सत्यमेव जयते

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

GODAVARI RIVER AT A GLANCE

JUNE 2024

Centres for Godavari River Basin Management Studies

Centre for Ganga River Basin Management and Studies

GODAVARI

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Centre for Ganga River Basin Management and Studies

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.

www.nrcd.nic.in

Centres for Mahanadi River Basin Management Studies (cMahanadi)

The Centre 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.

www.cgodavari.org

Centre 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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Team

Rajesh Biniwale, cGodavari, CSIR-NEERI Nagpur
Amit Bansiwal, cGodavari, CSIR-NEERI Nagpur
Yogesh Pakade, cGodavari, CSIR-NEERI Nagpur
Asheesh Sharma, cGodavari, CSIR-NEERI Nagpur
Rakesh Kadaverugu, cGodavari, CSIR-NEERI Nagpur
Sharda Kosankar, cGodavari, CSIR-NEERI Nagpur
Hemant Bherwani, cGodavari, CSIR-NEERI Nagpur
Asif Qureshi, cGodavari, IIT Hyderabad
Debraj Bhattacharyya, cGodavari, IIT Hyderabad
K.P Prabheesh, cGodavari, IIT Hyderabad
Satish Regonda, cGodavari, IIT Hyderabad
Anindita Majumdar, cGodavari, IIT Hyderabad
Pritha Chatterjee, cGodavari, IIT Hyderabad
Vinod Tare, cGanga, IIT Kanpur

सत्यमेव जयते

जल शक्ति मंत्री
भारत सरकार

Minister for Jal Shakti
Government of India

संदेश

मानव सभ्यता का विकास नदियों के किनारे हुआ है, और इसे सुरक्षित रखने के लिए नदियों का संरक्षण अत्यंत आवश्यक है। भारत की नदियों के स्वास्थ और सुरक्षा के लिए 2019 में संसद के संयुक्त सत्र में राष्ट्रपति ने गंगा नदी के उदाहरण पर अन्य प्रमुख नदियों के बेसिन प्रबंधन की आवश्यकता पर बल दिया था। इस उद्देश्य की पूर्ति हेतु छह प्रमुख नदियों के बेसिन प्रबंधन में सी–गंगा के समग्र समन्वय से 12 प्रतिष्ठित शैक्षणिक संस्थाओं को शामिल करने का निर्णय लिया गया। राष्ट्रीय नदी संरक्षण निदेशालय द्वारा संचालित कंडीशन एसेसमेंट एंड मैनेजमेंट प्लान (कैंप) प्रोजेक्ट नदियों के समग्र बेसिन प्रबंधन को साकार करने का प्रयास है।

नदियों के संरक्षण और उनके प्रबंधन के लिए इस तरह की पहल से न केवल हमारे प्राकृतिक संसाधनों का बचाव होगा, बल्कि स्थानीय समुदायों के जीवन और संस्कृति को भी संरक्षित किया जा सकेगा। यह अत्यंत हर्ष का भविष्य है कि इस प्रोजेक्ट के तहत तैयार की गई ''रिवर एट ए ग्लांस'' रिपोर्ट का लोकार्पण होने जा रहा है। जैसे किसी व्यक्ति के बाह्य स्वरूप से उसकी पुरी पहचान नहीं होती, वैसे ही नदी के व्यवहार और चुनौतियों को सिर्फ मुख्यधारा से नही समझा जा सकता। इसके लिए नदी के इतिहास, उसके किनारे बसे नगरों और गांवों की संस्कृति, सहायक नदियों और उस क्षेत्र के भूगोल को भी समझाना पड़ता है। इसी रिपोर्ट के जरिए नदी की पूरी प्रकृति, उसकी चुनौतियाँ, सहायक नदियां और आसपास के क्षेत्रों की सांस्कृतिक–भौगोलिक स्थिति को समझने के जो कोशिश की गई है, वह बहुत महत्वपूर्ण है।

हमें विश्वास है कि यह रिपोर्ट नदी, जल और पर्यावरण के क्षेत्र में काम करने वाले व्यक्तियों, संस्थाओं और हितकारकों के लिए अत्यधिक उपयोगी साबित होगी। रिपोर्ट के प्रकाशन और लोकार्पण के इस विशेष अवसर पर बधाई।

सीआर पाटील

सत्यमेव जयते

जल शक्ति राज्य मंत्री
भारत सरकार, नई दिल्ली

Minister of State for Jal Shakti
Government of India, New Delhi

संदेश

नदियां हमारे जीवन के लिए अत्यावश्यक संसाधन हैं और उनका पर्यावरणीय, सामाजिक, और आर्थिक महत्व भी बहुत अधिक है। नदियों का संरक्षण भविष्य की पीढ़ियों के लिए जीवन की गुणवत्ता सुनिचित करने की दिशा में एक महत्वपूर्ण कदम है। देश की छह प्रमुख नदियों के बेसिन प्रबंधन के लिए शीर्ष तकनीकी शिक्षण संस्थाओं के सहयोग से राष्ट्रीय नदी संरक्षण निदेशालय का कैंप (कंडीशन एसेसमेंट एंड मैनेजमेंट प्लान) प्रोजेक्ट संरक्षण के लिए वर्तमान सरकार की प्रतिबद्ता दर्शाता है। भारत सरकार के नमामि गंगे मिशन के अंतर्गत किये प्रयासों से आज गंगा नदी के पुनर्जीवन को वैशिक मान्यता मिल चुकी है। उम्मीद है की ऐसी ही सफलता हमें कैंप प्रोजेक्ट में भी मिलेगी।

मुझे यह देखकर बहुत प्रसन्नता हो रही है की कैंप प्रोजेक्ट आरंभ होने के बाद काम ने भी गती पकड़ ली है। इस प्रोजेक्ट के अंतर्गत ''रिवर एट ए ग्लेंस'' रिपोर्ट के प्रकाशन के लिए हार्दिक बधाई। यह रिपोर्ट नदी के संबंध में संपूर्ण जानकारी देती है, इस विस्तारित रिपोर्ट से नदी को प्रभावित करने वाले विभिन्न कारकों को समझने में सहायता मिलेगी। इन जानकारीयों का इस्तेमाल नदियों से संबंधित योजनाएं बनाने में मददगार साबित होगा।

नदी बेसिन प्रबंधन के लिए उठाए गए इन कदमों से न केवल जल संरक्षण सुनिश्चित होगा, बल्कि पर्यावरण संरक्षण और कृषि की स्थिरता भी बनी रहेगी। यदि हम आज जल संरक्षण और प्रबंधन के लिए ठोस कदम उठाते हैं, तो भविष्य में हम एक स्थिर समृद्ध समाज की दिशा में बढ़ सकते हैं।

डा. राज भूषण चौधरी

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.

cGodavari and cGanga

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LIST OF ABBREVIATION

BCE	:	Before Common Era
OD	:	Biological Oxygen Demand
CPCB	:	Central Pollution Control Board
CWC	:	Central Water Commission
DTE	:	Down to Earth
ESRI	:	Environmental Systems Research Institute
GIS	:	Geographical Information System
GoI	:	Government of India
GSI	:	Geological Survey of India
IMD	:	India Meteorological Department
ISRO	:	Indian Space Research Organization
LULC	:	Land Use and Land Cover
MLD	:	Million Liters per Day
MPCB	:	Maharashtra Pollution Control Board
MSME	:	Micro, Small & Medium Enterprises
NRSC	:	National Remote Sensing Center
RD & GR	:	River Development and Ganga Rejuvenation
RS	:	Remote Sensing
SoI	:	Survey of India
STP	:	Sewage Treatment Plant
USGS	:	United States Geological Survey
WRIS	:	Water Resource Information System

1. INTRODUCTION

The need to conserve and protect the Godavari River and its tributaries is never more important for ensuring sustainable regional growth. The current challenges the river and its tributaries face should be assessed for practical and implementable solutions for rejuvenating and restoring the rivers. Overall, the objective of the present study is to ensure *Nirmal* and *Aviraldhara* (clean and continuous river flow). In this report, the geographical, demographical, cultural, economic, and ecological aspects of the Godavari River basin have been discussed briefly. Further, the Godavari River characteristics have been briefly described along several segments considered in the study.

The Godavari River, also known as the Ganges of the South (*Dakshinganga*), is known for its significant cultural and economic aspects in India. Originating from the *Brahmagiri* hill in Maharashtra, it flows across central and southern India, including Maharashtra, Telangana, Andhra Pradesh, and eventually outfalls into the Bay of Bengal. The river's total length is around 1460 km from the origin to outfall into the Bay of Bengal. Its extensive drainage basin covers 312,812 km^2, making it one of the largest river basins in the country, which is nearly 10% of the geographical area of the country. The river is fed by numerous tributaries, including the Pravara, Manjira, Indravati, and Sabari rivers, significantly contributing to its flow and water volume as shown in Figure 1. The Godavari River has been harnessed for hydroelectric power generation through dams and reservoirs, providing irrigation, drinking water, and electricity to the surrounding regions. The river holds significant cultural and religious importance in India, with numerous temples, ghats, and pilgrimage sites along its banks. The Kumbh Mela, a major Hindu festival and pilgrimage, is held every twelve years in the riverine town of Nashik. The river supports agriculture in the fertile plains of the Godavari basin and serves as a transportation route for goods and people. Efforts are underway to conserve and restore the river's ecosystems, including protecting riparian habitats and mitigating pollution and habitat degradation.

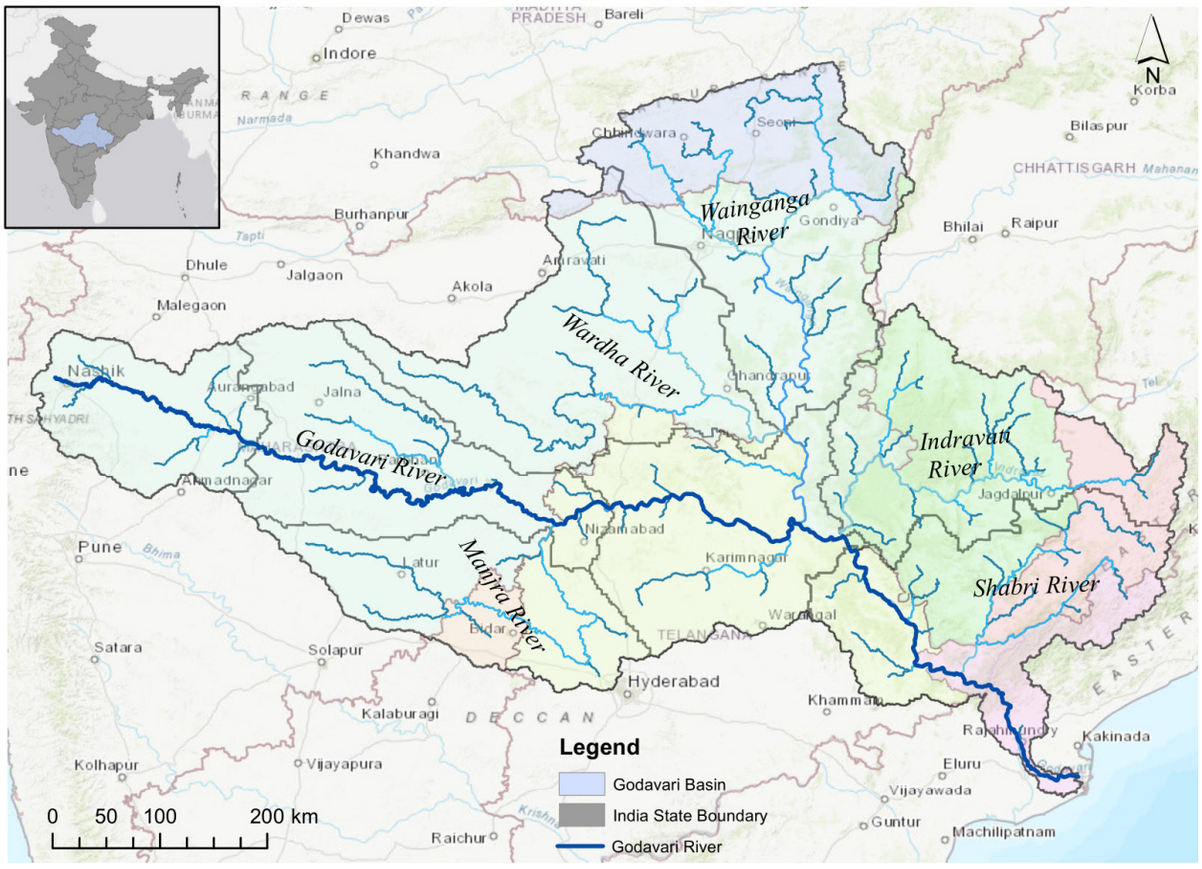

Figure 1: Godavari River and its major tributaries

2. SALIENT FEATURES OF THE BASIN

2.1. River basin, sub-basins, and its Tributaries

2.1.1. River Basin

The basin falls in the Deccan Plateau, lying between 73°24' to 83°4' 0E and 16°19' to 22°34' 0N. The basin is bounded on the north by the Mahadeo Hills, the Satmala Hills, on the north-west by the Ajanta Range, on the west by the North Sahyadri range of the Western Ghats, on the east and south-east by the Eastern Ghats and on the south by the Balaghat Range. The interior part of the basin lies in the Maharashtra Plateau, the more significant part of which is at an elevation of 300-600 m sloping eastward. The eastern part of the basin is majorly covered by the Dandakaranya Range, with the Eastern Ghats forming the eastern boundary of the peninsula.

The Godavari River Basin spans several states, providing essential water for agriculture, industry, and domestic use. The overly of the Godavari River and its tributaries with the administrative boundaries is shown in Figure 2. The Survey of India state maps reveal that Maharashtra covers 48.7% of the basin, supporting agriculture and livelihoods in regions like Marathwada and Vidarbha. Telangana and Andhra Pradesh have the second-largest portion (23.7%), supporting irrigation systems and paddy cultivation. Madhya Pradesh's south-eastern part occupies 7.8%, while Odisha's north-eastern regions occupy 5.7%. Karnataka's 1.4% share contributes to local agriculture and water resources, while Chhattisgarh's 12.4% share is significant. Puducherry's 0.01% share is symbolic but part of the basin's significant geographic delineation.

2.1.2. Sub-basins

Watersheds are natural hydrological entities that cover land surfaces where rainfall flows to a defined drain, channel, stream, or river. The Godavari River basin has 8 sub-basins, which are further divided into 466 micro-watersheds, each representing a different tributary system, governed by hydrological principles. The maximum number of watersheds falls in the Wainganga sub-basin (Table 1). The distribution of watersheds over the eight sub-basins of the Godavari basin is shown in (Figure 2 And Table 1).

Table 1: Godavari River Sub basins and its watershed distribution

No.	Sub-Basin	Area (km^2)	Size Range of Watersheds (km^2)	No. of Watersheds
1	Wardha	46242.09	361 - 946	69
2	Wainganga	49695.40	305 - 972	80
3	Godavari Lower	44492.93	304 - 990	67
4	Godavari Middle	36290.47	325 - 955	56
5	Godavari Upper	21443.23	331 - 988	33
6	Indravati	38306.10	343 - 993	60
7	Manjra	29472.88	421 - 981	44
8	Pranhita and Others	36119.60	326 - 982	57

2.1.3. Tributaries

The Godavari River is fed by numerous tributaries supporting the basin's extensive hydrological network. Significant tributaries include Manjira, Pravara, Purna, Penganga, Wardha, Wainganga, Pranahita, Sabari, Indravati, and Kolab (Table 2 and Figure 2). The Pravara and the Manjra are the main tributaries joining on the right bank of the river, and the Purna, the Pranhita, the Indravati, and the Sabari are the main tributaries joining on the left bank. The Pravara rises in the Western Ghats, flowing in an easterly direction, and falls into the Godavari, with its drainage area falling entirely in Maharashtra. The Purna rises in the Ajanta Range of hills flowing south-easterly and joins the Godavari. of its tributaries, the longest of which is the Dudna. The chief tributaries of the Purna on the south bank are the Pendhi, Uma, Katepurna, Nirguna, and Man. The Manjra rises in the Balaghat Range of hills flowing in a general east-south-east direction. The principal tributaries of the Manjra are the Tirna, the Karanga, and the Haldi, joining it from the right, and the Lendi and the Maner, which join from the left. The Pranhita is the largest tributary of the Godavari. It conveys the combined waters of the Penganga, the Wardha, and the Wainganga, and below its confluence with the Manjira, it falls into Godavari.

