commission 2014).

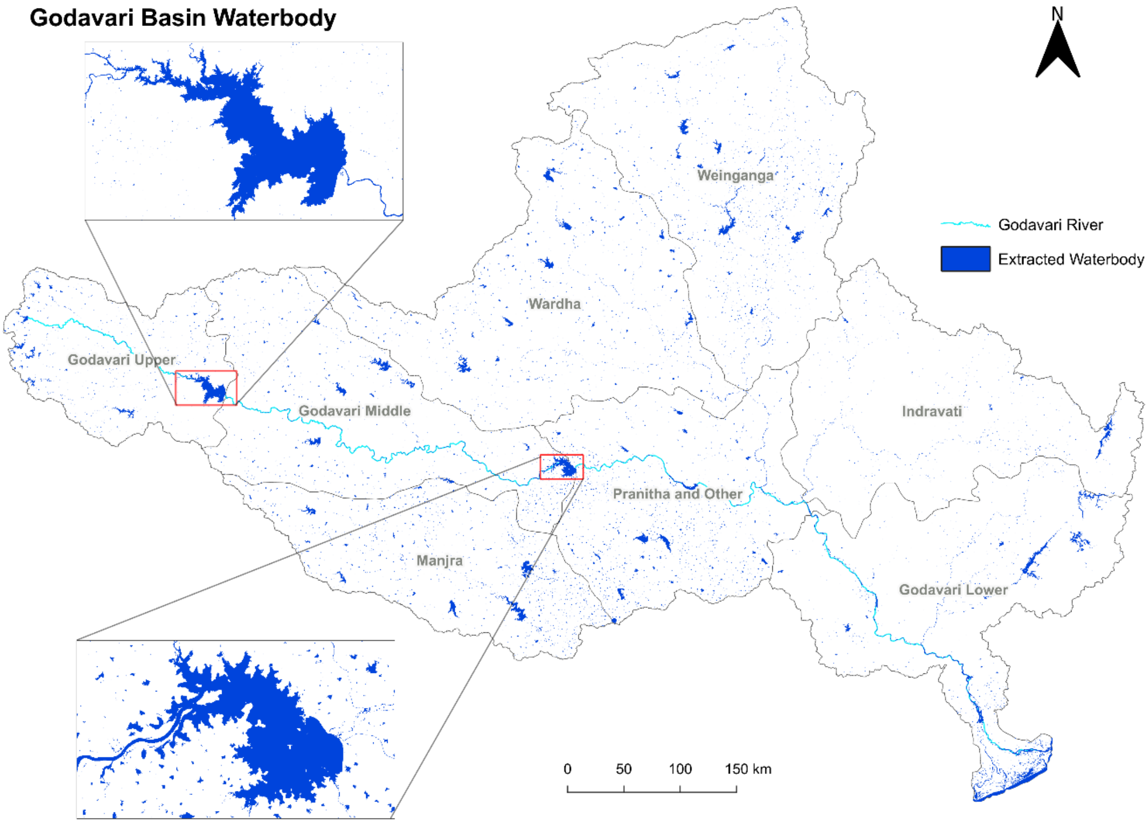

Figure 3: Major Lakes and Wetlands of Godavari Basin

Table 2: Waterbodies number and size (Central Water Commission 2014)

Sl. No.	Size Range (ha)	No. of Waterbodies
1	0 – 25	59951
2	25 – 50	1100
3	50 – 100	462
4	100 – 250	232
5	250 - 500	80
6	500 - 1000	34
7	1000 – 2500	26
8	More than 2500	29

Table 2 summarizes the number of waterbodies in the Godavari River Basin classified by size range, highlighting the pronounced dominance of small waterbodies within the basin. The inventory shows that waterbodies smaller than 25 ha constitute the overwhelming majority, accounting for nearly 60,000 units, reflecting the extensive presence of ponds, tanks, and minor storage structures developed for local water management. In contrast, medium-sized waterbodies between 25 and 250 ha are comparatively fewer, indicating a sharp decline in numbers as size increases. Large waterbodies exceeding 500 ha are relatively rare, with only 89 systems larger than 500 ha and just 29 exceeding 2,500 ha, corresponding primarily to major reservoirs and large natural lakes. This size-class distribution underscores the fundamentally decentralized nature of surface water storage in the basin, where numerous small and medium waterbodies collectively play a critical role in water availability, groundwater recharge, and local-scale irrigation, while a limited number of large reservoirs dominate total storage capacity.

