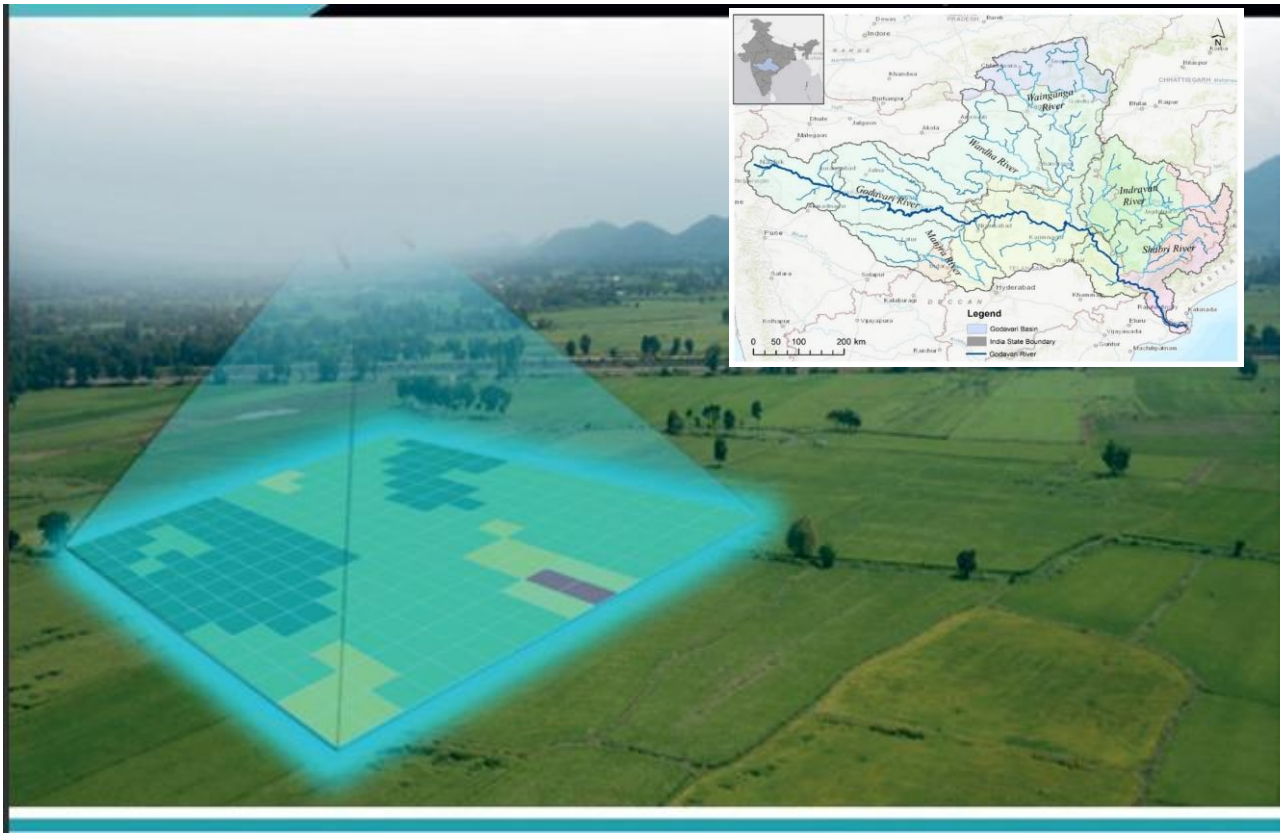
National River Conservation Directorate
Department of Water Resources,
River Development & Ganga Rejuvenation
Ministry of Jal Shakti,
Government of India

STATUS OF AERIAL/DRONE SURVEY OF GODAVARI RIVER BASIN



SEPTEMBER 2024

STATUS OF AERIAL/DRONE SURVEY OF GODAVARI RIVER BASIN

National River Conservation Directorate (NRCD)