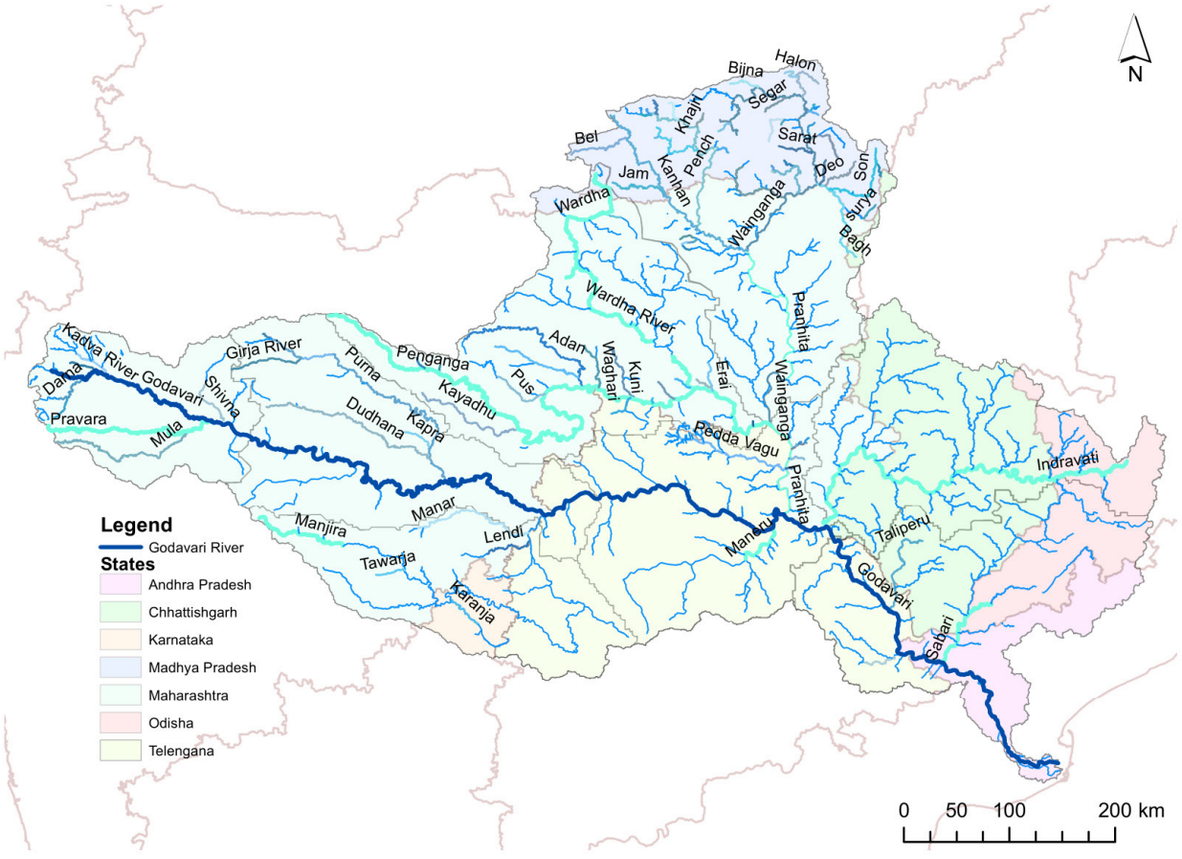

Figure 2: Overlay of the Godavari Basin and its tributaries with the state boundaries

Table 2: Major tributaries in the Godavari Basin

Name of Tributary	Sub-Basin Name	Origin Route	Length (km)	Joining Godavari
Pravara	Godavari Upper	Western Ghats, Ahmednagar, Maharashtra	208	Nivasa, Ahmednagar, Maharashtra
Purna	Godavari Middle	Ajantha-Satpura Ranges, Madhya Pradesh	373	Jambhulbet, Parbani, Maharashtra
Manjira	Manjra	Balaghat Range, Maharahstra	724	Kandakurthi, Nizamabad, Telangana
Manair	Pranhita and Other	Karimnagar, Telangana	225	Demarakunta
Pranahita	Pranhita and Other	Tumdi Hettty, Kouthala Mandal, Telangana	113	Kaleshwaram, Bhoopalapally, Telangana
Indravati	Indravati	Eastern Ghats, Kalahandi, Odisha	535	Bhadrakali, Bijapur, Chattisgarh
Sabari	Godavari Lower	Sinkaram Hills, Odisha	418	Kunavaram, East Godavari, Andhra Pradesh
Wainganga	Wainganga	Mahadeo Hills in the Seoni District of Madhya Pradesh	635	After joining the Wardha River, the united stream, which is known as the Pranahita River
Wardha	Wardha	Satpura Range	538	flows into the Wain ganga river to form the Pranhita river

The Indravati, a river in the Eastern Ghats, flows through the central part of the Dankaranya region and has catchments in Madhya Pradesh and Odisha. It joins the Godavari at an altitude of 915 m and has important tributaries like the Narangi, Boardhig, Kotari, Nibra, Bandia, Nandiraj, and Dantewara. The Kolab, a major tributary of the Sabari, drains the southern uplands of the Dandakaranya region. The discharge varies seasonally, with a monsoon season peak, and forms a large fertile delta at its mouth on the Bay of Bengal.

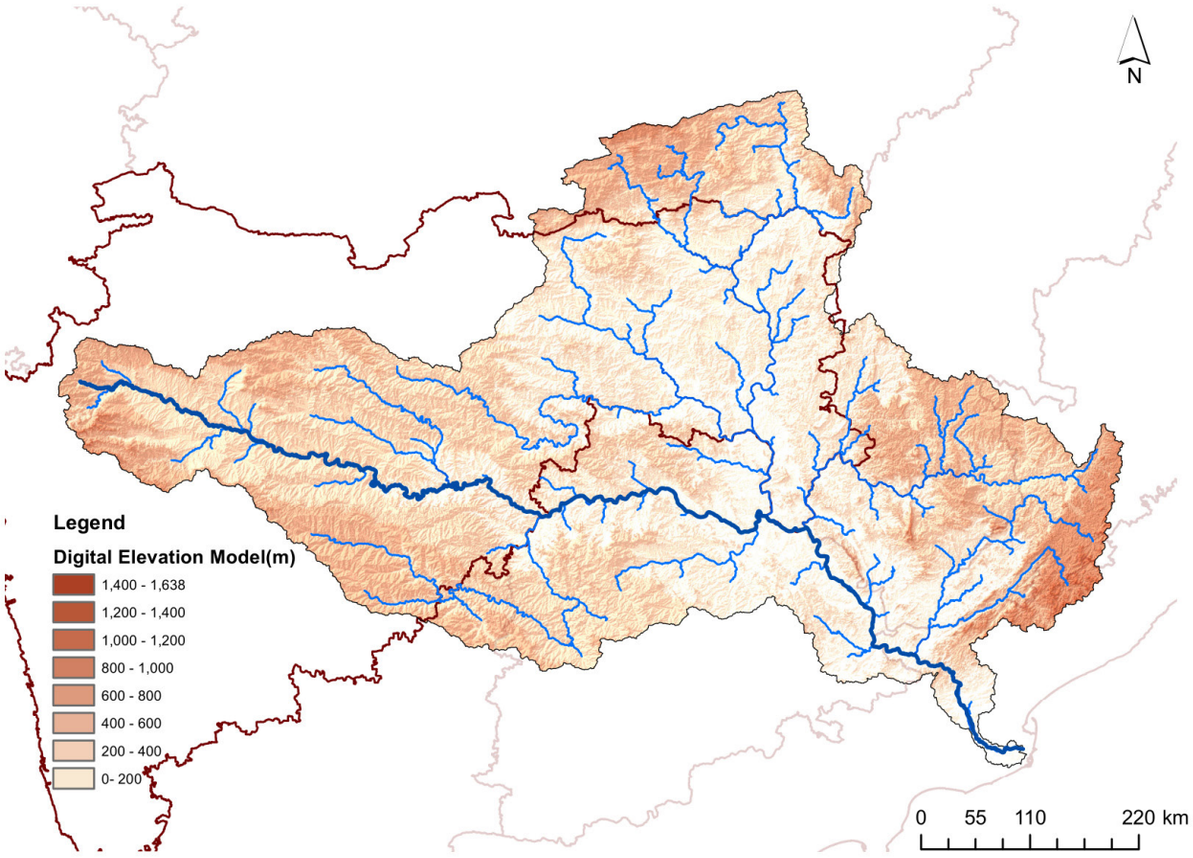

Figure 3: Elevation in the Godavari River Basin

(Source: SRTM)

2.2. Geographical features of the basin

The Godavari basin in India comprises the Deccan Plateau, hills, and plains. The Western Ghats, located in Maharashtra and Telangana, are known for their dense forests and biodiversity. The lower reaches are fertile plains, particularly in Telangana and Andhra Pradesh, which support intensive agriculture, mainly rice cultivation. The Godavari Delta, a major river delta, is characterized by fertile alluvial soil. The land slopes vary, with steep slopes in plateaus and hills and gentler slopes in plains.

The elevation data of the river basin was obtained from the SRTM datasets (USGS) of 30 m spatial resolution. The data shows that the elevation values range from the mean sea level to 1400 m (Figure 3). The western part of the basin has a higher elevation than the middle and eastern parts, except at the locations of the Eastern Ghats.

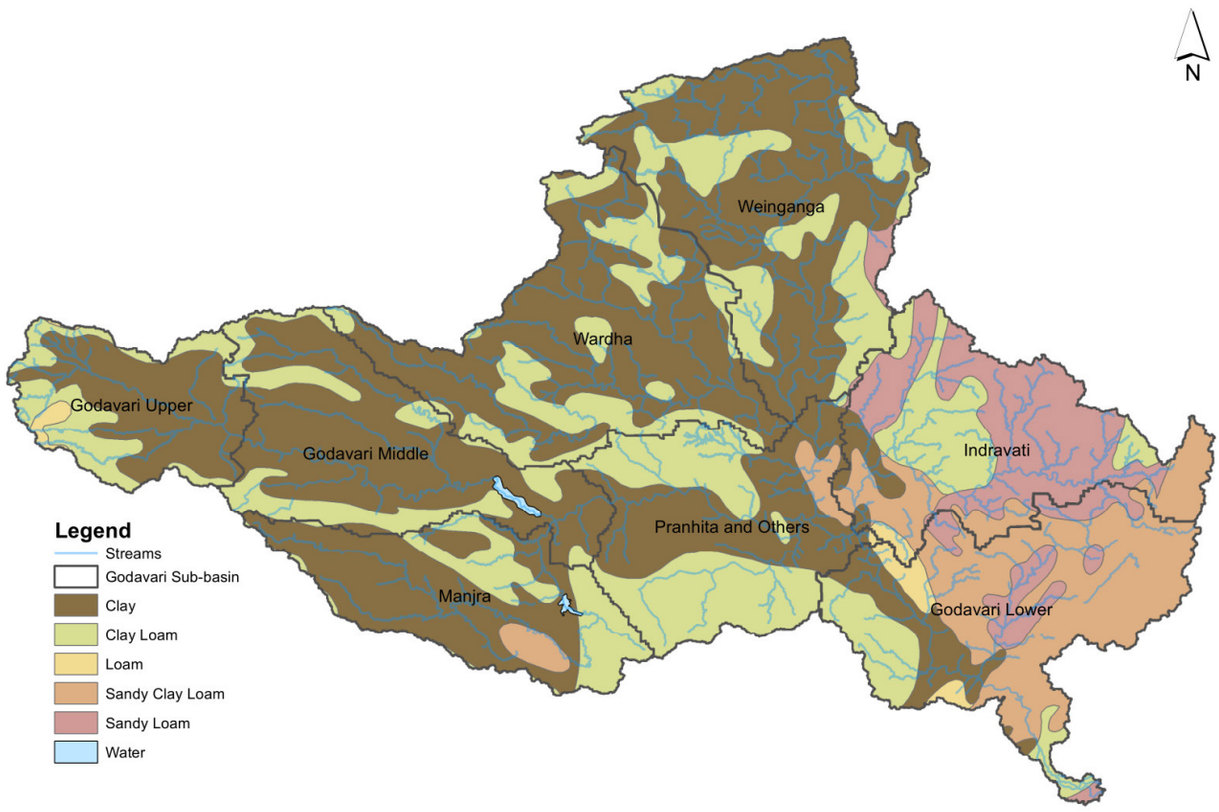

Figure 4: Soil type in Godavari River Basin

The soil map in the Godavari basin is shown in Figure 4, the data was obtained from the Food and Agriculture Organization Soils Portal (https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/en/).

Clay Soil, a type of soil with high clay content, is suitable for crops like rice, sugarcane, and certain vegetables. It is a blend of clay and loam, offering good water retention and drainage. Loam Soil, a balanced mixture of sand, silt, and clay, is fertile and versatile, supporting wheat, cotton, and vegetables. Sandy Clay Loam Soil, with a higher proportion of sand than clay, offers better drainage and moisture retention. It is suitable for maize, groundnuts, and soybeans. Sandy Loam Soil, a mix of sand, silt, and clay, requires frequent irrigation for excellent drainage.

Nearly 61% of the basin is covered with clay-type soil, followed by Sandy Clay Loam (16%), Sandy Loam (11%), Clay Loam (10%), and Loam Soil (0.3%). In Maharashtra State, the majority of the land is covered with Clay and Clay Loam.

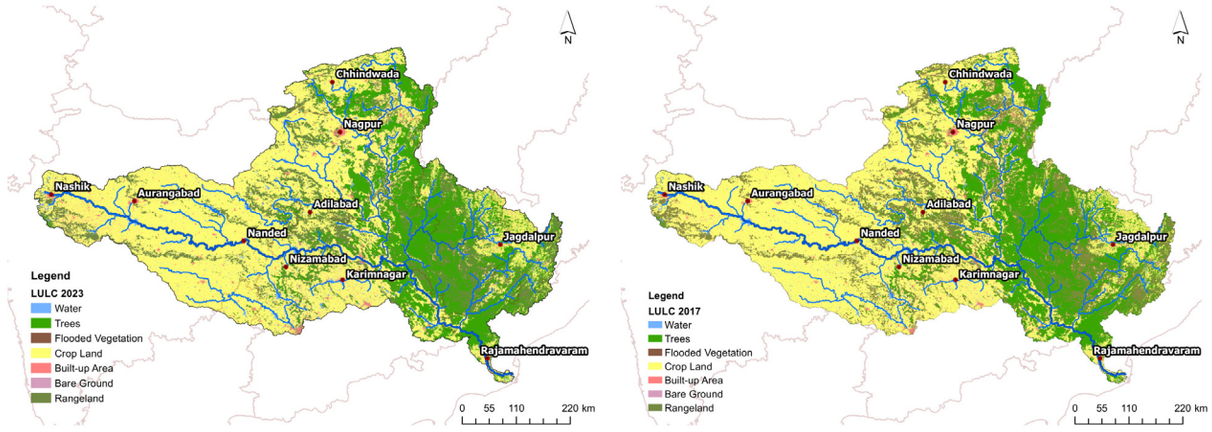

Figure 5: Land Use Land Cover of the Godavari River basin of 2023 and 2017

2.3. Natural Resources

Godavari basin has a rich variety of mineral wealth spread over vast areas. The principal minerals found are bauxite, manganese, iron ore and coal. Other minerals like lead, zinc, corundum, refractory minerals and kaolin are also found in small quantities in different parts of the basin. Mining of coal, manganese and other ores are important activities in the districts rich in minerals. Most of the ores are at present being exported. Some of the key mineral resources found in the Godavari River basin include: Coal, Limestone, clay, manganese, bauxite, iron ore, quartzite, granite, and other minor minerals like gypsum, dolomite, shale and sandstone.

2.4. Land use and land cover in the basin

The raster images of the LULC representing the Godavari Basin were obtained from ESRI datasets for 2017 and 2023 having a spatial resolution of 10 m (Karra, Kontgis, et al 2013). The data shows (Figure 5 and Table 3) the LULC in the river basin is covered with water bodies, trees, flood-prone vegetation, cropland, built-up areas, barred ground, and rangelands. The data shows that in 2023, 7353.54 km2 area (2.3%) is covered with rivers, lakes, ponds, and other water bodies. Trees cover 63433.47 km2 (20.47%), including forests, woodlands, and individual trees. Flooded vegetation may be submerged under water during periods of flooding. Cropland (54.7%) refers to areas where agricultural activities are conducted, including cultivated fields. Built-up areas (3.2%) include urbanized or developed areas with buildings, roads, infrastructure, and other human-made structures. Bare ground is devoid of vegetation or water cover, often consisting of deserts, rocky terrain, or soil degradation. Rangelands are open areas used for grazing livestock, which occupies around 18.6%.

Table 3: Land Use Land Cover Area in the Godavari River Basin

No.	Class	2017 Area (km^2)	2023 Area (km^2)
1	Water	6095.26	7353.54
2	Tree	69587.81	63433.47
3	Flooded Vegetation	170.09	125.23
4	Cropland	171558.60	169570.06
5	Built-up area	518.52	11385.74
6	Bare Ground	0.0036	286.74
7	Rangeland	62069.34	57728.17

2.5. Dams/barrages/Hydro-electric projects

The dams/barrages/hydro-electric projects spread in the Godavari River Basin are shown in the Figure 6 and Figure 7. The data was obtained from (WRIS-INDIA 2014). Table 4 presents data on the dams and barrages in the river basin.

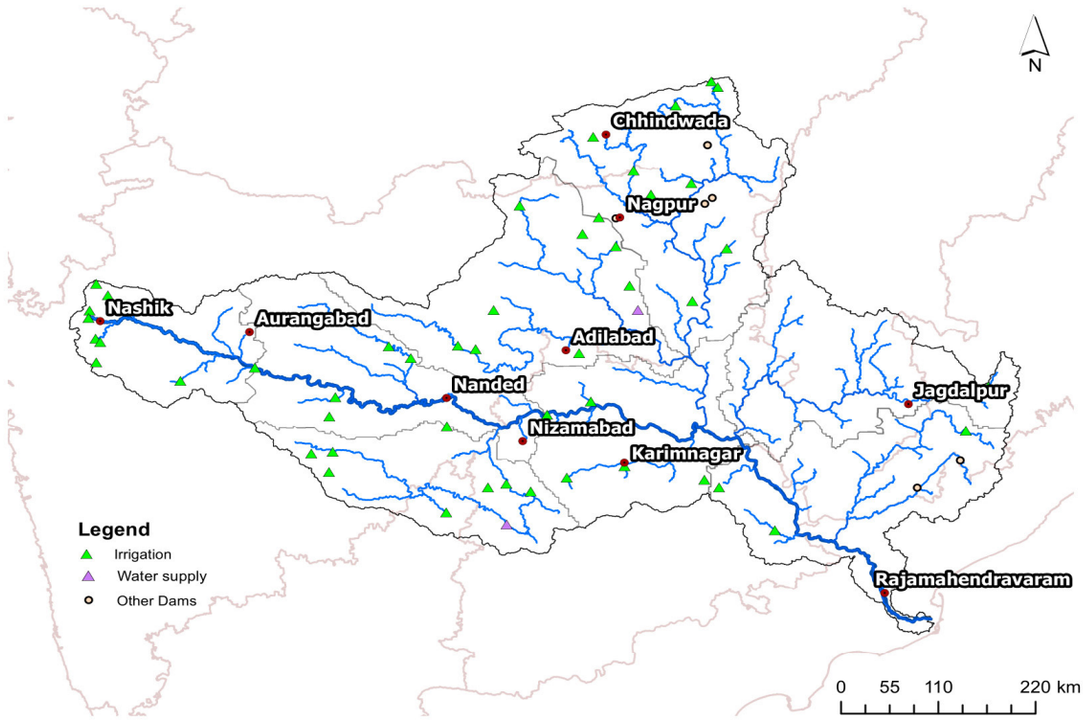

Figure 6: Dam on Godavari River basin (*WRIS 2014*)

Surface water is stored in the form of lakes, ponds, reservoirs, tanks, etc. Surface water bodies have played an important role by way of irrigation, drinking water supply, ecology, tourism and domestic uses. A large-scale inventory of surface water bodies in Godavari basin shows 19146 of such bodies. There are reportedly 870 major reservoirs in the basin. Some large reservoirs of this basin are Jayakwadi, Sriramsagar, Balimela, Yeldari, Singur, Pench, Isapur, Upper Kolab, Indrawati, and Nizam Sagar. Most of the water bodies have a size range of 0-25 ha whereas 29 big water bodies cover an area of more than 2500 ha.