Spatially, waterbodies exhibit clear clustering patterns. High densities occur across the middle plateau regions of Maharashtra and Telangana, where traditional tank systems coexist with modern irrigation reservoirs. In contrast, the steep uplands of the Western Ghats show comparatively sparse waterbody occurrence due to limited storage opportunities and rapid runoff, while the deltaic reaches display dense, interconnected networks of channels, wetlands, and backwaters.

Figure 3 illustrates these basin-wide patterns, highlighting extracted waterbodies across all sub-basins with major reservoirs emphasized in inset views. The figure underscores strong correspondence between waterbody density and physiographic zones—linear and compact forms in reservoir-dominated uplands, dispersed tank systems across the plateau, and intricate, fine-scale mosaics in the delta. The inset panels further demonstrate morphological contrasts, with large reservoirs exhibiting dendritic shorelines controlled by submerged valley topography, while deltaic systems show diffuse boundaries where land–water transitions are gradual and highly dynamic.

3.1.1 Reservoirs and Major Dams

Table 3 presents a selected inventory of 22 major reservoirs within the Godavari River Basin, representing the most significant storage structures across the main river and its major tributaries. These reservoirs are distributed across five states, highlighting the inter-state nature of large-scale water infrastructure in the basin. The listed reservoirs collectively account for an estimated ~25,000 MCM of gross storage capacity and occupy approximately ~2,100 km² of surface area. Storage capacities vary widely, from medium-sized projects such as Kaddam (137 MCM) and Gangapur (203 MCM) to large multipurpose reservoirs such as Jayakwadi (2,111 MCM), Sriram Sagar (2,280 MCM), Balimela (2,009 MCM), and Polavaram (5,490 MCM). This wide range reflects differing design objectives, catchment characteristics, and historical phases of development. Spatially, these reservoirs are predominantly located along the main stem of the Godavari River and its major tributaries, including the Manjira, Penganga, Wainganga, Indravati, Sabari, Kolab, and Pench rivers (Figure 4). Maharashtra hosts the largest number of reservoirs, while the highest individual storage capacities are associated with projects in Andhra Pradesh, Telangana, and Odisha. These infrastructure assets span nearly a century of construction history, from early twentieth-century (1923) projects such as Nizam Sagar to contemporary mega-projects such as Polavaram, reflecting evolving engineering priorities and basin-scale development strategies (Rao 1975; Central Water Commission 2014).

The surface area of reservoirs also shows considerable variation, with smaller hill and plateau reservoirs such as Bhandardara and Kaddam covering less than 20 km², while large valley projects such as Jayakwadi, Sriram Sagar, and Polavaram exceed 250 km². These differences influence evaporation losses, shoreline complexity, and the extent of land submergence. It is important to note that this analysis is descriptive and inventory-based, relying on reported storage capacity and mapped water spread area as presented in Table 3. The table therefore serves as a baseline reference for major reservoir characteristics within the basin rather than an assessment of operational dynamics.

Table 3. Major reservoirs of the Godavari River Basin

Sl. No.	Reservoir Name	River / Tributary	State	Storage Capacity (MCM)	Total Area (Km^2)
1	Donkarayi	Sabari	AP	360	22
2	Sriramsagar	Godavari	TG	2280	253
3	Sri G.V.Sudhakar Rao Lower Manair	Manair	TG	621	79
4	Nizam Sagar	Manjra	TG	482	132
5	Singur	Manjra	TG	822	120
6	Kaddam (K.N.R.)	Kaddam	TG	137	19
7	Upper Wainganga (Sanjay Sarovar)	Wainganga	MP	368	40
8	Jayakwadi (Paithan)	Godavari	MAH	2111	289
9	Isapur	Penganga	MAH	948	85
10	Mula	Mula	MAH	586	53
11	Yeldari	Purna	MAH	803	82
12	Pench (Totladoh)	Pench	MAH	935	63
13	Upper Wardha	Wardha	MAH	503	70
14	Bhandardara	Pravara	MAH	300	19
15	Darna Dam	Darna	MAH	195	27
16	Balimela	Sabari	ORI	2009	74
17	Machkund (Jalaput)	Sabari	ORI	786	72
18	Upper Kolab	Kolab	ORI	636	61
19	Upper Indravati	Indravati	ORI	707	98
20	Majalgaon Dam	Godavari	MAH	453	62
21	Gangapur Dam	Godavari	MAH	203	19
22	Polavaram Dam	Godavari	AP	5490	300