The National River Conservation Directorate, Ministry of Jal Shakti is implementing Centrally Sponsored Schemes of the National River Conservation Plan (NRCP) and provides financial assistance to state governments for conservation of rivers. The plan helps set up of infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

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The Centre for Godavari River Basin Management and Studies (cGodavari) is dedicated to River Science and River Basin Management. Established in 2024 at IIT Hyderabad and CSIR-NEERI, under the supervision of cGanga at IIT Kanpur, the centre serves as a knowledge wing of the National River Conservation Directorate (NRCD). The centre 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

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The Centre for Ganga River Basin Management and Studies (cGanga) is a think tank formed under the aegis of National Mission for Clean Ganga (NMCG). One of the stated objectives of cGanga 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 serves as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of seven Indian Institute of Technologies (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- IIT Hyderabad and CSIR-NEERI under the supervision of cGanga at IIT Kanpur. It is submitted to the National River Conservation Directorate (NRCD) in 2024. We gratefully acknowledge the individuals who provided information and photographs for this report.

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Preface

In an age marked by significant environmental challenges, understanding the dynamics of river systems has become increasingly essential. The Godavari River Basin is a lifeline to a substantial proportion of the Indian population.

This report seeks to offer a detailed examination of the Godavari as completed using aerial and drone surveys. The report identifies some key knowledge gaps, emphasizing the critical role the river plays in sustaining local ecosystems and supporting millions of livelihoods in eight states i.e., Maharashtra, Telangana, Andhra Pradesh, Odisha, Chhattisgarh, Madhya Pradesh, Puducherry and Karnataka.

Our aim is to provide readers with the insights needed to recognize importance the importance of the Godavari River Basin, assess its current health, and confront the challenges it faces. The following pages will present conditional assessment of the practices that contribute to the river's ecological integrity and the factors threatening its sustainability. Our dedicated team has meticulously gathered secondary data, case studies, and testimonials to illustrate the potential application of Drone /UAVs based surveys of the river basin. By sharing insights, we hope to inspire and mobilize our readers to participate in conservation efforts.

We extend our heartfelt gratitude to all contributors who have shared their expertise and perspectives, enriching this report. Their invaluable inputs have transformed this document into a comprehensive resource for all who engage with it.

It is our hope that this report will act as a catalyst for meaningful environmental action, fostering a culture of stewardship that benefits both present and future generations. As you explore the complexities of the Godavari River Basin, we invite you to embrace the opportunities and challenges that lie ahead. Together, we can ensure that this vital river continues to thrive and sustain life for generations.

Centres for the Godavari River Basin and Management Studies

IIT Hyderabad and CSIR-NEERI

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1. Executive Summary

The **Godavari River Basin**, spanning eight states in India (Fig. 1), plays a vital role in the many sectors of the country such as agriculture, water supply, and energy. Despite its significance, the basin faces numerous environmental challenges, including recurrent flooding, industrial pollution, deforestation, and inefficiencies in irrigation practices. This report offers an analysis of how **aerial drone surveys** and **Unmanned Aerial Vehicle (UAV)** technology have monitored the basin. Advanced drone technologies can be equipped with **LiDAR**, **thermal**, and **multispectral sensors** to gather real-time, high-resolution data essential for effective flood risk assessment, pollution monitoring, and irrigation optimization. The report evaluates current and planned drone surveys conducted by various authorities and stakeholders, focusing specifically on the Godavari River Basin. Further, a gap analysis on how they can further enhance monitoring and management efforts in the basin is presented.