Table 4: Total dams and barrages in the Godavari River basin (*WRIS 2014*)

Sr. No.	Sub Basin	Dams	Barrages
1	Godavari Lower	28	5
2	Godavari Middle Sub Basin	156	16
3	Godavari Upper Sub Basin	114	0
4	Indravati Sub Basin	21	0
5	Manjra Sub Basin	128	1
6	Pranhita Sub Basin	59	1
7	Wardha Sub Basin	236	3
8	Wainganga Sub Basin	149	2

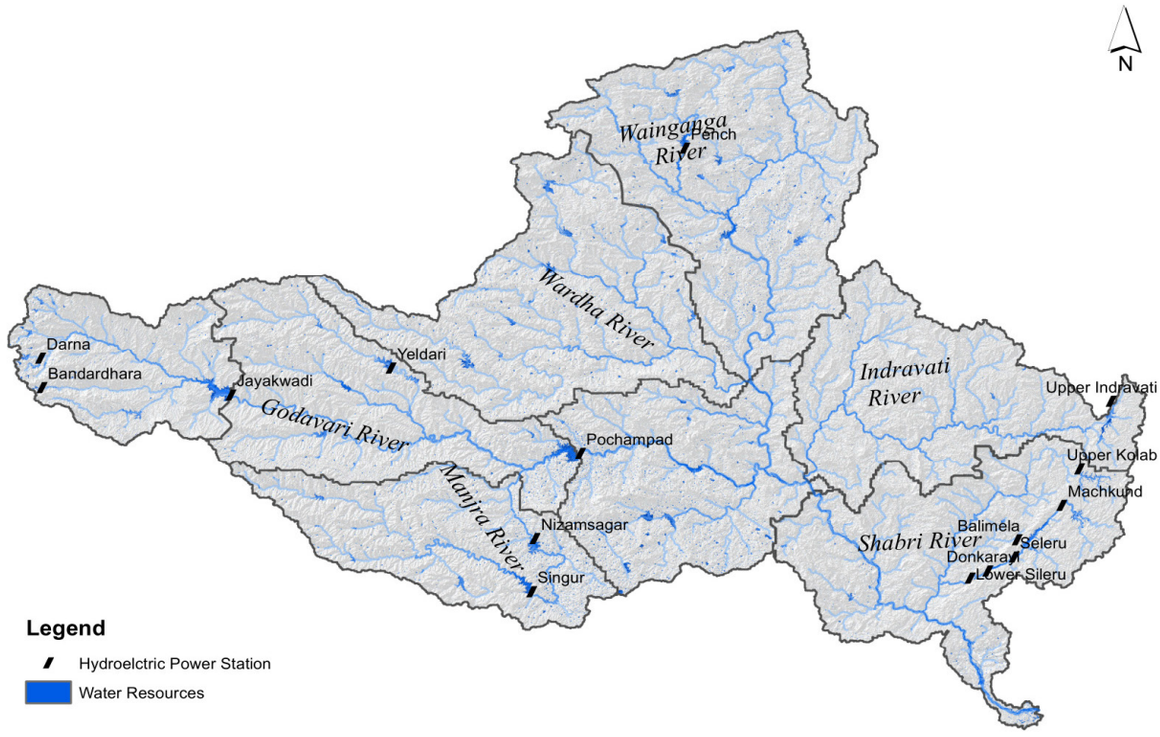

Figure 7: Hydrological Power Station in Godavari River Basin (*WRIS-INDIA 2014*)

Table 5: Hydroelectric power stations and their capacities

Sr. No.	Name of Hydroelectric Project	District	River	Capacity (MW)
1	Balimela Hydroelectric Project	Malkangiri	Sileru	510
2	Bandardhara Hydroelectric Project	Ahmadnagar	Pravara	34
3	Darna Hydroelectric Project	Nashik	Darna	4.90
4	Donkarayi hydroelectric project	Andra Pradesh	Sileru	25
5	Jayakwadi Hydroelectric Project	Aurangabad	Godavari	12
6	Lower Sileru Hydroelectric Project	Khammam	Sileru	460
7	Machkund Hydroelectric Project	Koraput	Machkund	114.75
8	Nizamsagar Hydroelectric Project	Hyderabad	Godavari	10
9	Pench Hydroelectric Project	Nagpur	Pench	160
10	Pochampad Hydroelectric Project	Nizamabad	Godavari	27
11	Singur Hydroelectric Project	Medak	Majeera	15
12	Upper Indravati Hydroelectric Project	Bhawamipatna	Indravati	600
13	Upper Kolab Hydroelectric Project	Koraput	Kolab	320
14	Seleru Hydroelectric Project	Visakhapatnam	Sileru River	240
15	Yeldari Hydroelectric Project	Parbhani	Purna	22.5

The Figure 7 presents data on the hydroelectric power stations in the river basin. The total installed capacity of the hydroelectric power generation in the basin is around 2555 MW. There are 15 hydroelectric projects in the basin, presented in Table 5. The hydroelectric projects are owned by many large organizations. The Hydroelectric projects are distributed in 4 states, where 7 projects are there in Andhra Pradesh, 4 in Maharashtra, 2 in Odisha, and 1 in Madhya Pradesh. There are 2 inter-state hydro-electric projects: a) The Machkund Hydroelectric Project between Andhra Pradesh and Odisha and b) the Pench Hydroelectric Project between Madhya Pradesh and Maharashtra.

2.6. Social aspects: People, Places and Human Settlements

The Godavari basin, spanning 55 parliamentary constituencies, has a total population of 60.48 million, influenced by human settlements. The basin is spread across 25 districts in Maharashtra, 18 in Andhra Pradesh, 4 in Madhya Pradesh, 3 in Chhattisgarh and Odisha, and 1 in Karnataka and Puducherry. The population density varies from 25-50 persons per km2 to 500-1000 persons per km2. East Godavari, West Godavari, Nagpur, Pune, Rangareddy,

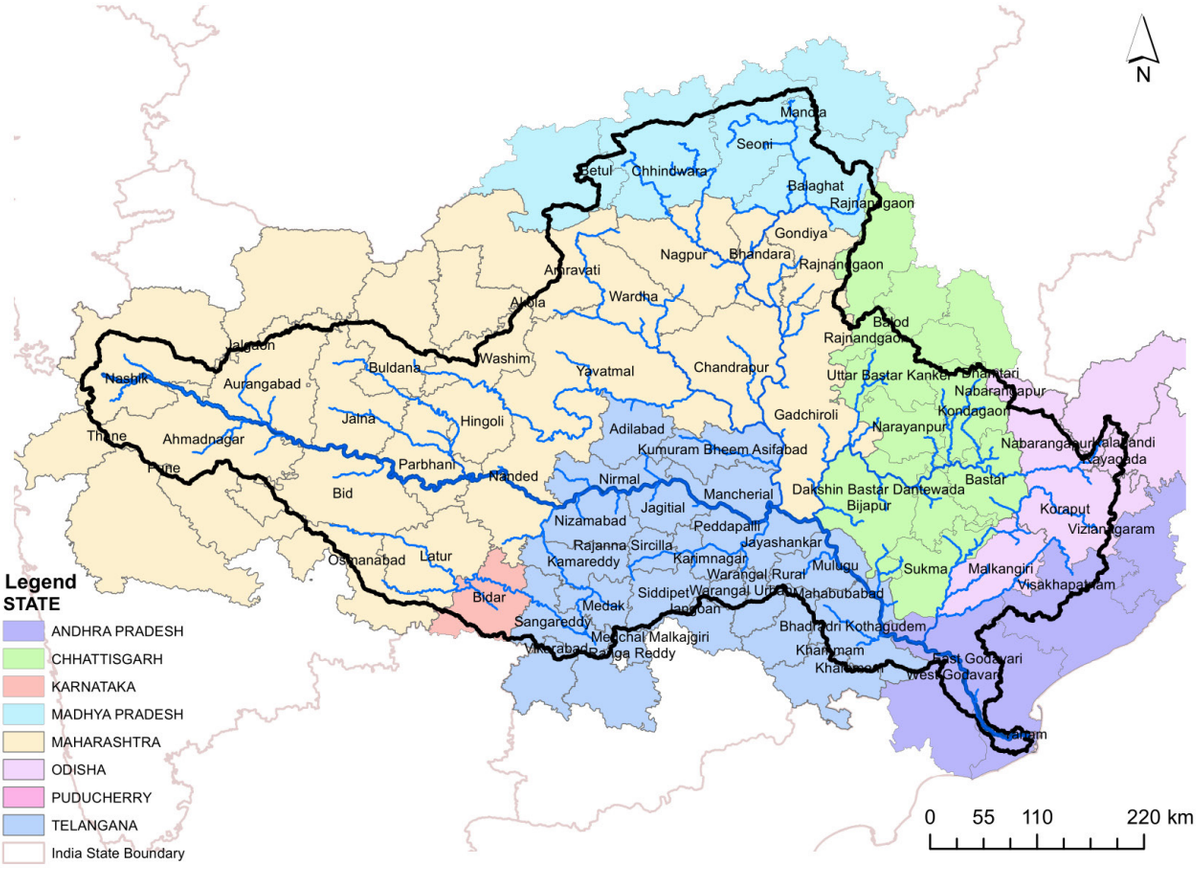

Figure 8: District Location in Godavari River Basin (SoI)

and Visakhapatnam districts have higher population density. Nagpur is the most important urban center, along with Nasik, Aurangabad, Warangal, Rajahmundry, Akola, Amravati, and Ahmednagar. The basin has high industrial potential, with over 441 towns, 58072 settlements, and 33 cities. Six airports are falling in the basin. The overlay of the administrative districts on the Godavari Basin is presented in Figure 8. The data were obtained from the Survey of India.

There are 74 administrative districts in the Godavari Basin comprising 7 states and 1 union territory Table 6. The cumulative population of all the districts in the basin is around 76.8 million according to the Census 2011 (data obtained from the Ministry of Home Affairs). Nearly 40.1 million of the population (50%) is from Maharashtra State, 17.9 million (24.37%) from Telangana State, 4.5 million (6.2 %) from Andhra Pradesh, 5.3 million (7.2 %) from Chhattisgarh State, 4.2 million (5.7 %) from Madhya Pradesh, 2.7 million (3.7%) from Odisha State, 1.8 million (2.4%) from Karnataka, and 0.1 million (0.01%) from Pondicherry Union Territory. The data were obtained from the Ministry of Home Affairs, GoI (Census, 2011).

Table 6: Administrative Divisions in the Godavari Basin Based on Fully Covered Districts

State	Dis-tricts	Blo-cks	Te-hsils	Gram Panchayats	Villag-es	Municipal Councils	Towns	Wards	Municipal Corporations
Telangana*	11	214	197	4257	6231	45	-	524	16
Andhra Pradesh*	6	168	211	4898	7375	33	118	1213	9
Odisha	3	31	44	520	3125	6	13	57	0
Maharashtra	8	-	96	7,302	11,502	67	140	605	7
Chhattisgarh	1	7	7	580	1150	2	6	15	11
Madhya Pradesh	3	29	30	1996	4936	11	31	106	1
Puducherry	1	1	1	0	-	1	1	10	0

* The population census data is from 2011, when Telangana and Andhra Pradesh were a single state. The districts included in this data reflect the boundaries before the state was divided in 2014.

The populations of the partially covered districts are calculated based on the % of the area covered in the basin.

2.7. Biodiversity and ecosystems at a glance

The Godavari River and its basin host a rich and diverse array of biodiversity, encompassing various ecosystems, flora, and fauna.

2.7.1. Aquatic Ecosystems

The Godavari River is home to numerous fish species, including commercially important ones like Indian Major Carps (Catla, Rohu, Mrigal) and other native species such as the Deccan Mahseer and Pulasa (Hilsa) fish, which are vital for local fisheries. Also, the river and its tributaries support a variety of aquatic plants, which provide habitat and food for numerous aquatic organisms. These plants play a crucial role in maintaining the ecological balance of the river system.

2.7.2. Terrestrial Ecosystems

The Godavari basin includes diverse forest types such as tropical rainforests, deciduous forests, and mangroves. These forests are crucial for maintaining biodiversity and providing ecosystem services like carbon sequestration and water regulation. The estuarine regions of the Godavari, especially around the delta, support extensive mangrove forests. These mangroves are critical habitats for many species of fish, birds, and invertebrates, and they act as buffers against coastal erosion and storms.

2.7.3. Flora

The basin is rich in plant biodiversity, including numerous tree species, shrubs, herbs, and grasses. Notable species include teak, sal, bamboo, and various medicinal plants. Certain regions of the basin, such as the Eastern Ghats, are home to endemic plant species that are not found elsewhere, highlighting the unique biodiversity of the area.

2.7.4. Fauna

The basin supports a variety of mammalian species, including tigers, leopards, elephants, deer, wild boars, and numerous smaller mammals. Protected areas like wildlife sanctuaries and national parks within the basin help conserve these species. The basin is a haven for birdlife, including migratory and resident species. Wetlands and forested areas provide critical habitats for birds such as the Indian Grey Hornbill, Painted Stork, and numerous waterfowl species. The basin is home to various reptiles and amphibians, including crocodiles, turtles, snakes, and frogs. The freshwater ecosystems and forested areas provide essential habitats for these species.

2.7.5. Invertebrates

The Godavari basin supports a diverse insect population, including pollinators like bees and butterflies, which are crucial for maintaining plant diversity and agricultural productivity. The river and its tributaries are home to numerous aquatic invertebrates such as mollusks, crustaceans, and insect larvae, which play vital roles in the aquatic food web and ecosystem health.

2.7.6. Riparian Ecosystems

The Godavari delta in India is home to a diverse range of riparian ecosystems, including mangrove forests, which are the second-largest in the country. The delta is home to 27 mangrove species, including 14 true mangroves, 5 associated species, and 8 halophytes. The dominant mangrove species include Acanthus ilicifolius, Avicennia officinalis, A. marina, Suaeda maritima, S. monoica, S. nudiflora, and Excoecaria agallocha. The estuary includes the Coringa Wildlife Sanctuary (CWS), which provides habitat for migratory birds like the painted stork, Asian openbill, and little egret. The mangrove forests are crucial for stabilizing the coastline and supporting reptiles, amphibians, and small mammals. The riverbanks are home to the Indian monitor lizard, Indian python, and Indian gray mongoose, while the floodplains and wetlands provide habitat for amphibians like the Indian bullfrog and Indian pond frog.

2.7.7. Forest Ecosystems

The Godavari basin is home to numerous protected areas, including national parks, wildlife sanctuaries, and reserve forests, which are home to a diverse range of flora and fauna. These forests support endangered species like the Bengal tiger, Indian leopard, sloth bear, and various deer species. The forests also support plant species like teak, Sal, and bamboo. The semi-evergreen forests in the region are home to valuable timber species like mahogany, rosewood, and ebony. Protected areas like Papikonda National Park in Andhra Pradesh offer rich floristic diversity with over 2,531 plant species, 173 endemic species, and carnivores like tigers, leopards, hyenas, and sambar.

2.7.8. Wetland Ecosystems

The Godavari basin includes important wetlands like Kolleru Lake Wildlife Sanctuary, which serves as a crucial stopover point for migratory birds. The sanctuary supports various aquatic plants, submerged macrophytes, and wetland vegetation. The Godavari estuary is one of the rarest eco-regions on earth, home to endangered species like fishing cats, Olive Ridley turtles, Indian smooth-coated otters, and fringed-lipped carp (Labeo fimbriatus).

3. ANTHROPOGENIC SIGNATURES AND WATER QUALITY

3.1. Anthropogenic activities

3.1.1. Urbanization

Urbanization and population growth along the Godavari River have led to illegal constructions and encroachments, obstructing the river's natural flow and increasing flood risks. Major cities along the river include Gangakhed, Rajahmundry, Nashik, Nanded, and Ramagudam, with populations ranging from 49500 to 229644. This rapid growth in population has increased water demand and wastewater generation rates, as seen in direct sewage discharge at Macherial and Ramagundam. Environmental regulations and zoning laws must be followed to prevent such issues (Figure 9).

Figure 9: Wastewater discharge without treatment

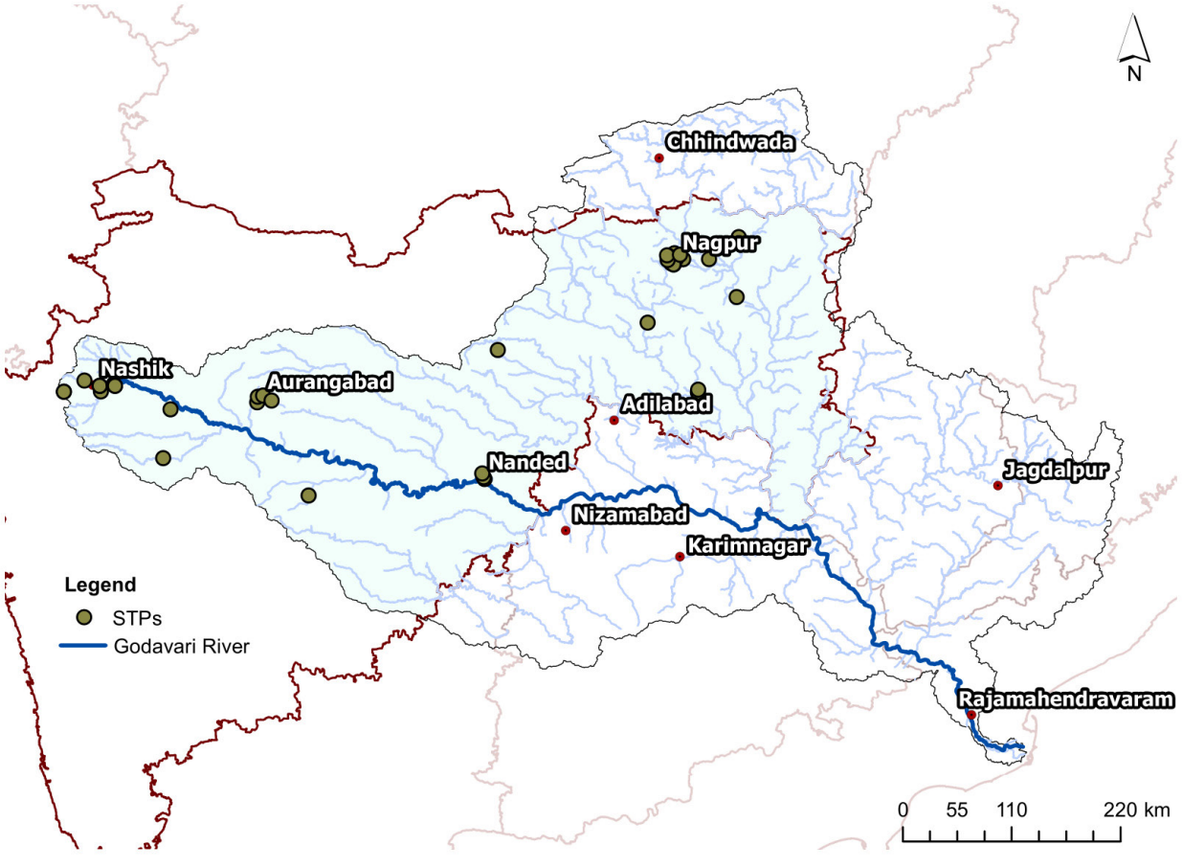

Figure 10:STPs in Godavari River Basin

There are around 112 sewage treatment plants in the Maharashtra State portion of the Godavari Basin (Figure 10) with a total installed capacity of 2156.99 MLD, a proposed capacity of 990 MLD, and an under-constructed capacity of 178.8 MLD. The STPs range from 1-200 MLD, and most of these STPs are identified in Nagpur, Nashik, and Nanded. The data were obtained from the Maharashtra State Pollution Control Board (MPCB 2024) and the report on the Godavari Basin, which is jointly prepared by (CWC and NRSC 2014).