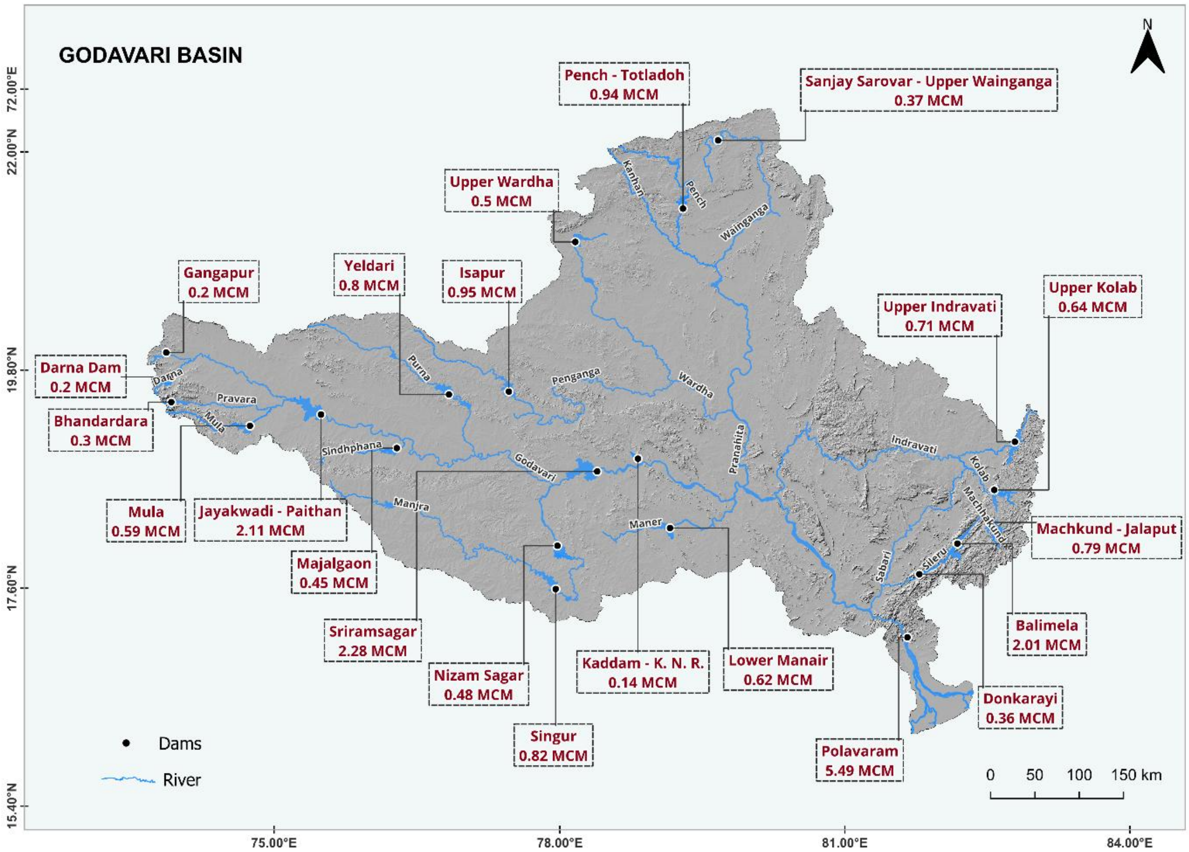

Figure 4: presents the spatial distribution of major reservoirs, illustrating their storage capacity, and geographic area of waterbody spread across the basin.

3.2 Waterbody Transition Dynamics in Godavari River Basin

To capture long-term changes in surface water extent and persistence across the Godavari River Basin, a waterbody transition analysis was carried out using JRC Global Surface Water transition classes (Figure 5). Unlike seasonal pre- and post-monsoon mapping, this analysis represents multi-year changes in water occurrence, identifying stable, newly formed, lost, and transforming waterbodies over time.

The transition analysis indicates that permanent surface water covers 1,562.87 sq.km, forming the hydrologically stable core of the basin. These areas are primarily associated with large reservoirs, major river channels, and long-established tanks that retain water throughout most years. In addition, new permanent waterbodies account for 848.55 sq.km, reflecting expansion of regulated storage systems, stabilization of previously seasonal waterbodies, and the influence of dam construction and reservoir enlargement. In contrast, the loss of permanent water is relatively limited (19.82 sq.km), suggesting that large, perennial systems remain largely resilient at the basin scale (Table 5).