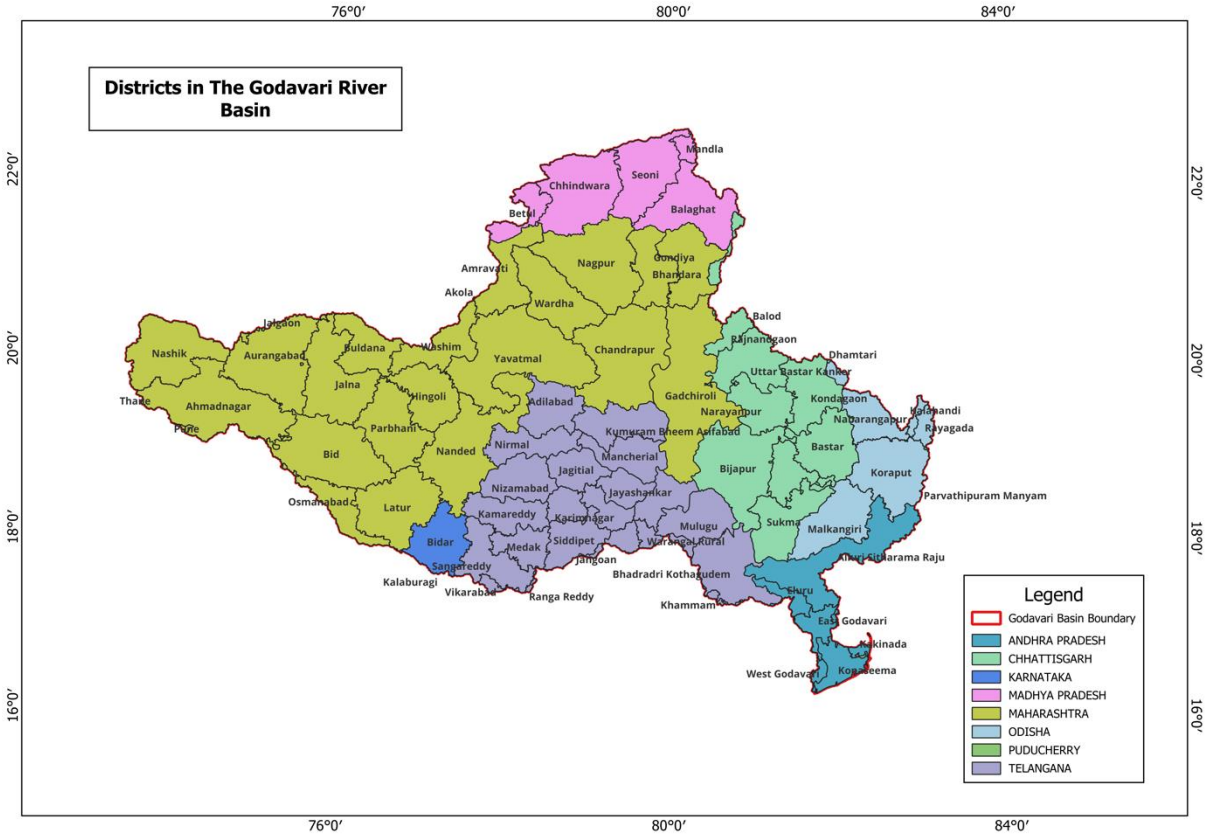

Figure 1. Districts in the Godavari River Basin

2. Introduction

In recent years, the use of unmanned aerial vehicles (UAVs), commonly known as drones, has revolutionized the landscape of surveying and data collection across various fields, including engineering, environmental studies, and urban planning. Aerial surveys conducted with drones offer the ability to capture high-resolution images and data swiftly and efficiently, providing detailed geographic, topographic, and spatial information over extensive areas [1]. These surveys are integral for generating 3D maps, models, and orthophotos, which facilitate informed decision-making in critical development and conservation projects.