3.1.2. Agriculture

The development of agriculture in lower reach areas has increased water demands, leading to the construction of numerous minor irrigation projects to harness available water. However, this has resulted in a scarce availability of inflows into different dams. The Godavari basin, covering 152.59 lakh ha, has a maximum of 90.74 lakh ha (59.50%) under crop sowing, 11.09 lakh ha (7.26%) fallow land, and 3.59 lakh ha (2.36%) and 3.16 lakh ha (2.07%) pasture and tree areas. The basin also has a forest area of 25.37 lakh ha (16.64%), uncultivable waste area of 6.81%), and barren land of 3.33%. The total cultivable land is 108.41 lakh ha (71.05%), with a cropping intensity of 107%. The total irrigated area is 29.46

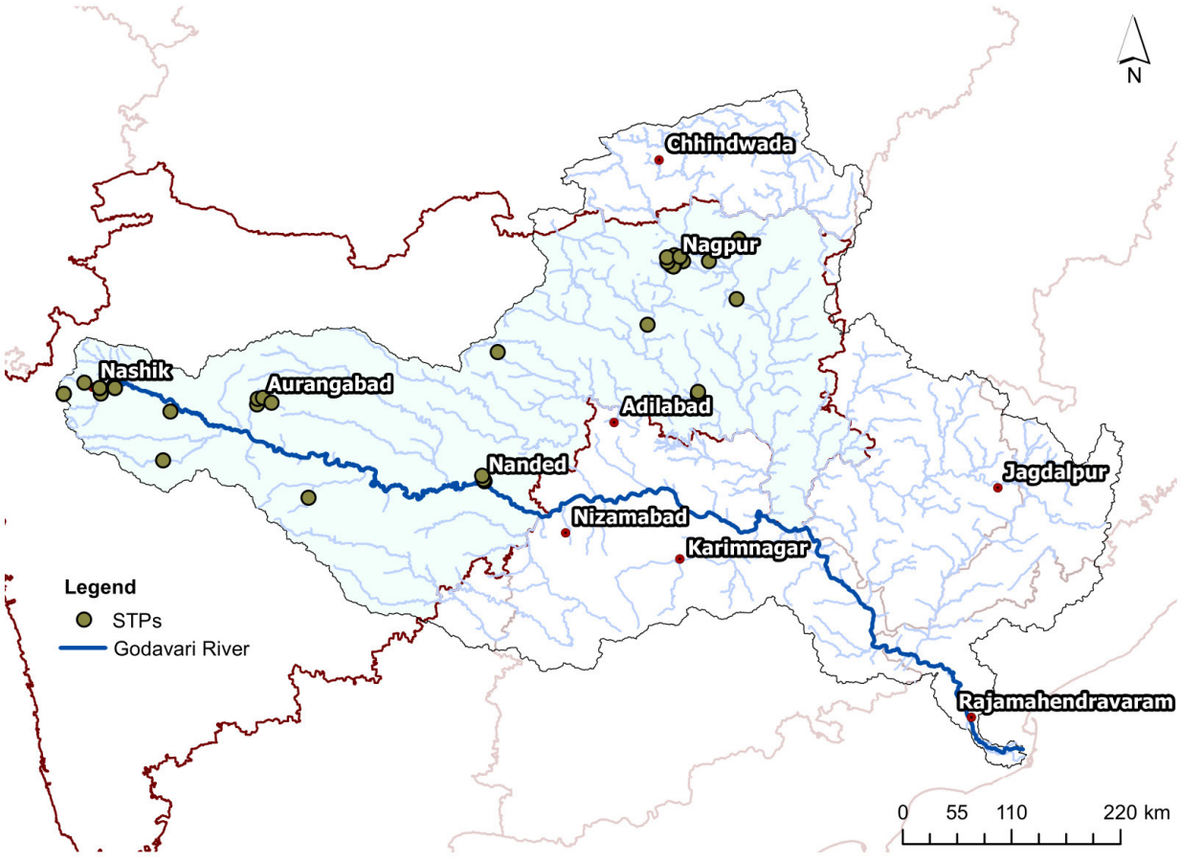

Figure 11: Industries in Godavari River Basin

lakh ha, with 15.63 lakh ha by canal, 0.35 lakh ha by lift, 1.22 lakh ha by micro-irrigation, 11.67 lakh on well, and 0.57 on tube well. The total rainfed area is 78.94 lakh ha, with 27.18% irrigation intensity (MWRD, 2018).

3.1.3. Industrial Activities

The major urban Centers in the basin are Nagpur, Aurangabad, Nashik, Rajahmundry. Nashik and Aurangabad have many industries especially automobile industries. Other than this, the industries in the basin are mostly based on agricultural produce such as rice milling, cotton spinning and weaving, sugar and oil extraction. Cement and some small engineering industries also exist in the basin.

Various industrial sectors include Textile, Sugar, Pharmaceuticals, Food, Power, and Chemical. Most of these Industries are located in Nashik, Chandrapur, Aurangabad, and Nagpur

Districts. A total of 141 major industries are identified in the Maharashtra part of the Godavari Basin (Figure 11). The data was obtained from the Ministry of MSME, Government of India (https://msme.gov.in/).

3.2. Water quality and pollution

3.2.1. Surface Water

Like all rivers across India, Godavari also faces severe pollution from sewage, agricultural runoff, and industrial effluents. In Maharashtra a whopping 300 km upper stretch of Godavari from Nashik District to Paithan has been declared as a priority I critically polluted stretch by CPCB with BOD ranging from 6 mg/L to 36 mg/L. A petition has been filed in the high court by a few activists from the city against Nashik Municipal Corporation (NMC), Government of India (GoI), Government of Maharashtra (GoM), and Maharashtra Industrial Development Corporation (MIDC) for failure on their part to clean the river [WRIS-INDIA]. Large stretches of major tributaries of Godavari are also critically polluted e.g. 150 km stretch of Wainganga from Tumsa to Ashti has been declared as critically polluted. Another 150 from Penganga River has also been critically polluted. 20 km stretch of Kanhan, 40 km stretch of Darna, 2 km stretch of Manjara among few others feature prominently through the CPCB report. Domestic wastewater from urban centres is one of the principal pollutants of Godavari. However, in Wardha basin the river is also critically polluted due to coal mining and thermal power plants. Mud from the coal mines and ash from the thermal power plants is routinely disposed in the river in this region [WRIS-INDIA]. The locations/ stretches of rivers not meeting the Primary water quality criteria for outdoor bathing for BOD parameter i.e. more than 3 mg/L are identified as polluted locations or polluted stretches [IEP-2022].

3.2.2. Ground water quality

The basin has 1875 observation wells to assess ground water potential in various hydrogeological settings, with priority given to drought-affected, tribal, hard rock, and pollution-affected areas. The Godavari Upper Sub Basin has the least observation wells, while Wardha Sub Basin has the most. Ground water levels fluctuate significantly during the pre and post-monsoon season, with significant recharge in some districts. However, upper and western parts experienced 2-4 m falls and more than 4 m rise due to draft. Interpolated maps for groundwater recharge and irrigation draft are prepared.

3.3. CWC Stations in the Godavari Basin

Total gauging stations operated by CWC in the Godavari Basin (Figure 12) are around 51, which measure Gauge Discharge (GD=27 No.), Sediment (GDS=1), water quality (GDQ=2), and all three parameters (GDSQ=21). The data were obtained from the Central Water Commission website (CWC 2024).

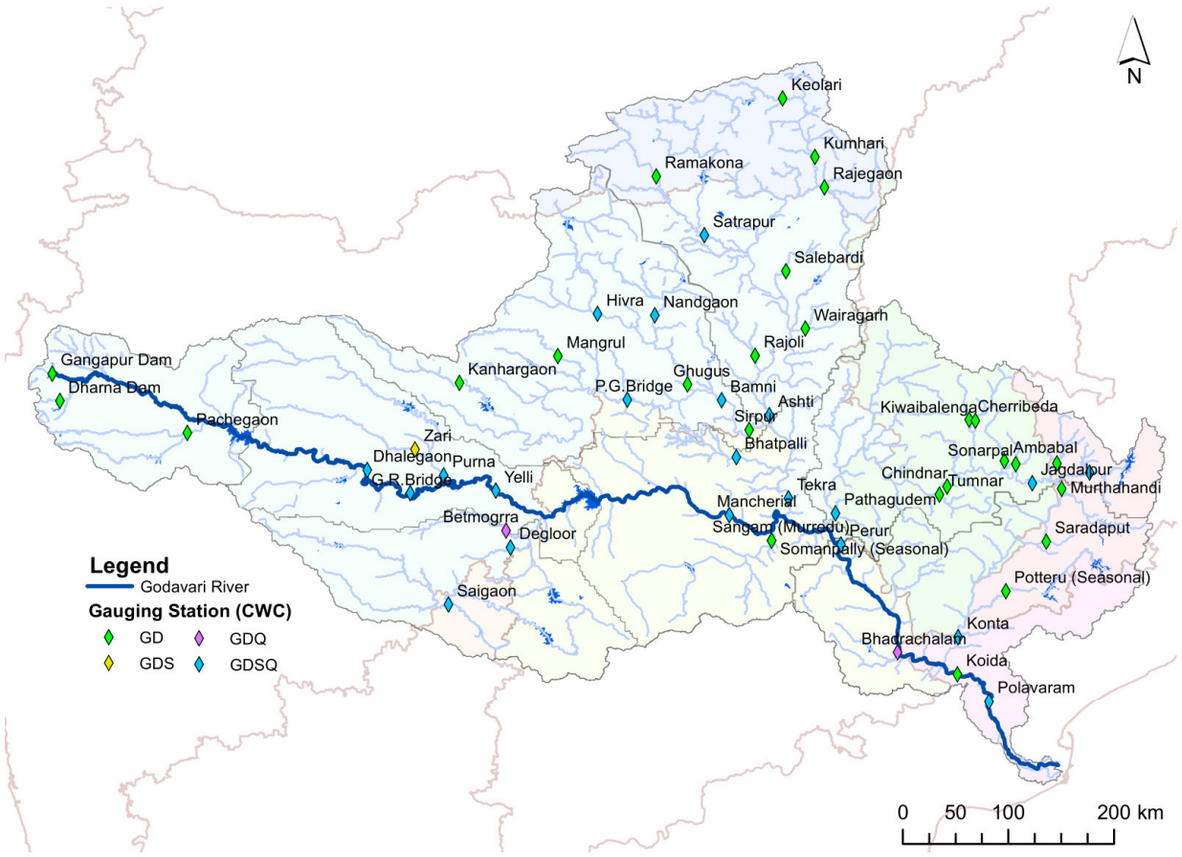

Figure 12: CWC station in Godavari River basin

4. CLIMATE OF GODAVARI BASIN

4.1. Rainfall

The Godavari Basin receives 85% of its annual rainfall during the southwest monsoon, which occurs from July to September. The upper reaches of the basin are located in the 25 km wide crest zone of Sahyadri, the heaviest rainfall region in Maharashtra. The average rainfall ranges from 515 to 1937 mm from 1970-2022.

Analysis of the historical gridded precipitation data (from 2014 to 2023) over the basin shows that the precipitation varied between 300 and 5300 mm. The data were obtained from IMD Pune having a spatial resolution of 0.25 degrees. The high intensity of the precipitation is in south-eastern part of the basin, which is around 1250-2250 mm. The western part of the basin is drier relative to the eastern part of the basin (Figure 13). Over the years, the annual rainfall has been increasing in the central and south-eastern parts. The spatial average of the rainfall in the basin area follows an increasing trend, the values ranging from 947 mm to 1435 mm, with 2022 being the year with the highest spatial average annual rainfall in the study period (2014 to 2023).

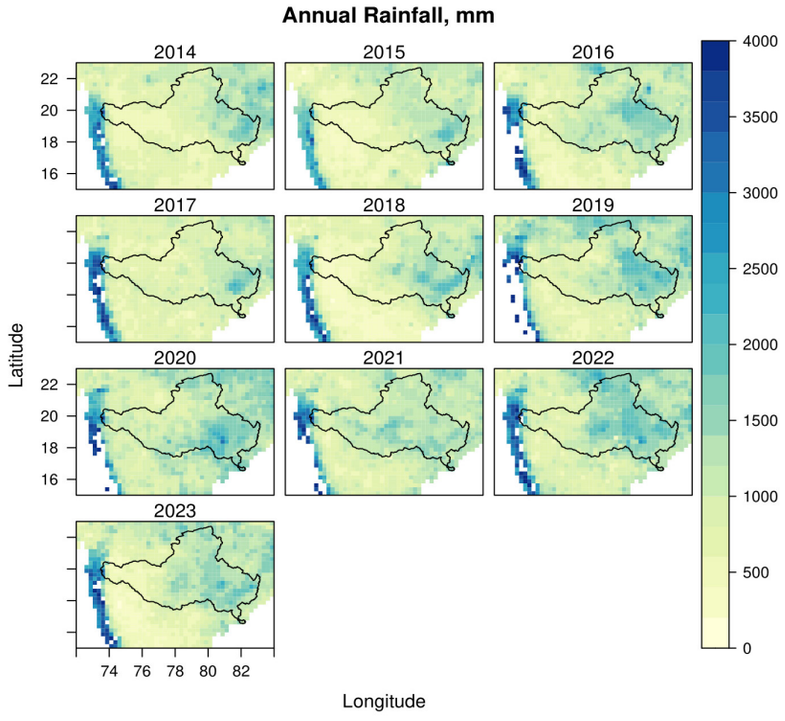

Figure 13: Annual rainfall pattern in the Godavari Basin (2014-2023)

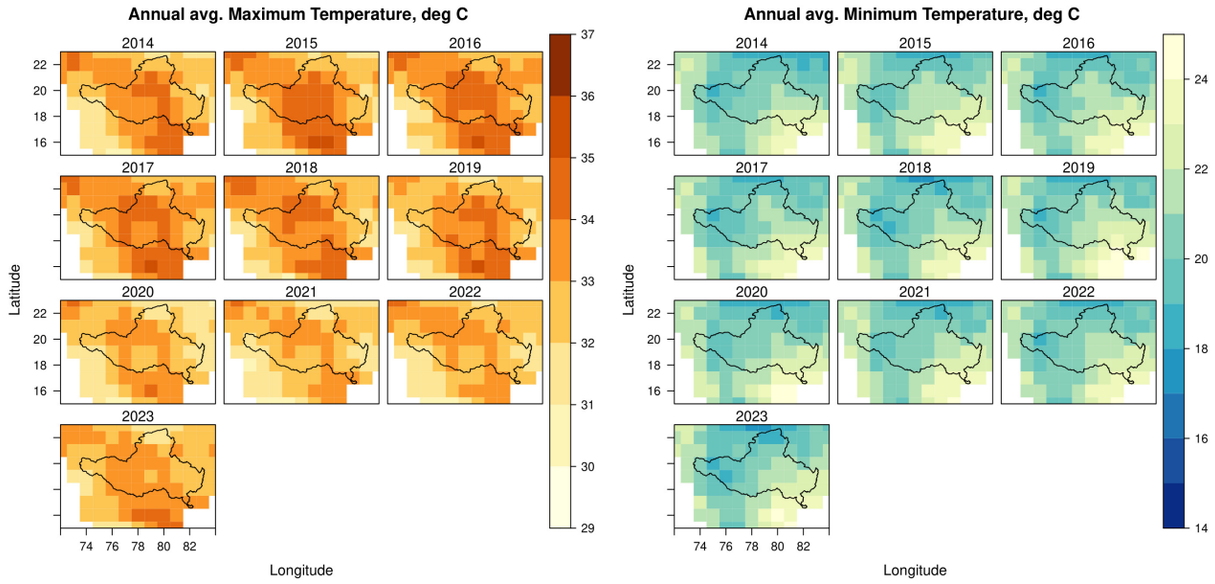

Figure 14: Annual average maximum and minimum temperatures in the Godavari Basin for years 2014-2023

4.2. Temperature

The annual average maximum daily temperature in the basin varied between 32 to 35 oC during the study period 2014-2023. Southern, norther and central parts of the basin experienced relatively higher temperatures compared to the rest (Figure 14). The annual average minimum daily temperature in the basin varied between 18 to 23 oC during the study period 2014-2023. North-western and central parts of the basin experiences relatively lower temperatures compared to the south-eastern part (Figure 14).

5. HISTORICAL AND CULTURAL SIGNIFICANCE

As referenced in the Valmiki Ramayana (Aranya Kanda, Sarga 16) mention of Panchavati, a place, where Shri Rama along with Shri Laxaman and devi Sita stayed and bathed in river Godavari. Further, it is mentioned in the ancient literature that Rama has immersed remains of Shri Dasharath (his father) in Ramkunda of Godavari river. Therefore, the refrence of Godavari is as early as Ramyana. Subsequently, Puranas, particularly Skanda Puran in Goutami Mahatmya references are made to river Godavari. The reference is made both to the origin of river at brahmagiri and its confluence with sea. The confluence with sea is described as;

तुल्यात्रेयी भरद्वाज गौतमी वृद्धगौतमी। कौशिकीच वशिष्ठाच तथा सागरं गतः॥

Godavari, also called Goda (cow given), Vriddhaganga (older Ganga), and Dakshinganga (Southern Ganga), is a significant river that flows through the states of Andhra Pradesh, Maharashtra, and Telangana. It is also known by other names. The Mahabharata, the Ramayana, and the Purana all refer to it as a sacred river. The river is thought to split into seven different places. Each bears the name of a sage from the list of Saptarishis. Three of the seven have vanished. The Puranas state that there was a 12-year terrible drought on Earth. The distress of living things without water affected Sage Gautama. The sage prayed to Varuna, the God of water and the oceans, and engaged in severe penance. Gautama received a pit from Varuna that would never run out of water. This was the Godavari River's origin.

5.1. The Kumbh at Godavari

The river Godavari is an important venue for the sacred festival of the Kumbh. Hosted at spiritual-religious venues across North and Central India, Nashik hosted the last Kumbh in 2015. The Kumbh of the South or the Godavari Pushkaram is a mega event, which was held across key sites of the river in Telangana and Andhra Pradesh. The Godavari Maha Pushakaralu, which is celebrated in Telangana and Andhra Pradesh is especially sacred, as it occurs once in 144 years (unlike the 12-year cycle of the Pushkaram)—culminating in large scale celebrations across the states. The last Maha Pushkaralu was celebrated in 2015, and the next one is anticipated in 2159.