Seasonal waterbodies constitute a substantial and highly dynamic component of the basin's hydrology. Existing seasonal water covers 1,866.50 sq.km, while new seasonal water accounts for 3,758.83 sq.km, making it the largest transition class. This dominance highlights the strong dependence of surface water availability on monsoon rainfall, floodplain inundation, and short-term storage in tanks, wetlands, and agricultural landscapes. The loss of seasonal water (221.20 sq.km) points to localized impacts of land-use change, siltation, drainage modification, and encroachment, particularly in intensively cultivated and peri-urban areas. Transitions between hydrological regimes further reveal changing water permanence across the basin. Approximately 200.77 sq.km of water shifted from seasonal to permanent, indicating stabilization through infrastructural regulation or improved retention capacity. Conversely, 186.54 sq.km transitioned from permanent to seasonal, suggesting reduced storage reliability due to sedimentation, operational changes, or altered inflow regimes. These bidirectional shifts underline the non-static nature of waterbodies and the influence of both natural variability and human interventions. Ephemeral waterbodies, though smaller in extent, remain hydrologically significant. Ephemeral seasonal water covers 572.49 sq.km, while ephemeral permanent water accounts for 9.66 sq.km, representing short-duration inundation in floodplains, agricultural lowlands, and depressions during high-rainfall events. These areas play a critical role in temporary water storage, groundwater recharge, and sediment deposition, despite their limited persistence.

The transition analysis highlights a basin characterized by high surface water dynamism, with expanding seasonal and newly permanent water areas alongside localized losses and regime shifts. These patterns emphasize the need for adaptive, basin-scale water management approaches that recognize not only the presence of waterbodies but also their evolving stability and persistence over time.

Table 5: Surface Water Transition Classes and Areal Extent in the Godavari River Basin

Water Transition Class	Area (Km^2)
Permanent	1563
New permanent	849
Lost permanent	20
Seasonal	1867
New seasonal	3759
Lost seasonal	221
Seasonal to permanent	201
Permanent to seasonal	187
Ephimeral permanent	10
Ephimeral seasonal	572