Drone and UAV technology significantly enhances the assessment of river basins through a range of applications that improve monitoring and management practices. These technologies enable effective flood monitoring by providing real-time data and imagery, facilitating rapid assessments of affected areas [2,3]. Drones play a crucial role in mapping river courses and tributaries, documenting flow patterns and surrounding landscapes to track geographical changes. They are also instrumental in monitoring landscape alterations resulting from natural events or human activities over time. Furthermore, drones facilitate the estimation of bank erosion and morphological changes, assessing the rate and impact of erosion on riverbanks. Equipped with advanced sensors, drones can monitor water quality by detecting pollutants and identifying contamination sources. In addition, they are valuable for deforestation monitoring, mapping forest cover, and detecting illegal logging activities, there by aiding conservation efforts [4].

In agriculture, drones optimize irrigation practices by assessing crop health and moisture levels, contributing to improved land use and cover analysis. They assist in ecological monitoring, surveying, and infrastructure inspection, supporting disaster response efforts through rapid damage assessments. The technological capabilities of drones enhance water resource management [5] by analysing topography and drainage patterns, which are essential for effective flood prediction and planning. Drones also help identify environmental degradation by detecting areas at risk or over-exploited, guiding sustainable land use strategies.
Moreover, topographic mapping using drone technology creates detailed elevation maps that improve understanding of drainage patterns and flood zones. Waterbody monitoring is facilitated through mapping the distribution of reservoirs, lakes, and wetlands, contributing to effective water resource management. Lastly, floodplain and erosion mapping, supported by drones, identifies flood-prone areas and analyses bank erosion rates, informing flood management strategies. management strategies.

Figure 2. Applications of Drone/UAV Technology in River Basin Management

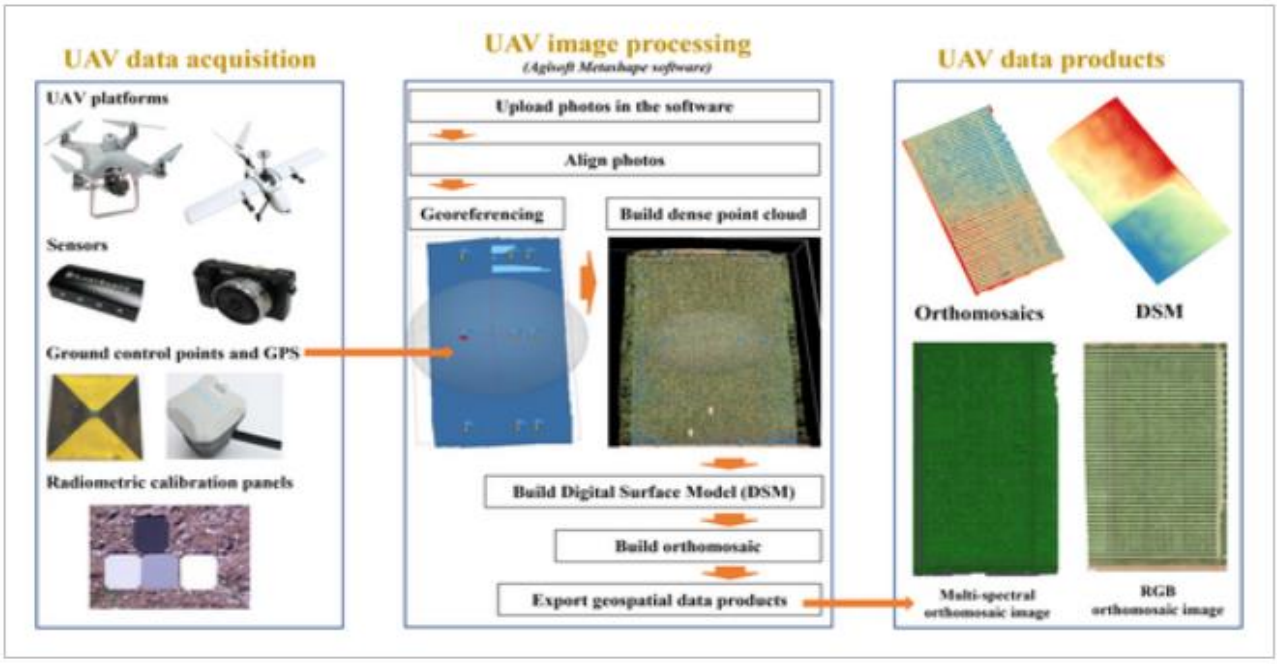

Figure 3. General unmanned aerial vehicle image processing workflow of Red, Green and Blue and multi-spectral images in agricultural water management

This report provides an overview of the available topographical and aerial drone surveys undertaken in the Godavari River Basin, emphasizing its implications for future projects and the benefits it brings to local communities.