The celebration of the Godavari Kumbh is a mammoth infrastructural initiative with close to 1500 crores spent in 2015 in Andhra Pradesh in organizing bathing ghats, providing special train services, etc. At Rajahmundry, arrangements included providing dedicated ghats, security,

CCTVs, etc. Rajahmundry is special as Godavari flows out to the sea here, and is thus host to multiple special rituals during the Kumbh.

Kumbh celebrations in India involve taking a dip in the river's waters to cleanse sins. The practice is linked to the Hindu mythological rendering of the 'churning of the ocean' (Amrit Manthan), where drops of 'amrit' or nectar fell from the God's vessel at four key sites: Haridwar, Prayagraj, Nashik, and Ujjain. Holy dips are also organized around ritualistic importance, with'shahi snans' designated for three auspicious days of the 58-day Kumbh celebration. In 2015, around 80 lakh people were expected to take a dip at Trimbkeshwar and 25-30 lakh at Nashik.

Figure 15: The First Snan at the Godavari Kumbh, Nashik, 2015
Courtesy: kmhouseindia http://kmhouseindia.blogspot.com/2015/08/hindu-devotees-take-holy-dip-in-river.html

The Kumbh celebrations in India have led to a significant increase in bacteria in the river, including those resistant to beta-lactams, folate, antimicrobial peptide, and vancomycin. This poses a serious threat to public health in the long run. Scientists found that mass bathing increased turbidity and salinity, reduced dissolved oxygen content, and increased the biological and chemical oxygen demand of Godavari water, significantly downgrading the water quality. Open defecation, lack of proper sanitation management, and waste disposal also pose challenges for the Godavari river during these celebrations.

5.2. Major places of worship

Glimpses of the some of the major places of worship in Maharashtra State are shown in Figure 16. Some of the major places of worship in Telangana and Andhra Pradesh States include but not limited to Basara Gnana Saraswathi Devi Temple, Sri Sita Ramaswami Devasthanam in Badrachalam, Nirmalagiri Matha Church, among others (Figure 17).

Figure 16:Some major places of worship situated along the Godavari River in Maharashtra State a) Origin of the river on Brahmagiri hill, b) Main temple on the Brahmagiri hill, c) Ganga-Godavari Temple on Bhramagiri hill, d) Gangadwar temple on Brahmagiri hill

Figure 17: The River Goddess at Basara Saraswati Temple, Adilabad (left), and the Nirmalagiri Matha Church (right)

5.3. Religion, languages and tribes

The diversity of people, places and cultures is also seen in Table 7. While most of the major religions in India are followed in all the regions of the Godavari Basin, the languages and dialects spoken are vast. The variety of tongues including major languages such as Marathi, Telugu, Hindi, Urdu, Odia—are accompanied with many different dialects, local languages, and speech forms. It's important to note that many of these languages and dialects may not have scripts and may be at risk of extinction, unless protected and harnessed.

Table 7: Religions, Languages, and Tribes of the Godavari Basin

State	Religions Followed	Languages/Dialects Spoken	Tribes
Telangana	Hinduism, Islam, Christianity, Sikhism, Buddhism, Jainism, Others or not stated	Telugu, Urdu, Lambadi, Marathi, Gondi	Gonds, Kolams, Pardhans, Thotis, kondareddy, savara, kondh, proja, chenchu, Gadaba
Andhra Pradesh	Hinduism, Islam, Christianity, Sikhism, Buddhism, Jainism, Others or not stated	Telugu, Koya, Urdu, Hindi	Konda Reddy, Savara, Gadaba, Chenchu, Kondh, Kolam, Proja, Koya and Valmiki, Dora, Kondakapu
Madhya Pradesh	Hinduism, Islam, Christianity, Sikhism, Buddhism, Jainism, Others or not stated	Hindi, Marathi, Gondi, Pawari, Urdu, Korku	Gond, Pardhan, Bharia, Korku, Baiga, Bhumia bharia, Oraon, Saharia, Bhinjwar, Parja, Munda, Nagesia, Mawasi, Majhwar, Korwa, Baiga, Bhaina, Bharia Bhumia, Bhil, Binjhwar, Korku
Maharashtra	Hinduism, Islam, Christianity, Sikhism, Buddhism, Jainism, Others or not stated	Marathi, Hindi, Urdu, Lambadi, Khandeshi, Bhili, Kukna	Koli, Mahadev, Dongar Koli, Kokna, Kokni, Kukna, Bhil, Bhil garsia, Thakur, Thakar, Varli, Pardhi, Advichincher, Andh, Mannerwarlu, Arakh, Halba, Halbi
Odisha	Hinduism, Islam, Christianity, Sikhism, Buddhism, Jainism, Others or not stated	Odia, Desia, Kui, Proja, Telugu, Kuvi, Gadaba, Bhatri, Bhuiyan, Hindi, Bengali	Bhotra, Paraja, Halva, Bagata, Banjara, Bhumia, Bhunjia, Binjhal, Bonda, Poraja, Durua Gadaba Gandia Jatapu Kandha Gauda Kolha Konda Dora Kotia Koya Kulis Mati Mirdha Munda Parenga Pentia Santal Saura Shabar Lodha Sounti
Chattisgarh	Hinduism, Islam, Christianity, Others or not stated	Halbi, Bhatri, Hindi, Duruwa, Chattisgarhi, Gondi, Odia	Gond, Maria, Muria, Bhadra, Halba, Dhurua
Puducherry	Hinduism, Islam, Christianity, Sikhism, Buddhism, Jainism, Others or not stated	Telugu, Tamil, Malayalam, English, and French	--

6. BEHAVIORAL AND POLITICAL ASPECTS

6.1. Behavioral aspects

The Godavari River basin is characterized by various behavioral aspects, including traditional practices of water conservation, irrigation, and farming, as well as cultural significance. These practices are deeply rooted in the region's Hinduism, with festivals like Pushkaram attracting millions of pilgrims. Social dynamics include community cooperation for managing water resources, dispute resolution, and sustainable fishing practices.

Economic activities involve agriculture, with the majority of the population relying on it for their livelihood. Water availability and weather patterns influence crop selection, planting, and harvesting. Fishing communities exhibit behaviors closely tied to the river ecosystem, and sustainable practices and community regulations are crucial for maintaining fish populations and livelihoods. Environmental stewardship involves conservation efforts, such as participation in reforestation programs and pollution control initiatives. Communities are also adopting adaptive behaviors in response to climate change impacts, such as altered rainfall patterns and water scarcity. Non-Governmental Organizations (NGOs) play a significant role in shaping these behaviors through awareness programs, training, and community participation in conservation and development projects.

Urbanization and industrialization also impact the basin, with behaviors related to water consumption, waste management, and environmental conservation being critical. Industries are encouraged to adopt environmentally friendly practices and comply with regulations to reduce pollution and manage waste. Corporate social responsibility initiatives often focus on water conservation and community development. Education and awareness programs are conducted by schools and community organizations to raise awareness about the importance of the Godavari River, environmental conservation, and sustainable practices. Public participation in decision-making processes related to water management and environmental policies ensures that local needs and behaviors are considered.

6.2. Political aspects

The Godavari River basin is a critical region in India with significant political, economic, and social dimensions. Some of the key aspects include: (a) Inter-State Water Disputes which deals with Allocation of Water Resources: The Godavari River flows through several states, including Maharashtra, Telangana, Andhra Pradesh, Chhattisgarh, and Odisha.

This has led to disputes over water allocation and usage rights, with each state seeking to maximize its share for agriculture, drinking water, and industrial purposes. The Godavari Water Dispute Tribunal is Established to resolve conflicts among the states regarding water sharing. The tribunal's awards and agreements have shaped the legal framework governing water distribution in the basin. (b) Water Management and Policies, which considers Central and State Government Policies and River interlinking projects. Both central and state governments have implemented various policies and schemes aimed at improving water management, irrigation efficiency, and sustainable usage in the Godavari basin. River Interlinking Plans like the Polavaram Project and the interlinking of rivers aim to transfer surplus waters from the Godavari to other water-deficient regions, creating political debates about environmental impact, displacement of local communities, and equitable distribution of benefits. (c) Environmental and Social Concerns, which impacts local communities and area governed by environmental legislation. Large-scale projects and dam constructions often lead to displacement of indigenous and rural communities. Addressing the rehabilitation and compensation issues becomes a significant political challenge. The need to balance developmental goals with environmental conservation has led to stringent regulations and legal battles over deforestation, loss of biodiversity, and pollution in the river basin.

Political Representation through regional political parties: Politicians and political parties in the states within the Godavari basin often campaign on issues related to water resources, promising better management and development projects. Advocacy Groups and NGOs: Various non-governmental organizations and advocacy groups play a role in shaping public opinion and influencing political decisions regarding water conservation, sustainable development, and the rights of affected communities.

The Godavari River basin is a region where political dynamics are heavily influenced by water resource management, inter-state disputes, environmental concerns, and developmental goals. The interplay of these factors makes it a significant area of focus for policymakers and stakeholders at both the state and central levels.

7. ECONOMIC IMPORTANCE

7.1. Disturbed areas based on population density

Agriculture plays a crucial role in driving economic activities in the states of central India. The Godavari River and its extensive network of tributaries provide vital irrigation, supporting diverse and robust agricultural activities in Maharashtra, Telangana, Andhra Pradesh, Chhattisgarh, and Odisha. These states have experienced significant growth over the last few decades. The data shows that in most cases, the growth rate of the state domestic product is much higher than the national average. Additionally, the per capita income in these states is generally higher than the national average, with the exceptions of Chhattisgarh and Odisha (Figure 18).

Given the superior economic performance of these states compared to the national average, the contribution of agriculture to this growth is particularly noteworthy. Figure 19 illustrates the trends in the share of agriculture, forestry, and fishing activities in these states' output. This clearly demonstrates that these sectors contribute a substantial share, around 34.8% in Andhra Pradesh, during 2022-23. In contrast, the share of these sectors in the other states ranges from 14% to 16% during the same period. Maharashtra has the lowest dependence on agricultural activities (14%) among these states. However, it is interesting to note that the contribution of agricultural activities to income exceeds the national average of 15.4% in all states except Maharashtra.

Similarly, Table 8 shows that the share of crop production contributes around 14.5% to state output in Andhra Pradesh and 10.2% in Chhattisgarh. In contrast, it accounts for only 6.2% in

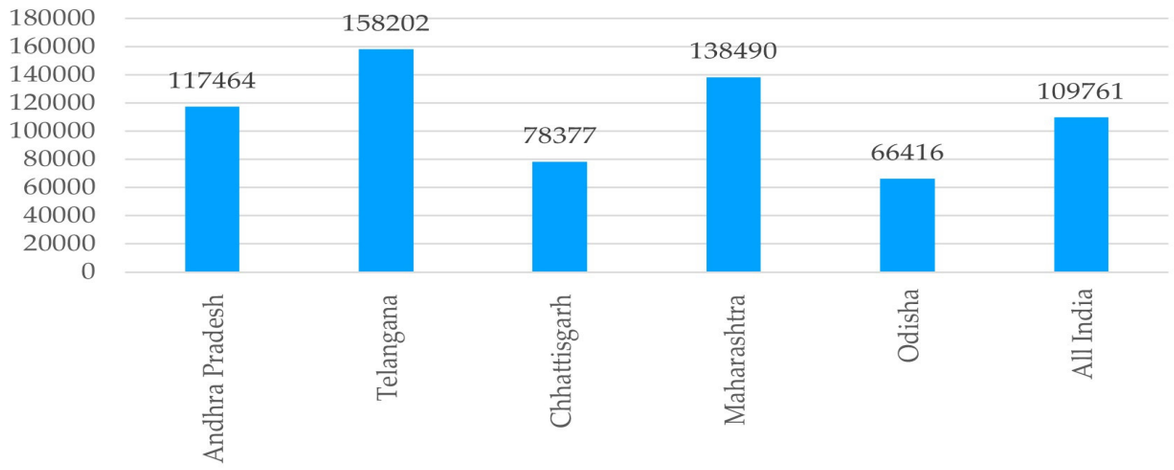

Figure 18: Per Capita Income in Rs. at Constant (2011-12) Prices for the year (2021-22) Source: Ministry of Statistics and Programme Implementation (MoSPI)

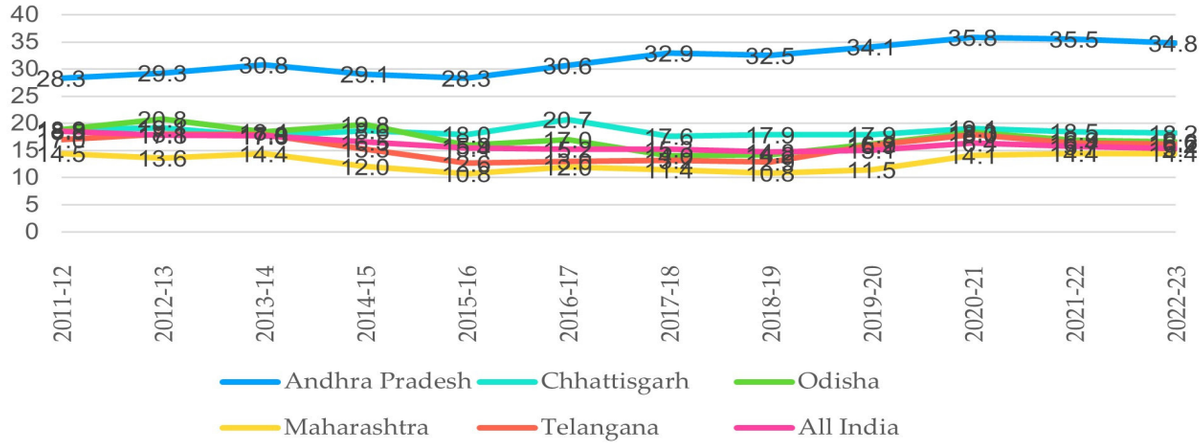

Figure 19:Trends in the Share of Agriculture, Forestry and Fishing to Net State Value Added

NOTE: This figure shows the % share of Agriculture, Forestry and Fishing to Net State Value Added. The values are calculated using data from Net State Value Added by Economic Activity (At Constant Prices, 2011-12), Handbook of Statistics On the Indian Economy, Reserve Bank of India.

Telangana. Additionally, the share of fishing and aquaculture contributes 8% to state output in Andhra Pradesh, which is the highest among the five states.

Employment trends in agriculture and related sectors reveal significant engagement across these states, with Chhattisgarh and Odisha showing the highest levels of agricultural employment at 62.6% and 48.13%, respectively (Figure 19). Andhra Pradesh, despite its substantial agricultural output, has a lower percentage of its workforce engaged in agriculture (44.51%), indicating higher productivity and possibly more mechanized farming practices. These trends highlight the critical role of agriculture in providing livelihoods and sustaining economic growth in the region.

Table 8: Share of Crops production and Fishing and aquaculture to Net State Value Added (2017-18)

States	Share of Crops (%)	Share of Fishing and aquaculture (%)
Andhra Pradesh	14.5	8.0
Chhattisgarh	10.2	2.2
Odisha	7.4	1.7
Maharashtra	7.0	0.2
Telangana	6.2	0.4

NOTE: This table shows the % share of Crop and Fishing and aquaculture g to Net State Value Added. The values are calculated using data from Net State Value Added by Economic Activity (At Constant Prices, 2011-12), Handbook of Statistics On the Indian Economy, Reserve Bank of India.

8. SEGMENT-WISE OBSERVATIONS IN MAHARASHTRA STATE

The length of the Godavari River in Maharashtra State is around 716 km, which originates from Bhramagiri Hill in the Western Ghats and merges into the Bay of Bengal while flowing towards the east, cutting across peninsular India. For the convenience of the study, the Godavari River stretch is described in various segments (shown in Figure 20), their location and elevation information are presented in Table 9. The observations are based on visual inspection carried out in the second week of June 2024.