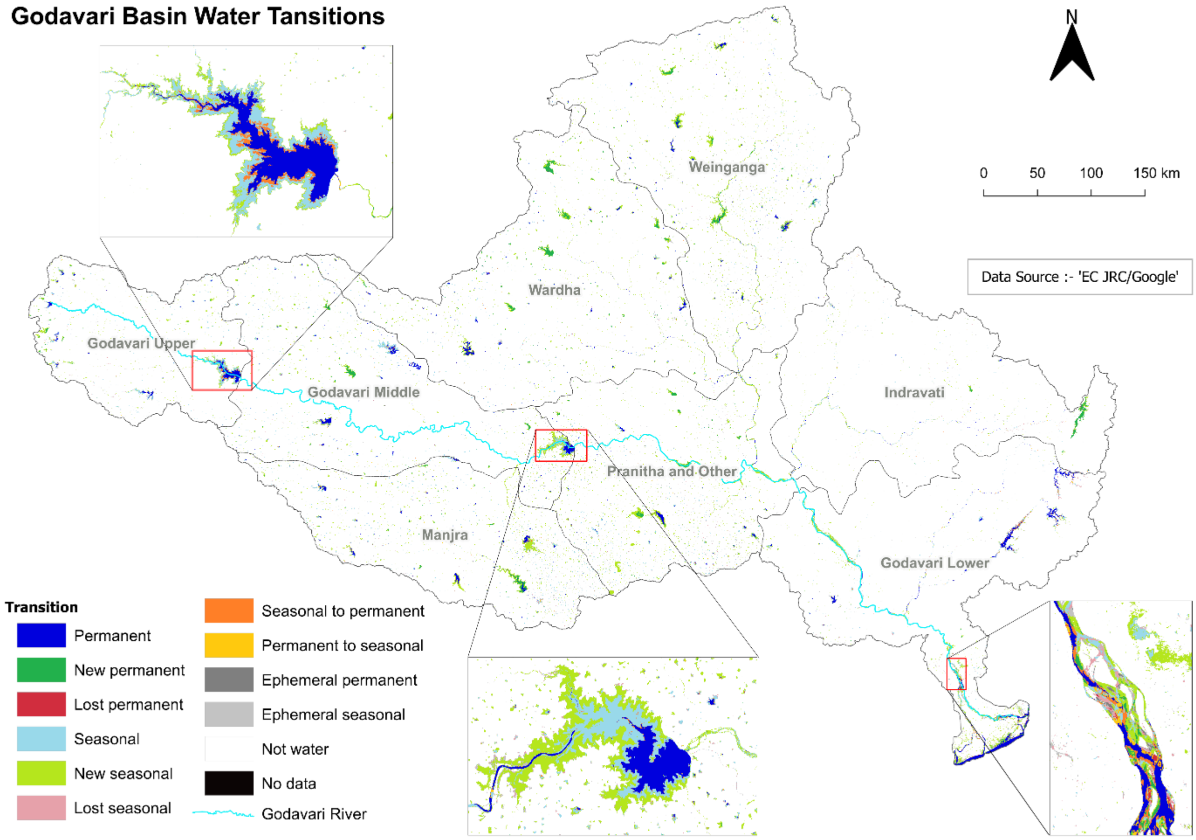

Figure 5: Surface Water Transition Map of the Godavari River Basin derived from JRC Global Surface Water dataset, showing permanent, seasonal, newly formed, lost, and transitional waterbody classes

3.3 Target: future objectives

The spatial products generated in this study i.e. NDWI-based water extent, extracted waterbody inventories, Sentinel-2 false color composites, and long-term water transition maps, establish a baseline for understanding the present hydro-spatial dynamics of the Godavari Basin. The future objective is to evolve this Waterbodies Atlas from a static mapping product into a dynamic monitoring and decision-support system capable of tracking change, supporting adaptive management, and informing policy interventions. Priority actions include increasing temporal monitoring frequency to better capture rapid seasonal transitions, particularly during monsoon onset and withdrawal; integrating satellite-based observations with existing hydrological and meteorological monitoring networks; and expanding database coverage to include smaller waterbodies that play a critical role in local water security and groundwater recharge. The observed patterns of permanent, seasonal, and transitional waterbodies highlight the need for multi-sensor approaches, including radar-based observations, to ensure continuity during cloud-prone periods.

Further development should emphasize automation of change detection using advanced image analysis techniques, while maintaining expert oversight for interpretation. Complementing satellite monitoring with community-based participatory inputs can improve validation, enhance local relevance, and strengthen stewardship of water resources. Together, these steps will enable the Atlas to function as an operational platform supporting resilient and evidence-based water management across the Godavari Basin.

4. Applications for water resource management

The Waterbodies Atlas of the Godavari River Basin is designed as an applied decision-support tool that translates satellite-derived water information into actionable insights for planning, monitoring, and management across sectors. By systematically documenting the location, extent, and transitions of waterbodies, the atlas supports informed decision-making at basin, sub-basin, watershed, and local scales.

4.1.1 Irrigation Planning and Water Allocation

Accurate mapping of reservoirs, tanks, ponds, and irrigation-linked waterbodies enables improved estimation of available surface water during different seasons. Transitional water spread analysis supports irrigation scheduling by identifying areas with reliable post-monsoon storage and regions vulnerable to early drying during pre-monsoon periods. The atlas helps irrigation departments assess command area performance, prioritize rehabilitation of tanks in water-stressed zones, and optimize water releases from major reservoirs in coordination with downstream demands.

4.1.2 Flood Management and Risk Reduction

The spatial inventory of floodplain wetlands, river-connected backwaters, and seasonal storage areas provides critical inputs for flood risk assessment. Identification of natural detention zones supports flood mitigation planning by highlighting areas that attenuate peak flows. Monitoring reservoir water spread and seasonal transitions assists in coordinating reservoir operations during high-flow events, reducing downstream flood impacts while maintaining safety margins.

4.1.3 Drought Monitoring and Preparedness

Inter-annual and seasonal variability in waterbody extent serves as an early indicator of emerging drought conditions. Declining pre-monsoon water spread, reduced seasonal filling of tanks, and shifts from permanent to seasonal water categories highlight areas of increasing vulnerability. The atlas supports drought preparedness by enabling comparison with historical baselines and by identifying regions dependent on limited or highly variable surface water sources.