3. Objectives

The primary objective of this study is to identify regions within the Godavari River Basin where aerial drone surveys have already been conducted, while also identifying regions that still need further surveying for future assessments of the basin's health.

4. Drone Rules, 2021

The "Drone Rules, 2021" introduced by the Indian government classify airspace into different flying zones to regulate the operation of drones effectively.

4.1 Green Zones:

- Approximately **90%** of Indian airspace is classified under Green Zones.
- Drone operations are generally permitted in these areas.
- Maximum altitude for flying drones is **400 feet**.
- **No special permission** is required for operations, making these zones ideal for commercial and recreational activities.

4.2 Yellow Zones:

- Drones can be flown in Yellow Zones but require **prior permission** from the relevant authority.
- Typically encompass regions near **airports** and other **sensitive locations**.
- There is a higher need for air traffic management and safety due to proximity to critical infrastructures.

4.3 Red Zones:

- Designated as **Prohibited Areas** where drone operations are strictly prohibited.
- Includes airspace above critical infrastructure, **military installations**, and other sensitive sites.

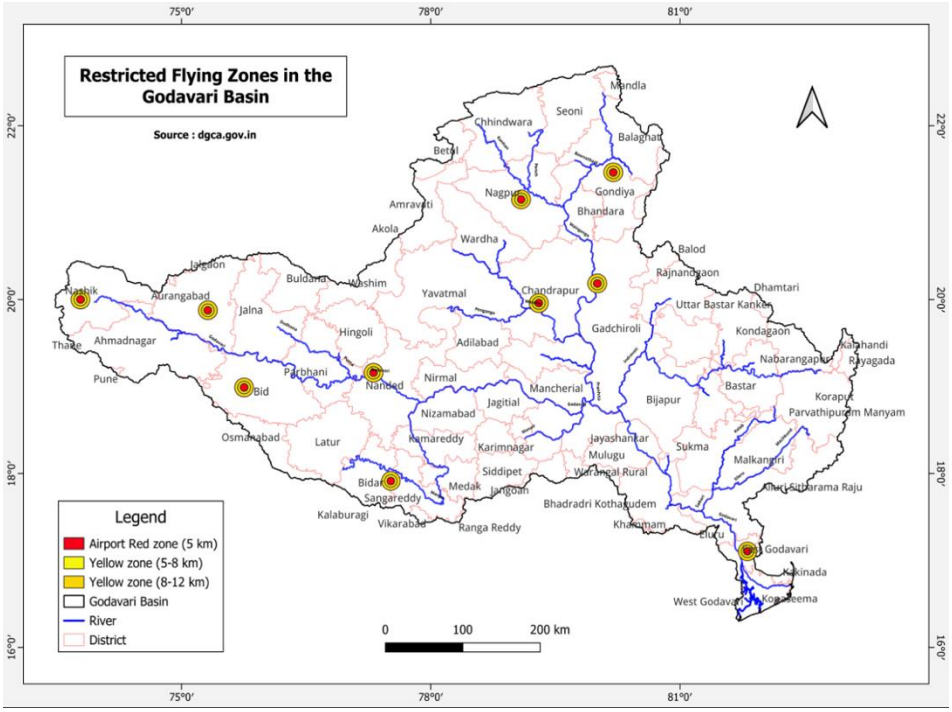

Figure 4. Restricted Zones or drone operations under the Drone Rules, 2021

5. Data Sources and Methodology

This section outlines our approach to assess the conditions of the Godavari River Basin through the use of secondary data. We sourced information from a variety of avenues (Fig. 5), including government reports, satellite imagery, and prior research studies. To enhance our data collection, we engaged directly with various government departments and communicated with senior officials via calls and emails to acquire the necessary information. Furthermore, we also attempted in-person (onsite) data collection to ensure the accuracy the specific data requirements needed for a comprehensive assessment.