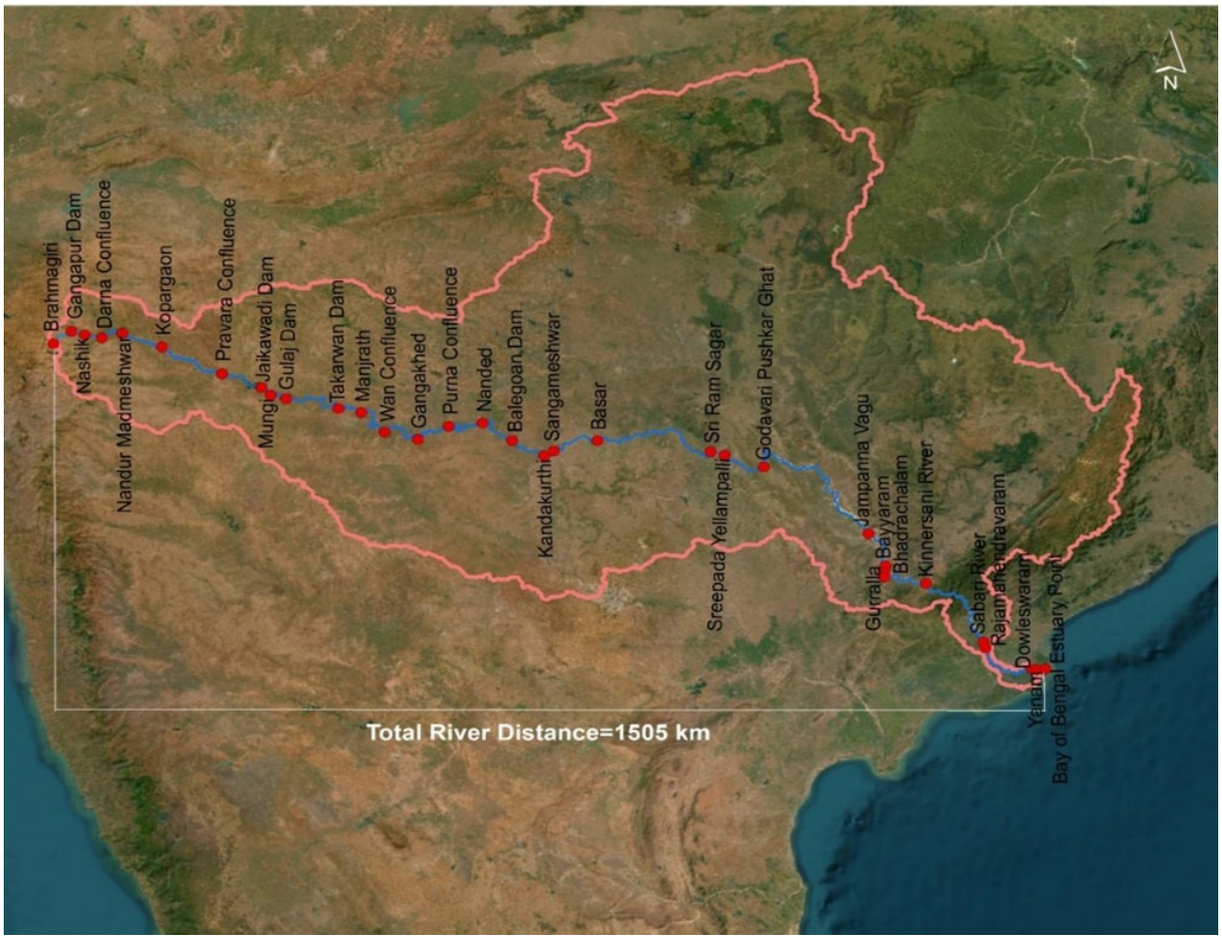

Figure 20: Godavari River and the segments considered in the study

Table 9: Segments considered in the study

No.	Name	Length Between points (km)	Length From Starting Point (km)	Elevation (m)
1	Brahmagiri	0	0	906
2	Gangapur Dam	25.79	25.79	582
3	Nashik	18.48	44.27	548
4	Darna Confluence	21.78	66.05	524
5	Nandur Madmeshwar	31.12	97.17	519
6	Kopargaon	50.14	147.31	475
7	Pravara Confluence	84.69	232	441
8	Jaikawadi Dam	44.75	276.75	436
9	Mungi	15.78	292.53	416
10	Gulaj Dam	20.06	312.59	413
11	Takarwan Dam	74.84	387.43	391
12	Manjrath	31.34	418.77	384
13	Wan Confluence	55.1	473.87	376
14	Gangakhed	55.51	529.38	354
15	Purna Confluence	46.33	575.71	344
16	Nanded	55.35	631.06	325
17	Balegoan Dam	45.29	676.35	320
18	Kandakurthi	40.46	716.81	310
19	Sangameshwar	4	720.81	310
20	Basar	7.11	727.92	305
21	Sri Ram Sagar	57.18	785.10	295
22	Sreepada Yellampalli Projects	150.26	935.36	149
23	Pushkar Ghat	17.37	952.73	113
24	Jampanna Vagu	48.76	1001.49	107
25	Bayyaram	198.85	1200.34	49
26	Gurralla Bairu Vagu	47.54	1247.88	29
27	Bhadrachalam	7.04	1254.92	29
28	Kinnersani River	5.63	1260.55	29
29	Sabari River	50.51	1311.06	8
30	Rajamahendravaram	105.28	1416.34	6
31	Dowleswaram Barrage	7.12	1423.46	3
32	Aquacultural Ponds, Yanam	66.08	1489.54	3
33	Estuaries	4.13	1493.67	2
34	Bay of Bengal	12.44	1506.11	0

8.1. Segment 1: Brahmagiri to Gangapur Dam

The Godavari River is widely believed to have originated in the Brahmagiri Hill (1295 m above msl), which is located in the Western Ghats of Maharashtra State of India. The river is believed to be dripping out from the peak of the hill to the Gangadwar Temple; later, it is seen in the Kushavarth temple located in Trimbak City, right below the Brahmagiri hill. The Godavari River's physical form is seen as a stream adjacent to the Trimbakeshwar Jyotirling temple in the city, where the river confluences with the Ahilya stream. The flow in the Godavari River is quite negligible in the pre-monsoon season, mostly constituting the sewage of Trimbak City and municipal solid waste and waste through the religious activities in the ghats Figure 21. Eutrophication and aquatic weeds are quite evident in this stretch of the river, characterized by turbid, dark color and odor. Breeding of mosquitoes and insects is also observed. Further downstream, the Godavari River collects into the Goutami-Godavari Dam, where a steady discharge volume is observed. The river width is narrow with a flat slope and meandering throughout till reaching the Gangapur Dam. Land use around the river in this segment is predominantly comprises agricultural activities and rural settlements. Further downstream, the river is collected at Gangapur Dam, located on Nashik City's outskirts. The approximate length of the river from Brahmagiri to Gangapur Dam is 26 km. Maharashtra Tourism organizes recreational activities, including boating, speed boating, etc., in the backwaters. Siltation in the dam storage area is prominent.

8.2. Segment 2: Gangapur Dam to Nashik

The stretch between Gangapur Dam to Nashik City is around 19 km, with an elevation drop of around 34 m. The river in this segment is a 4th order stream. The downstream of the Gangapur Dam consists of the discharges/leakages from the dam, which flows steadily through Nashik City. Several ghats are located along the river in the city for cultural and religious activities. The riverfront in the city is seen to be accessed by the early morning walkers, joggers, etc, for recreational activities. The river water

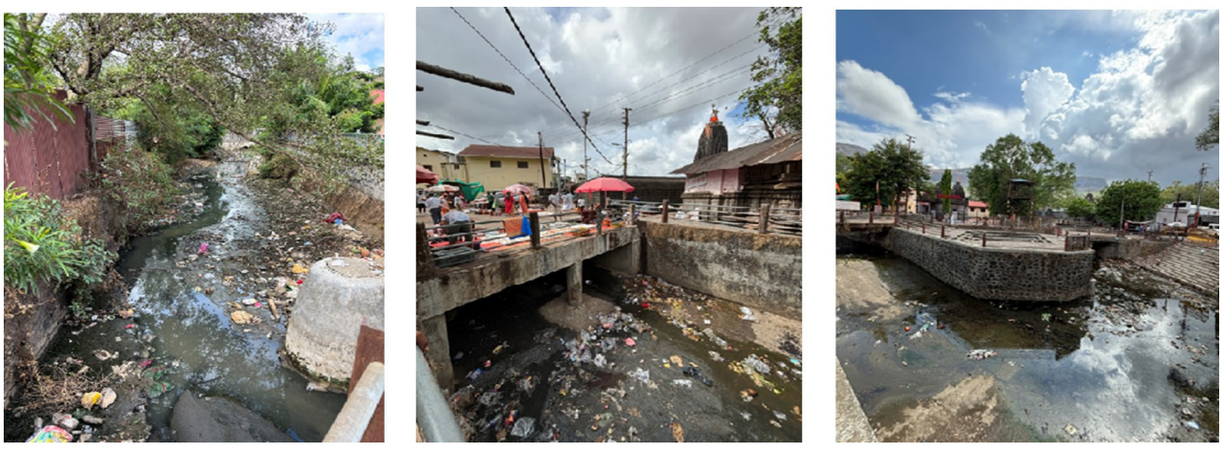

Figure 21: State of the Godavari River in Trimbak City in pre-monsoon season

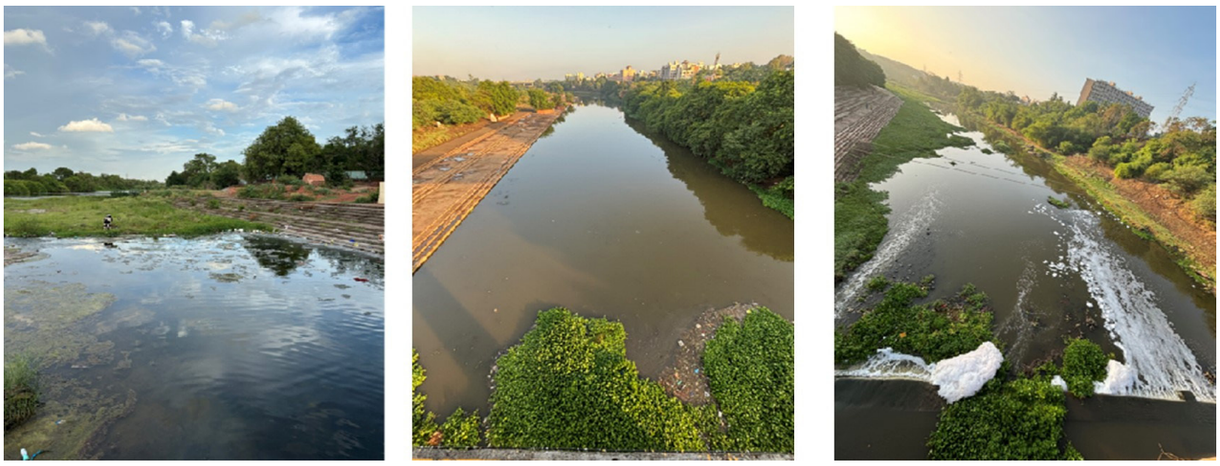

Figure 22:The glimpses of the Godavari River in Nashik City in pre-monsoon season

quality is deteriorated while it flows through the city. Industrial effluent and sewage discharge could be possible reasons resulting in poor river water quality in Nashik City; along with that, the river banks are aesthetically unpleasant due to municipal solid waste. Eutrophication, aquatic weeds/hyacinths, blackish-grey color, and bad odour are rampant in the river segment throughout the city, as shown in Figure 22. Foaming in the river segment is also observed in the city, which could be due to grey water discharge containing surfactants. The riverbed is flat and narrow, built-up area is the dominant land use in the riparian zones.

Further down, the river enters Tapovan and Panchavati, which are known for significant religious and cultural destinations. Many devotees take a dip in the river in Panchavati and perform last rites of the deceased. The flow in this stretch is regulated by weirs and construction of ghats and parking areas are noticeable, shown in Figure 23.

8.3. Segment 3: Nashik to Darna Confluence

The length of the segment between Nashik and Daria Confluence is around 22 km, and the elevation drop of 24 m. The river in this segment is a 4th order stream. Downstream of the river flowing through Nashik City is quite polluted with both industrial and sewage effluents with steady flow on flat bed with meandering throughout the stretch. The color of the river is dark to light grey and with significant foaming on rills, shown in Figure 24. As the river flows further downstream, the quality of water starts improving until the confluence of the river with Dharna stream near Dharna-Sangvi village. However, at the confluence, although the flow is moderate and the depth of the river segment is suitable for across the river transport, the river banks are quite significantly covered with aquatic weeds and the banks have been undergoing significant erosion.

Figure 23:The glimpses of the Godavari River in Panchavati area in Nashik City in pre-monsoon season

Figure 24: The glimpses of the Godavari River downstream of Nashik City near Nandur Naka in pre-monsoon season

8.4. Segment 4: Darna Confluence to Nandur-Madhmeshwar Dam

The segment is approximately 31 km. The river bed is flat with lean flow. The river in this segment is a 5th order stream. The land use along the river is predominantly covered with agriculture, mainly with sugarcane

Figure 26. At some locations, brick-kilns are noticed on the river banks. Further downstream, Nandur-Madhmeshwar is a Ramsar wetland site situated along the Godavari River and Kadwa River confluences with the Godavari River. The wetland has been created by the intervention of the dam, which is host to many avian fauna and migratory birds. Studies show that nearly 150 birds species are reported. The river water retained in the dam is home for many fish species as well, which are being harvested by the local people. In pre-monsoon season, large swaths of the backwater in the dam are covered by aquatic weeds, probably due to the upstream sewage contamination and non-point source agriculture run-off, shown in Figure 25.

Figure 25: The glimpses of the backwaters in Nandur-Madhmeshwar Dam

Figure 26:The Land use in the river banks and the variety of fishes being harvested in the Dam backwaters

Figure 27:Downstream of the Godavari River near Kopargaon City

8.5. Segment 5: Nandur-Madhmeshwar Dam to Kopargoan

This segment is approximately 50 km long, and the elevation drop is around 44 m. The river in this segment is a 5th order stream. The flow in the river has been quite significant compared to the upstream segments. Several barrages and bridges are constructed on the river to harvest the flow. The upstream side of the river from the barrages have good amount of stored water for agricultural use and that has been recharging the groundwater. Whereas the downstream side is fed with the overflow from the barrages with lean flow of water in the river. The river bed is flat with wide banks, covered significantly with trees and grass. However, at many instances significant patches are cleared on the banks that is susceptible for bank erosion. The land use on banks is predominantly agriculture and rural settlements. Animal grazing, vehicles washing, washing clothes, and bathing, etc are predominantly observed in the villages along the river. The water quality appears to be near pristine compared to the upstream locations. At some instances, sand mining from the river bed is being noted and many floating motor pumps are installed for drawing water for cultivation on the banks. As the river approaches the downstream cities, the drop in flow has been noted, which could be due to obstruction of flow in barrages situated upstream (Figure 27).

8.6. Segment 6: Kopargoan to Pravara Confluence

Kopargaon to Pravara confluence segment is around 85 km, and the elevation drop is around 34 m. The river in this segment is a 5th order stream. The downstream locations of the river although has a wide river bed, the flow is intermittent due to several barrages. In some instances, the river seems to be dried out and without flow, representing stagnant conditions. The water quality appears to be cleaner as compared with upstream segments. There are several ghats situated along the river in a few villages on the bank, which has significant religious importance.

Figure 28: The glimpses of the water stored in Jaikwadi Dam in pre-monsoon season

The river meanders several times before reaching the confluence location with Pravara River on the upstream of Jaikwadi Dam. The confluence location of the two rivers has significant religious importance where several temples are located with historical anecdotes. The LULC on the banks are dominated by agriculture and rural settlements. Bank erosion is observed in several instances.

8.7. Segment 7: Pravara Confluence to Jaikwadi Dam

The segment is approximately 45 km long with flat bed, which consists mainly the backwaters of the Jaikwadi Dam situated near Paithan City (Figure 28). The river in this segment is a 6th order stream. Jaikwadi is a flat terrain dam constructed to store Godavari River waters for multipurpose applications including irrigation, drinking water supply and for industrial applications. The dam area has been declared as a bird sanctuary and eco-sensitive zones around 500 m surrounding the backwaters. The dam length is around 10 km, with a storage capacity of around 2900 Mm^3.

8.8. Segment 8: Jaikwadi Dam to Mungi

The segment from Jaikwadi Dam to Mungi is around 16 km, with an elevation drop of 20 m. The river in this segment is a 6th order stream. The downstream of the Jaikwadi Dam in June is without much flow. The river bed is wide and flat. Anthropogenic actives are observed in the river bed when there is no outflow from the dam and covered with plastic and cloth rags. The lean flow continued till Mungi in the downstream, except at barrages where the river water has been stored. Pumping of water for agricultural activities is quite common, and the majority of the LULC on banks is agriculture and rural settlements. Sand mining and brick-kilns are observed on the banks of the river in a few locations (Figure 29). The stored water near barrages appeared to be clean.

Figure 29: Brick-kilns on the river bank heading towards Mungi Village

8.9. Segment 9: Mungi to Gulaj Dam

The segment from Mungi to Gulaj Dam is around 20 km long, with a flat bed. The river in this segment is a 6th order stream. The flow of river is lean in June and the river width is around 170 to 270 m, meandering throughout. River flows through flat bed, and the sand aggradation on the banks is significant. Bank erosion is also noted. The water quality is near pristine, no visuals of aquatic weeds. LULC on the banks is dominated by agricultural activities and rural settlements. Tilling of crop area is quite evident where the preparations of crops for the ensuing monsoon is being done. The storage of the dam appears dry in June (pre-monsoon) and expected to be full during monsoon (Figure 30).

Figure 30: Glimpses of Godavari River near Mungi village and Gulaj dam, respectively.

8.10. Segment 10: Gulaj Dam to Tarakwan Dam

The stretch between Gulaj and Tarakwan dam is around 75 km, with an elevation drop of 22 m. The river in this segment is a 6th order stream. The width of the river bed varies between 270 and 280 m. The discharge from Gulaj Dam gets stored near the upstream of Tarakwan Dam. In June, pre-monsoon seasons the storage in Tarakwan dam is almost negligible. The LULC along the river in this stretch is predominantly occupied by agriculture and rural settlements. The water in the river bed is not free flowing, and the stored water is being pumped for irrigation.

8.11. Segment 11: Tarakwan Dam to Manjrath

The stretch is around 31 km, with a flatbed, the river width varies between 270 to 280 m. The river in this segment is a 6th order stream. The water in the river stretch is almost in near pristine condition. Sand mining activities have been observed in several locations. Bank erosion/gully erosion is quite prominent on the banks. Sediment deposits on the meandering locations are observed. In summer season/ pre-monsoon the river bed is almost dry. The LULC in the river banks is predominantly covered by agriculture and rural settlements. A few ghats are located in the villages near to the river, and religious solid waste has been observed on the river banks. The household grey and dark water are being discharged into the river from the villages. Further downstream, the Sindphana River confluences with Godavari River at Manjrath (Figure 31).

8.12. Segment 12: Manjrath to Wan River Confluence

The stretch between Manjrath and the Wan River confluence location is around 55 km, with a flat bed. The drop in elevation is around 8 m. The river in this segment is a 6th order stream. The Godavari River water is seen to be more turbid compared to upstream locations (Figure 32). The flow in the

Figure 31: Sediment aggradation on the river bank and the instances of sand being mined.

Figure 32: Confluence of Wan River with Godavari River

river in pre-monsoon is lean. The bank erosion and sediment aggradation at meandering locations are quite prominent. The width of the river bed varies between 270 and 290 m. religious activities are prominent at the confluence locations.

8.13. Segment 13: Wan Confluence to Gangakhed

The segment between Wan confluence and Gangakhed town is around 56 km long, with an elevation drop of around 22 m. The river in this segment is a 6th order stream. The flow in the river is lean and turbid. The LULC is predominantly agriculture, with intense tilling activities. The water in the river at Gangakhed appeared to be turbid. The banks are prone to erosion and covered with shrubs and bushes. The upstream of the barrage in Gangakhed stores the river water, whereas the downstream is almost dry. Ghats and several temple complexes have been located on the downstream of the river in Gangakhed. The river bed is dry, which is spread with plastic and religious wastes. Stray animals and cattle grazing on the river bed is quite evident. Along the river banks, many brick-kilns and heaps of fly ash have been observed.

8.14. Segment 14: Gangakhed to Purna River Confluence

The stretch between Gangakhed City to Purna River confluence is around 46 km long, with a drop in elevation of 10 m. The river in this segment is a 6th order stream. River meanders several instances in this stretch. The flow in the river is lean in pre-monsoon season. River bed width varies between 235 and 280 m. Bank erosion and aggradation of sediments at meandering locations are evident. The river water is observed to be greenish turbid. The LULC on the banks is predominantly occupied with agriculture and rural settlements (Figure 33).


Figure 33: Downstream of the barrage on Godavari River in Gangakhed. Instances of brick-kilns in the vicinity of the river.