4.1.4 Groundwater Recharge and Watershed Planning

Mapping of tanks, percolation ponds, check dams, and seasonal waterbodies supports identification of recharge zones critical for sustaining groundwater resources. The atlas aids watershed development planning by locating areas where restoration or construction of small water harvesting structures would maximize recharge benefits. Monitoring seasonal persistence of these structures also provides indirect assessment of recharge performance and maintenance needs.

4.1.5 Environmental Flow and Ecosystem Management

The atlas improves understanding of river-connected wetlands, seasonal pools, and aquatic habitats that depend on specific flow regimes. This information supports environmental flow assessments by identifying ecosystems sensitive to altered reservoir operations. Mapping of wetland extent and seasonality helps guide reservoir release strategies that balance human water use with ecological requirements, particularly in the deltaic and middle basin reaches.

4.1.6 Biodiversity Conservation and Wetland Protection

Detailed mapping of lakes, wetlands, and seasonal waterbodies supports identification of ecologically important habitats, including migratory bird sites and fish breeding areas. The atlas enables prioritization of wetlands for protection and restoration, monitoring of encroachment and hydrological alteration, and assessment of habitat connectivity. These applications are particularly relevant for Ramsar sites and state-designated conservation areas within the basin.

5. Management Implications and Recommendations

The Waterbodies Atlas of the Godavari River Basin provides a spatially explicit foundation for improving water resource management, strengthening ecosystem resilience, and enhancing climate adaptation across the basin. The mapped patterns of permanent, seasonal, and transitional waterbodies highlight both opportunities and risks that require coordinated, multi-level governance. Effective implementation of atlas-based strategies will depend on institutional integration, prioritization of interventions, and sustained stakeholder engagement.

5.1 Waterbody Restoration and Rejuvenation Priorities

Restoration efforts should be strategically prioritized based on water scarcity levels, hydrological connectivity, community dependence, and clarity of ownership and management responsibility. Water-stressed sub-basins in the middle and upper Godavari, where seasonal variability is pronounced, stand to gain the most from tank rehabilitation. Degraded wetlands, particularly in upper catchments and floodplain zones, also warrant restoration due to their role in flood attenuation, sediment trapping, and biodiversity support. Existing schemes such as MGNREGA, watershed development programmes, and state tank rejuvenation missions provide viable financing pathways. However, long-term success will depend on shifting focus from construction-led approaches toward post-restoration maintenance, desilting cycles, and institutional accountability.

5.2 De-silting and Storage Capacity Recovery

Given the high costs and logistical challenges associated with desilting, interventions should prioritize waterbodies that support multiple functions, including irrigation, drinking water supply, flood moderation, and groundwater recharge. Community-managed tanks with demonstrated usage and maintenance capacity should receive preference. Where feasible, excavated sediments may be repurposed for agricultural soil improvement, embankment strengthening, or land reclamation, reducing disposal challenges and increasing local acceptance. Periodic satellite-based monitoring can be used to track sediment accumulation rates and inform preventive catchment treatment measures such as afforestation, contour bunding, and erosion control.

5.3 Encroachment Monitoring and Prevention

The atlas reveals significant encroachment pressure on waterbodies, particularly in peri-urban areas, transport corridors, and rapidly expanding settlements. Regular satellite-based monitoring provides an objective mechanism for early detection of encroachment, land-use conversion, and reduction in water spread area. These insights should support enforcement of buffer zone regulations, wetland protection rules, and land-use zoning policies. Strengthening legal frameworks for rapid response, combined with clear demarcation of waterbody boundaries and public disclosure of waterbody maps, can reduce disputes and unauthorized land conversion. Community awareness campaigns and local vigilance committees can further reinforce protection efforts by linking conservation outcomes with local water security benefits.

5.4 Integration with Basin-Scale Planning and Governance

To maximize its utility, the Waterbodies Atlas should be formally integrated into river basin master plans, state water policies, and irrigation management frameworks. Cross-state coordination is particularly critical in the Godavari Basin, where hydrological connectivity transcends administrative boundaries. Shared access to standardized waterbody data can improve coordination of reservoir operations, drought response measures, and flood management strategies. Regular updates to the atlas, supported by automated workflows and institutional mandates, will enable adaptive management by reflecting new infrastructure, restoration outcomes, and climate-driven changes in water availability.

5.5 Stakeholder Engagement and Capacity Building

Sustainable management of waterbodies ultimately depends on the active participation of local communities, water user associations, panchayats, and civil society organizations. Training programmes focused on basic monitoring, maintenance practices, and interpretation of atlas outputs can build local capacity and ownership. Incentive mechanisms—such as recognition schemes, performance-linked funding, and priority access to restoration support—can encourage community stewardship. Participatory approaches, supported by transparent data sharing and feedback mechanisms, can bridge the gap between technical assessments and on-ground action, ensuring that atlas-based recommendations translate into lasting improvements in water security and ecosystem health.

6. Limitations and Uncertainties

While the Waterbodies Atlas provides a comprehensive basin-scale assessment, several limitations and sources of uncertainty should be considered when interpreting the results and applying them for management decisions. These constraints are largely inherent to large-area remote sensing–based assessments and highlight areas for future refinement rather than deficiencies of the approach.

6.1 Spatial Resolution Constraints

The analysis relies primarily on Sentinel-2 imagery with a spatial resolution of 10 meters, which is well suited for mapping medium to large waterbodies but limits the reliable detection of very small features. Farm ponds, narrow channels, and temporary pools smaller than approximately 0.25 hectares are likely underrepresented, particularly in agricultural landscapes where such structures are abundant. As a result, the atlas may underestimate the true number of micro-waterbodies that contribute to local water security and groundwater recharge. Incorporation of higher-resolution satellite data or targeted local surveys would improve representation of these features.

6.2 Temporal Gaps and Cloud Cover Effects

Persistent cloud cover during the monsoon season poses a significant challenge for optical satellite analysis. In some parts of the basin, prolonged cloud presence restricts observation of peak inundation and limits precise timing of seasonal transitions. Approximately 12% of the basin experiences recurrent cloud obstruction during critical post-monsoon periods, occasionally requiring interpolation or reliance on multi-date composites. While compositing reduces this impact, short-duration flood events and rapid drawdown phases may not be fully captured. Integration of cloud-penetrating radar datasets (e.g., Sentinel-1) can partially mitigate this limitation in future updates.

6.3 Classification Uncertainty and Dynamic Hydrology

Waterbodies in the Godavari Basin exhibit strong seasonal and inter-annual variability driven by monsoon intensity, reservoir operations, and land-use change. This dynamic behavior introduces uncertainty in classifying features as permanent, seasonal, or transitional. Shifts in waterbody status may reflect climate variability, sedimentation, infrastructure modification, or management practices rather than long-term hydrological change. Regular updates and multi-year analysis are therefore essential to avoid over-interpretation of short-term fluctuations.

6.4 Validation and Ground Truth Limitations

Field validation across a basin of this size is logistically challenging. Remote locations, difficult terrain, seasonal inaccessibility, and safety constraints limit systematic ground verification of all mapped features. In addition, many traditional tanks and ponds lack reliable historical documentation, complicating validation of long-term change trends. While cross-comparison with established datasets and visual interpretation improves confidence, some uncertainty remains, particularly for smaller and intermittently inundated waterbodies.

6.5 Incomplete Attribute Information

Although the spatial mapping of waterbodies is extensive, associated attribute data—such as construction year, ownership, operational status, and management responsibility—are incomplete for a large proportion of features, especially smaller traditional structures. Historical records are often fragmented or unavailable, constraining detailed analysis of aging infrastructure, governance effectiveness, and long-term performance. Strengthening linkages between spatial inventories and administrative databases will be critical for enhancing the atlas's analytical depth.

7. Conclusion

This Waterbodies Atlas provides a basin-scale synthesis of the location, extent, and seasonal dynamics of waterbodies across the Godavari River Basin. By integrating NDWI analysis, extracted waterbody mapping, high-resolution satellite composites, and long-term water transition data, the study moves beyond static inventories toward a dynamic understanding of how water is stored, redistributed, and transformed across space and time. The results underscore a central paradox: despite extensive large-scale infrastructure, local and traditional waterbodies remain indispensable to water security and ecological functioning. Seasonal variability—amplified by climate uncertainty—makes adaptive management not optional, but necessary. The Atlas lays a technical and conceptual foundation for such adaptation, but its ultimate value will depend on institutional uptake, regular updating, and meaningful stakeholder engagement. If sustained and expanded, this framework has the potential to support more resilient, equitable, and ecologically informed water management—not only in the Godavari Basin, but as a transferable model for other large river systems facing similar challenges.

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