8.15. Segment 15: Purna Confluence to Nanded

The stretch extends 55 km between Purna River confluence and Nanded City, with a drop in elevation of around 20 m. The river in this segment is a 7th order stream. The river meanders several instances before reaching the city. The river water is found to be greenish turbid. River width varies between 230 and 270 m. The flow is lean in the pre-monsoon season. The pumping of water for irrigation is quite evident. Instances of sand mining is also observed. The bank erosion is quite prominent and also aggradation on the meandering sites is also observed. The flow in the river is regulated by several check dams/barrages situated along the river stretch. Many brick-kiln and fly-ash heaps have been observed in the river bank zones. The LULC is predominantly agriculture and semi-urban to urban establishments. Further downstream the river flows thought Nanded City.

8.16. Segment 16: Nanded to Balegaon Dam

The segment between Nanded to Balegaon Dam is approximately 45 km long, with a flat bed. The river in this segment is a 7th order stream. Godavari River water in Nanded City is greenish turbid. The water level is significant compared to other upstream locations, due to the flow regulation in barrages. The banks of the river are mostly developed into ghats for recreational and religious activities. Water hyacinth is a commonly observed

in the river stretches along the river in the city (Figure 34). Banks which are not covered with vegetation are seen to be eroded, predominantly due to gully type of erosion. Municipal solid waste along with plastic and cloth rags are prominently observed in river sections that are poorly managed. Instances of sand mining from the river bed and along the banks are observed. Further downstream of the city, the flow in the river is regulated by Balegaon Dam, where the water is utilized for irrigation.

Figure 34: Greenish turbid water in Godavari River in Nanded City and instances of aquatic weeds.

8.17. Segment 17: Balegaon Dam to Kandakurthi

The segment between Balegaon Dam to Kandakurthi extends about 40 km, with an elevation drop of around 10 m. The river in this segment is a 7th order stream. At kandakurthi, the Manjira River confluences with the Godavari River, which flows through Telangana State and subsequently enters Andra Pradesh. The water quality in this segment appears to be clean and the flow is steady. The river bed is flat and varies between 270 and 300 m, which is considerably wider compared to the upstream segments. The flood plains are covered with trees, shrubs and agricultural land. The confluence of the two rivers is known for immense religious importance.

9. SEGMENT-WISE OBSERVATIONS IN TELANGANA AND ANDHRA PRADESH STATES

9.1. Segment 18: Kandakurthi to Basar

From the Kandakurthi sangam, the river enters Telangana State. The iconic Sangameswar Temple is situated at this sangam (Figure 35). The river bed is flat. The river changes from steady and less visibly impacted by the anthropogenic activities. The Pushkar Ghat at Basar appeared to be very busy even during the hot month of June. Many devotees were seen performing religious activities. However, new and old litter were observed in the ghat area, highlighting the need for a better solid waste management plan at the least.

9.2. Segment 19: Basar to Sri Ram Sagar Project

Further downstream of the Basar Pushkar Ghat, the river contributes its water to the Sri Ram Sagar Reservoir. The Sri Ram Sagar reservoir was filled with water, however, during the visited summer month, there was very little downstream flow of water.

Figure 35: Left panel: the iconic Sangameshwar Temple; Right panel: a small temple within the river marking the confluence of Manjeera and Godavari.

Figure 36: Pushkar Ghat, Mancheriyal

9.3. Segment 20: Sri Ram Sagar Project to Sreepada Yellampalli Project

Between the Sri Ram Sagar Project and Sreepada Yellampally project, there is an elevation drop of approximately 154 m. The river meanders through many towns such as Eradandi, Mogilipet, Bhutkur, Godserial, Dharmapuri, Rayapatnam, reaching Sreepada Yellampalli. Throughout this segment, the river is surrounded by agricultural fields in most places.

9.4. Segment 21: Sreepada Yellampalli Project to Godavari Puskar ghat, Mancherial

This segment is approximately 18 km long having an elevation drop of 155 m. The downstream of the project side is fed with the overflow from the barrages. The water flow was lean in the pre-monsoon period. The river bed is flat with wide banks, and was covered substantially with trees and grass. However, at many instances significant patches are cleared on the banks, making it susceptible for erosion. Mainly the downstream of the Sreepada Yellampalli project. The project is a part of the Kaleswaram lift irrigation project, meant to supply water to the upland of Karimnagar, Adilabad, Nizamabad, Warangal and Medak districts in Telangana. There are several ghats situated along the river on both sides. Both cities have a number of industries that depend on the Godavari River (Figure 36).

It was noted that untreated wastewater was discharged directly into the river from both Ramagundam and Mancherial sides; through canals Raulla Vagu and Tholla Vagu in the Mancherial side and as the NTPC Ramagundam effluent on the Ramagundam side. There is also a landfill being operated by Ramagundam Municipal corporation besides the river. Some of the glimpses of the river in this segment are shown in Figure 37, Figure 38, and Figure 39.

Figure 37: Lake Point, Mancheriyal

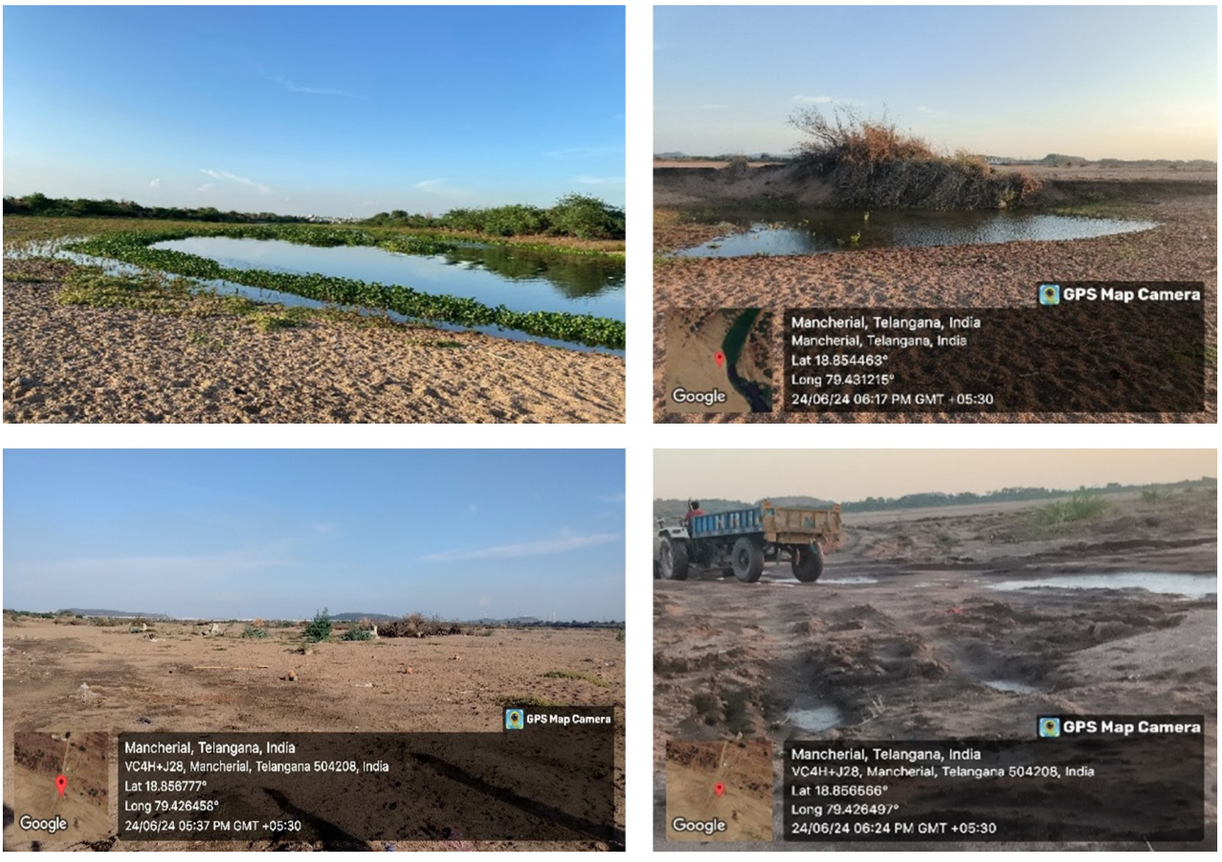

Figure 38: Ralla Vagu, Mancherial

Figure 39: Pushkar Ghat, Ramagundam

9.5. Segment 22: Mancherial to Manir River confluence point

This segment of the river is approximately 50 km in length, and has an elevation drop of 130 m. The downstream side of Mancherial contains industrial with several industries. On the other side of the river, near Ramagundam city, Singareni open cast mines are located, in addition to the NTPC Ramagundam plant. There is substantial wastewater drainage in river Godavari (Figure 41). The NTPC balance reservoir is also situated along with floating solar power unit in it. Although a fecal sludge treatment plant has bene established by the Ramagundam Municipal Corporation (RMC), it was not in operation.

Figure 41: Discharge point of wastewater into Godavari River

9.6. Segment 23: Jampanna Vagu Confluence point to Bayyaram Confluence point

This segment is approximately 200 km long. There is an elevation drop of 123 m. This segment spans from Jampanna Vagu confluence point to Bayyaram confluence point. The river passes through Eturnagaram Wildlife Sanctuary, confluence point Jampanna Vagu, and the Mangapet Bridge in Telangana state. The Eturnagaram Wildlife Sanctuary encompasses Blackberry Island, an Integrated Tribal Development Agency, tribal habitat settlements throughout the sanctuary, and a Residential Industrial Training Institute (RITI) for tribals. The Point of Sand mining is located inside the Wildlife Sanctuary. At the confluence point in Jampanna Vagu, a Government Authorized Sand Mining Point and a fishing Pond were present. The channel was mostly dry, and bank encroachment, and bank erosion were observed July 2024. At the Mangapet Bridge, sand mining was taking place.

9.7. Segment 24: Bayyaram Confluence point to Gurralla Bairu Vagu point

This segment is approximately 50 km long and has an elevation drop of 65 m. Some of the major industries in the basin are Bhadradri Thermal Power Station, Manuguru Singareni Coal Mines, open case (OC) 1, 2 and 3, and a Heavy Water Plant, Department of Atomic Energy. The Bhadradri power station is of capacity 1,080 MW and is owned by that Telangana Power Generation Corporation Ltd.

In the adjacent fields of the thermal power plant, rice cultivation and other agricultural activities are carried out. The dust pollution is an issue around the open cast mines, due to mining activities and the use of heavy mining vehicles. The final point of this segment was the Heavy Water Plant (HWP) of the Department of Atomic Energy Government of India. Water is pumped from the Godavari River to the HWP plant.

9.8. Segment 25: Gurralla Bairu Vagu point to Bhadrachalam City

This segment is approximately 10 km long and has an elevation drop of 49 m. This segment extends from Gurralla Bairu Vagu point to Bhadrachalam City. ITC Paper Boards and Specialty Paper division, Sarapaka and ITC Mission Sunehra Kal are located in this segment. The ITC Paper Boards and Specialty Paper division is the largest paper-producing plant on the border of Telangana and Andhra Pradesh. The final point of this segment was the pump house of Bhadrachalam city. This pump house is located on the Bhadrachalam bridge on the Godavari River and serves as a well-intake structure for the drinking water supply of Bhadrachalam town.

9.9. Segment 26: Bhadrachalam City to Confluence Point Kinnersani River

This segment is approximately 6 km long and has an elevation drop of 44 m. It is the region where river Godavari enters the state of Andhra Pradesh. The channel is dry with fragmented channels, observed in July 2024, as its downstream side of Sitammam Sagar Barrage. Additionally, a trade


Figure 42: Bhadrachalam Bridge on Godavari river and Bhadrachalam Temple Ghat

fair (Mela) was organized on the river bank. The Bhadrachalam Temple, a Hindu pilgrimage site, is situated on the banks of the river. Next to the Bhadrachalam temple, is the Bhadrachalam Ghat (Figure 42). The water appeared black in color, with a pungent smell in the surrounding areas. In the adjoining river areas sand mining is done prominently with heavy hydraulic vehicles and sand is being stored in adjacent stock yards. Several big heaps of sand were found adjacent to the river bank on both sides of the road, serving as stock yards. Overall in the segment, solid waste accumulation, water hyacinth, sewage discharge, stagnant water pools in the riverbed, poor water quality, and sand mining were observed.

9.10. Segment 27: Confluence Point of Kinnersani River to Confluence of Godavari Sabari River

This segment is approximately 50 km long and has an elevation drop of 36 m. This segment spans from the confluence point of the Kinnersani River to the confluence of the Godavari Sabari River. The confluence Point of Kinnersani River with Godavari is the point where Kinnersani River drains into Godavari. On both sides of the road, big heaps of sand dunes are found where sand is stockpiled for further transportation.

9.11. Segment 28: Confluence of Godavari Sabari River to Rajamahendravaram

This segment is between the forested area of Bhadrachlam and Rajamahendravaram (also known as Rajahmundry). It has a span of 106 km, and an elevation difference of 27 m. Rajamahendravaram is one of the oldest cities in the state of Andhra Pradesh. The city is situated on both sides of a

river and is home to several ghats and has many mythological temples. As Rajamahendravaram is situated in the upstream side of Dowleswaram Barriage, there was a substantial amount of water in the river in July 2024.

The ghats in Rajamahendravaram are used for fishing, bathing, and as crossing points for commuters. Additionally, there are several temples and churches established along the river bank. Andhra Sugars Pvt. Ltd., a chemical and fertilizer company is situated on the bank of river Godavari in Rajamahendravaram city. There is a landfill and dumping yard in the area as well. It was found that solid waste is being dumped on Godavari bank. Open defecation has been observed instead of toilet usage. Sand mining was taking place at this point.

9.12. Segment 29: Rajamahendravaram to Dowleswaram Barrage

This segment is approximately 8 km long, and has an elevation drop of 16 m. This segment spans from Rajamahendravaram city into Dowleswaram Barrage, and entails the Water Treatment Plant, Rajamahendravaram, Dhobi Ghat near the railway bridge Rajamahendravaram, a 30 MLD (million liters per day capacity) sewage treatment plant (STP) and a discharge location. The water treatment plant supplies potable water to the city and the Dhobi Ghat located near railway bridge is primarily used for laundry. Open defecation was also a problem. This stretch was among the most polluted stretch along the river bank in July 2024. Solid waste accumulation, water hyacinth/ aquatic weeds, algal bloom, sewage discharge, and poor water quality was observed. Surplus untreated wastewater is being discharged into River Godavari without any treatment. At this point, solid waste accumulation, water hyacinth, algal bloom, sewage discharge, industrial effluent discharge, and narrow channels were observed (Figure 43). Dowleswaram Barrage is located across the Godavari River and is managed by the Water Resources Department, Government of Andhra Pradesh.

Figure 43: Rajamahendravaram domestic discharge location

Figure 44: Kottipalli Village East Godavari, Kottipalli Fishing Ghat and Boat point transportation purposes

9.13. Segment 30: Dowleswaram Barrage to Landfill, Yanam, Puducherry

This segment is approximately 70 km long and has an elevation drop of 13 m. The flow of the river was lean in the month of July 2024 due to the presence of upstream barrage. River ferries for cross-river transportation were observed. Issues such as encroachment, deposition on the banks, bank erosion, and solid waste accumulation were visible (Figure 44). One stop point in this stretch was the Kottipalli village in East Godavari district. It is a small village supported by fishing and aquaculture. Further downstream, along the bank, agricultural activities were taking place, from Kottipalli village to Yanam along the Godavari River.

9.14. Segment 31: Landfill, Yanam, Puducherry to Aquacultural Ponds, Yanam, Puducherry

This segment is approximately 5 km long and has an elevation drop of 8 m. This segment starts with a heap of landfill at the entrance of Yanam, a number of Aquacultural Ponds, passing through Korangi River and its confluence with Godavari River at Yanam. On the banks of the canal, there are landfill sites and a fish market on both sides of the road (Figure 45). Some issues were observed, such as the accumulation of solid waste, discharge of sewage, and poor water quality. The Korangi River confluence point at Yanam is where the Korangi and Godavari rivers meet, and the local community relies on fishing as their livelihood, using large motor boats for their fish catches. Also, the issue of sand mining was observed there. The aquacultural ponds at Yanam are artificial ponds constructed on the riverbank. These ponds are primarily used for prawn farming and other aquaculture purposes.

9.15. Segment 32: Mangroves Forest, Yanam Puducherry to Godavari Bay of Bengal Estuary Point, Yanam, Puducherry.

This segment is approximately 13 km long and has an elevation drop of 6 m. This segment spans through Mangroves Forest in Yanam, Puducherry into the Bay of Bengal. Yanam is part of the

Figure 45: Land fill site Yanam and Adjacent fish market

union territory of Puduchcherry. There are many prawns cultivating aquaculture ponds in whole stretch and adjoining villages too. It can be observed that the Godavari River brings a substantial amount of fertile soil and silt before meeting the Bay of Bengal, which favors the mangrove forest ecosystem. The mangroves are also a famous tourist destination for people in Yaman. This is the point where the river meets its destination, the Bay of Bengal, after traveling approximately 1500 km through hills, mountains, forests and plains, finally draining into the mighty sea (Figure 46).

Figure 46: Godavari Bay of Bengal Estuary Point, Yanam

10. LEAST/MODERATELY/HIGHLY DISTURBED AREAS

Classifying areas in the Godavari River and its basin as least disturbed, moderately disturbed, and highly disturbed involves assessing various factors such as human activity, pollution levels, habitat degradation, and conservation status. Here is a general classification based on these criteria:

10.1. Least Disturbed Areas

Protected Areas and National Parks: Regions within designated protected areas like Kanger Valley National Park and Papikonda National Park are relatively undisturbed due to strict conservation measures. Forest Reserves and Wildlife Sanctuaries: Certain forest reserves and wildlife sanctuaries, such as the Pocharam Wildlife Sanctuary and Kawal Tiger Reserve, maintain a higher level of ecological integrity and face less anthropogenic pressure. Upper Catchment Areas: Remote upper catchment areas in the Western Ghats and Eastern Ghats, where human activities are minimal, are generally less disturbed.

10.2. Moderately Disturbed Areas

Agricultural Regions: Areas where traditional agriculture is practiced with sustainable methods, resulting in moderate disturbance. This includes parts of the basin in Maharashtra and Chhattisgarh. Rural Settlements: Rural areas with low to moderate population density where human activities such as small-scale farming and local fishing occur, causing moderate environmental impact. Managed Forest Areas: Forest areas that are managed for timber and non-timber forest products but still retain significant biodiversity, such as some regions in Telangana and Andhra Pradesh.

10.3. Highly Disturbed Areas

Urban and Industrial Zones: Cities like Nashik, Nanded, Rajahmundry, and industrial areas along the river, where urbanization and industrial activities lead to high levels of pollution and habitat degradation. Intensive Agricultural Areas: Regions with intensive agriculture, particularly in the delta areas of Andhra Pradesh, where the use of fertilizers, pesticides, and irrigation leads to significant ecological disturbance. Dams and Reservoirs: Areas around

major dams and reservoirs like the Sriram Sagar Dam, Polavaram Project, and Nagarjuna Sagar Dam, where large-scale water diversion and infrastructure development have altered natural habitats and river flow. Mining Areas: Regions with extensive mining activities, such as parts of Maharashtra and Chhattisgarh, where mining operations lead to land degradation, deforestation, and water pollution.

10.4. Conservation and Rehabilitation Efforts

Afforestation and Reforestation: Efforts to plant trees and restore forested areas help mitigate disturbance levels in degraded regions. Pollution Control Measures: Implementing stricter pollution control regulations and promoting cleaner technologies in industrial areas can reduce the environmental impact. Sustainable Agriculture Practices: Encouraging sustainable farming practices and organic agriculture can help reduce ecological disturbance in agricultural regions. Community Engagement: Involving local communities in conservation efforts and promoting awareness about sustainable practices are essential for long-term environmental health.

In summary, the least disturbed areas in the Godavari River basin are typically found in protected regions and remote upper catchment areas, while moderately disturbed areas include rural settlements and managed forests. Highly disturbed areas are primarily urban and industrial zones, intensive agricultural regions, areas around dams and reservoirs, and mining zones. Conservation and rehabilitation efforts are crucial to mitigate disturbance and promote ecological sustainability in the basin.

11. MAPPING OF SENSITIVE AREAS

Mapping sensitive, vulnerable, and undisturbed areas in the Godavari River basin based on sedimentation deposits involves analyzing how sediment accumulation affects different regions. Sedimentation can impact water quality, aquatic habitats, and agricultural productivity. Here's a classification:

11.1. Sensitive Areas (Moderately Affected by Sedimentation)

Riverbanks and Floodplains: These areas are subject to periodic sediment deposition, which can affect agriculture and habitats. Moderate sedimentation can enrich soils but also cause issues with drainage and flooding. Examples: Lower stretches of the Godavari River in Telangana and Andhra Pradesh.

Delta Regions: Sediment deposits in the delta are crucial for maintaining landforms and soil fertility but can also lead to changes in water flow and increased flood risks. Examples: Godavari Delta in East Godavari and West Godavari districts.

11.2. Vulnerable Areas (Highly Affected by Sedimentation)

Reservoirs and Dams: Sedimentation in reservoirs reduces storage capacity and affects water supply for irrigation, drinking, and hydropower. Examples: Areas around the Sriram Sagar Dam, Polavaram Dam, and Nagarjuna Sagar Dam. Urban and Industrial Zones: High levels of sedimentation from upstream erosion and pollution can impact water quality and infrastructure. Examples: Urban areas like Rajahmundry and industrial zones in Maharashtra and Telangana. Agricultural Lands: Intensive farming practices can lead to soil erosion, increasing sediment load in rivers, which can then deposit in downstream agricultural areas, impacting soil quality and crop productivity. Examples: Intensive agricultural regions in Andhra Pradesh and Telangana.

11.3. Undisturbed Areas (Low Sedimentation Impact)

Protected Forest Areas: Dense vegetation in protected forests helps to reduce soil erosion and sediment transport, maintaining clear water conditions. Examples: Papikonda National Park, Kawal Tiger Reserve. Upper Catchment Areas: These regions, particularly in the Western Ghats and Eastern Ghats, have minimal human activity and well-preserved vegetation cover, leading to low sedimentation levels. Examples: Upper reaches in Maharashtra and Chhattisgarh.

11.4. Conservation and Mitigation Strategies

Afforestation and Reforestation: Planting trees in degraded areas to reduce soil erosion and sediment runoff. Soil Conservation Practices: Implementing terracing, contour plowing, and cover cropping in agricultural areas to minimize erosion. Sediment Management in Reservoirs: Regular dredging and sediment removal in reservoirs and dams to maintain storage capacity and water quality. Buffer Zones: Establishing riparian buffer zones along riverbanks to trap sediments and reduce their flow into rivers.

11.5. Implementation

GIS Mapping: Use Geographic Information Systems (GIS) to map sedimentation rates, erosion-prone areas, and land use patterns across the Godavari basin. Remote Sensing: Utilize satellite imagery and remote sensing data to monitor changes in sedimentation and identify vulnerable areas. Field Surveys: Conduct field surveys to collect data on soil erosion, sediment deposition, and water quality in different parts of the basin.

By categorizing and mapping areas based on sedimentation deposits, targeted conservation and management strategies can be developed to protect sensitive and vulnerable regions while maintaining the ecological integrity of undisturbed areas in the Godavari River basin

12. FACTORS RESPONSIBLE FOR THE RIVER DEGRADATION

The Godavari river basin faces a myriad of challenges that impact its water resources and management. From interstate water disputes to climate change impacts and deforestation, the basin grapples with complex issues that require urgent attention and sustainable solutions. This document delves into the critical issues affecting the Godavari river basin, shedding light on the intricacies of water governance, flood management, deforestation, and the need for adaptive strategies in the face of changing environmental conditions. The major issues are discussed below.

12.1. Water scarcity

Despite being one of India's largest rivers, parts of the basin experience water shortages, especially during dry seasons. Water scarcity in the Godavari basin is a complex issue stemming from various factors -- Seasonal variation: The basin experiences significant fluctuations in water availability between monsoon and non-monsoon periods. During dry seasons, many areas face acute water shortages. Uneven distribution: While some parts of the basin receive ample rainfall, others are drought-prone, leading to disparities in water availability across the region. Increasing demand: Growing population, urbanization, and agricultural expansion have substantially increased water demand, straining available resources. Inefficient irrigation practices: Agriculture consumes a large portion of the basin's water, often using inefficient flood irrigation methods. Groundwater depletion: Overexploitation of groundwater for irrigation and other uses has led to declining water tables in many areas. Climate change impacts: Changing rainfall patterns and increased evaporation due to rising temperatures are affecting water availability. Infrastructure limitations: Inadequate storage and distribution infrastructure in some areas hinders effective water management.

12.2. Pollution

Industrial effluents, agricultural runoff, and urban sewage contaminate the river water. Pollution in the Godavari river basin is a significant environmental concern with multiple sources and impacts -- Industrial pollution: Many industries along the river discharge untreated or partially treated effluents containing heavy metals, chemicals, and other pollutants. Agricultural runoff: Pesticides, fertilizers, and animal waste from agricultural

activities contribute to water pollution, leading to eutrophication in some areas. Urban sewage: Inadequate sewage treatment facilities in urban areas result in the discharge of untreated or partially treated domestic wastewater into the river. Solid waste dumping: Improper disposal of solid waste, including plastics, directly into the river or its tributaries. Religious and cultural practices: Mass bathing events and the disposal of religious offerings contribute to organic pollution and solid waste in the river. Mining activities: Runoff from mining operations can introduce sediments and pollutants into the river system. Oil and grease pollution: From boats, riverside workshops, and other sources, contributing to surface water pollution. Thermal pollution: Power plants using river water for cooling can cause localized increases in water temperature, affecting aquatic ecosystems. These pollution sources have led to degradation of water quality, impacts on aquatic ecosystems, health risks for populations using the river water, and challenges for water treatment facilities.

12.3. Sedimentation

Soil erosion in the upper catchment leads to siltation in reservoirs and riverbeds, reducing water storage capacity. Sedimentation rates and impacts can change over time due to various factors including climate change and land use modifications. The total sediment yield of the Godavari basin is estimated to be about 170 million tons per year, with a significant portion of this ending up in reservoirs and riverbeds. The annual sedimentation rate in some reservoirs in the Godavari basin is as high as 0.5% to 1% of their storage capacity, significantly reducing their useful life. These sediments are transported downstream. As water velocity decreases, sediments settle in reservoirs and riverbeds. This reduces storage capacity of reservoirs, decreased lifespan of dam infrastructure, and increases the maintenance costs for dams and reservoirs. Thus, water availability for various uses reduces posing challenges to irrigation and hydropower generation. The other effects include altered river morphology, changes in flood patterns, increased flooding risks in some areas, thereby impacting the aquatic ecosystems.

12.4. Flood management

Some areas are prone to flooding during monsoons, causing damage to crops and infrastructure. Flood management in the Godavari basin is a significant challenge, particularly during the monsoon season. The lower Godavari region experiences severe floods almost every alternate year, with major floods occurring once in 10-15 years. During the 2006 floods, about 460 villages were affected, with nearly 200,000 people evacuated and significant damage to crops and infrastructure. For improved flood forecasting systems, better coordination between states and the integration of structural (e.g., dams, embankments) and non-structural (e.g., floodplain zoning, flood insurance) measures are required for effective flood management. It is very challenging to manage inter-state rivers like the Godavari for flood control since

the decisions on water release from reservoirs in upstream states can significantly impact flooding in downstream areas. Flooding caused damage to agricultural crops, destruction of infrastructure (roads, bridges, buildings), loss of human life and livestock, displacement of populations, and economic losses to industries and businesses

12.5. Interstate water disputes/political aspects

Conflicts between states sharing the river's water, particularly regarding dam projects and water allocation. Interstate water disputes in the Godavari basin are complex and long-standing issues. The river flows through several states, including Maharashtra, Telangana, Andhra Pradesh, Chhattisgarh, and Odisha, leading to conflicts over water sharing and utilization. Key areas of conflict include water allocation among riparian states, construction and operation of dams and irrigation projects, sharing during drought years, and the impact of upstream projects on downstream availability. The Godavari Water Disputes Tribunal, constituted in 1969, gave its final award in 1979, allocating water shares to different states and sub-basins. Despite this, conflicts persist, particularly regarding large projects like Polavaram. This project is a major point of contention, with Odisha and Chhattisgarh raising concerns about submergence of their territories and impact on tribal populations. Other notable disputes include the Maharashtra-Andhra Pradesh conflict over Polavaram, Odisha-Andhra Pradesh disagreements over Polavaram and the Neradi barrage, and new issues between Telangana and Andhra Pradesh following the latter's bifurcation in 2014.

Dispute resolution faces ongoing challenges such as changing water needs due to population growth and economic development, climate change impacts, political considerations, and the need to balance irrigation, hydropower, and environmental requirements. The limitations of existing resolution mechanisms highlight the need for more flexible, adaptive approaches to water sharing. These factors, along with political dynamics and changes in state boundaries, complicate efforts to find lasting solutions to the interstate water disputes in the Godavari basin.

12.6. Overexploitation of groundwater

Excessive pumping of groundwater for irrigation has led to declining water tables in some regions. Overexploitation of groundwater is a significant concern in many parts of the Godavari basin. It's important to note that groundwater conditions can change relatively quickly due to factors like rainfall patterns and changes in extraction rates. However, the general trend is that the average groundwater level has significantly reduced due to overexploitation. Agricultural intensification and shift to water-intensive crops are the major causes of groundwater depletion. A report by the Central Ground Water Board of India (2019) titled "Ground Water Year Book - India 2017-18" provides data on groundwater levels across Indian states, including those in the Godavari basin.

12.7. Deforestation

Loss of forest cover in the basin affects water retention and increases soil erosion. A paper by Behera et al. (2018) provided a comprehensive analysis of deforestation trends in the Godavari basin over three decades. The paper highlighted that the Godavari basin experienced significant deforestation between 1985 and 2005, with a loss of about 7,712 km² of forest cover. The loss of forest cover has severe impacts on water retention in the basin. It leads to reduced infiltration of rainwater into the soil and increased surface runoff.

12.8. Vulnerable Areas with Respect to Soil Erosion in the Godavari River Basin

The Godavari River Basin is significantly affected by soil erosion, which is categorized into four zones: Very Severe, Severe, Moderate, and Slight. The data indicates that the Moderate zone is the most extensive, covering 67.16% of the area, followed by the Severe zone at 23.40%, the Low zone at 7.34%, and the Very Severe zone at 2.20% as shown in Figure 47 and Table 10.

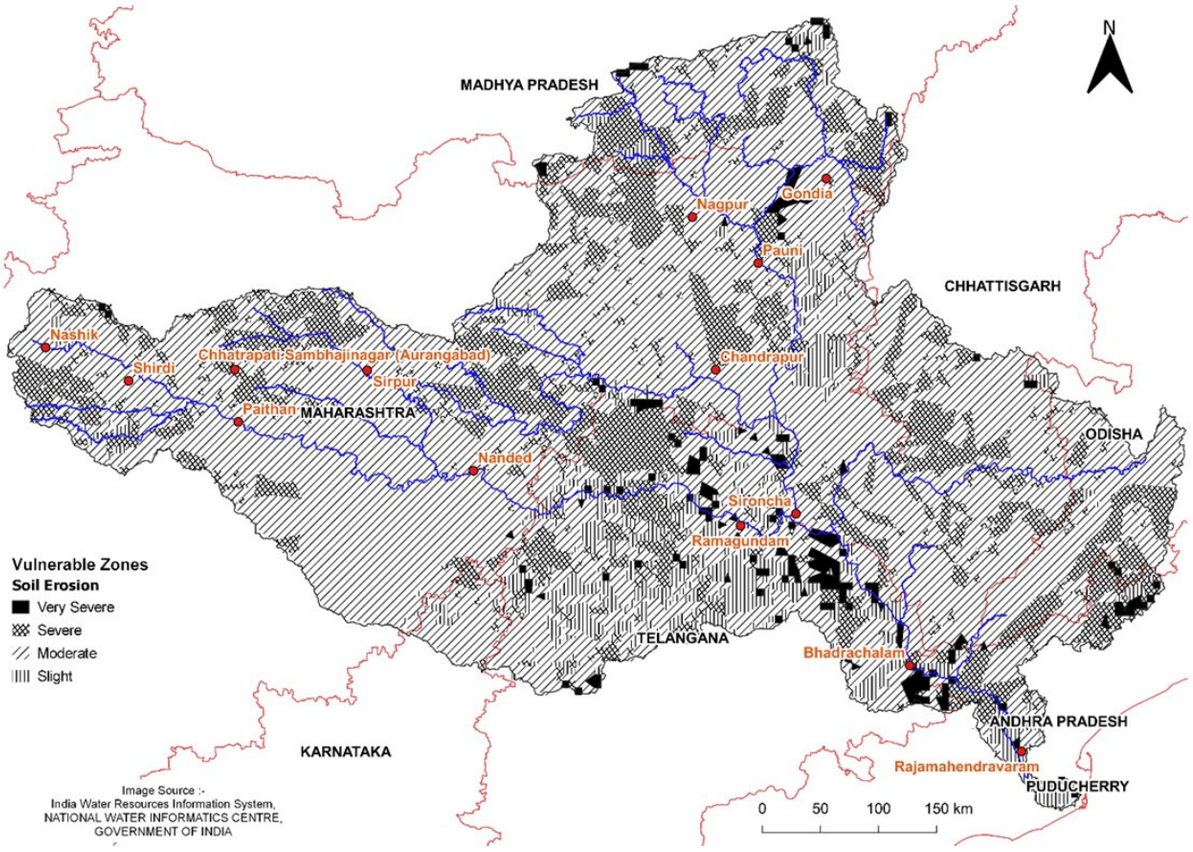

Figure 47: Vulnerable Areas with Respect to Soil Erosion in the Godavari River Basin

Table 10: Different zones of soil erosion area in km2

Sr. No.	Soil erosion	Area (km^2)	Area (%)
1	Very Severe	6787.25	2.20
2	Severe	72121.14	23.40
3	Moderate	207634.01	67.16
4	Slight	22603.58	7.34
	Total	**309145.99**	**100**

12.9. Climate change impacts

Extreme weather events are becoming more common. The basin is experiencing an increased frequency and intensity of droughts, while also facing more frequent occurrences of heavy rainfall events and floods. Heat waves are also more prevalent, leading to higher evaporation rates and further stressing water resources.

These changes are having profound impacts on water availability in the basin. River flow patterns are being altered, affecting both surface water availability and the timing of flows. Groundwater recharge rates are changing, potentially threatening long-term groundwater sustainability. During dry periods, water stress is intensifying, putting additional pressure on both ecosystems and human water needs. Water management in the basin faces several challenges due to these climate change impacts. Predicting water availability for allocation has become more difficult, complicating water resource planning and distribution.

12.10. Inadequate water governance

Challenges in coordinating water management across multiple states and sectors. Inadequate water governance in the Godavari basin is a complex issue stemming from various factors. The multi-state jurisdiction of the river presents a significant challenge, as the Godavari flows through multiple states, each with its own water policies and priorities.

Institutional fragmentation also hinders effective governance. Multiple agencies at central, state, and local levels are involved in water management, often with overlapping responsibilities and a lack of clear role demarcation. This fragmentation frequently leads to inefficiencies and conflicting decisions. To address these challenges, there is a pressing need for improved inter-state coordination mechanisms and more integrated, basin-wide approaches to water management. Enhanced data sharing and transparency are crucial for informed decision-making. Stronger implementation of water-related policies and regulations is necessary to

ensure effective governance. Finally, adaptive governance structures capable of responding to changing environmental and socio-economic conditions are essential for the long-term sustainability of water resources in the Godavari basin.

12.11. Ecosystem degradation

Loss of biodiversity and damage to aquatic ecosystems due to pollution and altered river flows. A recent study by Vanjare et al. (2017) observed 76 species of zooplankton in the Godavari, indicating significant biodiversity. However, it noted variations in species composition and abundance along the river, likely due to varying environmental conditions and anthropogenic pressures. Lower zooplankton diversity has been observed in more polluted stretches of the river. Certain pollution-tolerant species became more abundant in these areas, indicating ecosystem stress. Zooplankton communities varied with river flow, highlighting the importance of maintaining natural flow regimes for ecosystem health. Few studies underscore the complex nature of ecosystem degradation in the Godavari basin and highlight the need for comprehensive pollution control measures, maintenance of environmental flows in the river, habitat restoration and protection initiatives, long-term biodiversity monitoring programs and integrated river basin management approaches that consider ecosystem health.

12.12. Sand mining

Sand mining in the Godavari river has become a significant environmental concern in recent years. This activity occurs along various stretches of the Godavari and its tributaries, with both legal and illegal mining operations present. The primary drivers of sand mining are the high demand for sand in the construction industry and the economic benefits it provides to local communities and state revenues. However, sand mining has substantial environmental impacts. It leads to riverbed degradation and changes in river morphology, affecting aquatic ecosystems and biodiversity.

A 2020 report by the Central Pollution Control Board on the Godavari River highlighted that despite regulations, illegal sand mining continues to be a problem in many stretches of the river. The report noted that sand mining activities contribute to increased turbidity and sedimentation in the river, and recommended stronger monitoring and enforcement measures to control illegal operations.

Addressing these issues requires a multifaceted approach, including more comprehensive assessment of sand mining impacts, stricter enforcement of existing regulations, exploration of alternative materials to reduce sand demand, involvement of local communities in river management, and the development of sustainable sand mining practices that consider river ecosystem health.

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