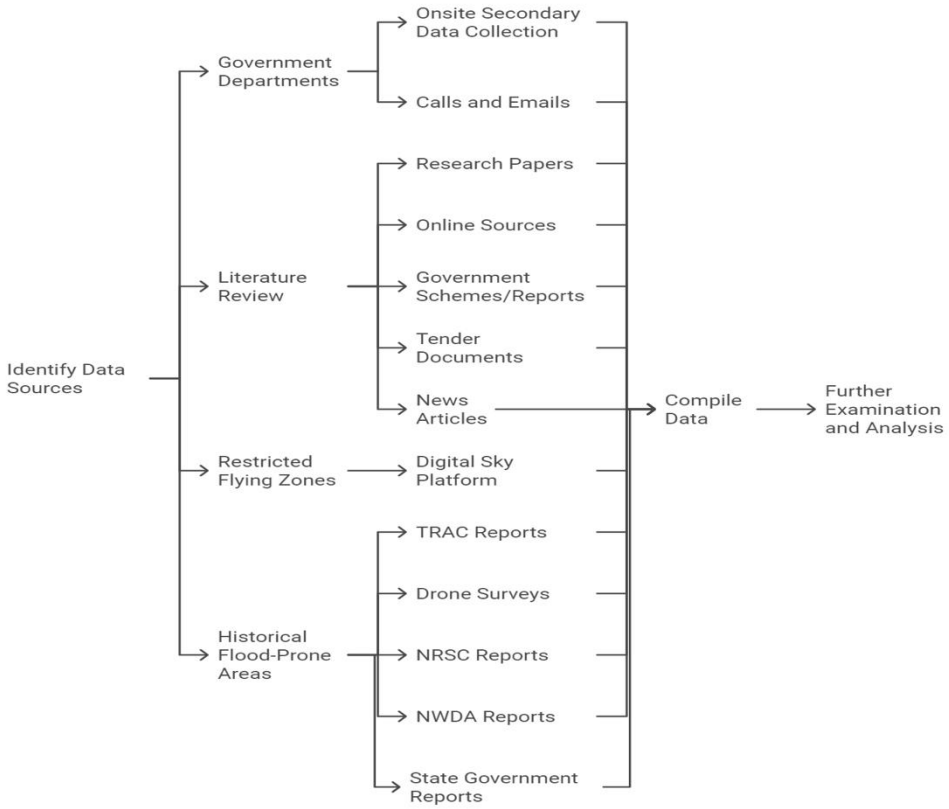

Figure 5. Methodology for data collection and GAP Analysis

6. A Summary of Surveys in the Godavari Basin

Table 1 below summarizes various projects by different organizations focused on the Godavari River Basin, detailing the year, surveyed areas, and technologies utilized.

Table 1. A list of surveys covering various locations of the Godavari River Basin

1) Telangana

ORGANIZATION	PROJECT	YEAR	AREA SURVEYED	TECHNOLOGY USED
Irrigation and Command Area Development Department (I&CAD), Telangana	Kaleshwaram Lift Irrigation Project (KLIP)	2017	Godavari River Basin(18.25 lakh acres), key reservoirs like Mallannasagar and Kondapochamma Sagar, and 1,832 kilometres of canal systems.	LiDAR, Remote sensing and GIS, Ground-Penetrating Radar (GPR)
	Godavari River Flood Management	2016	Godavari River Basin, Karimnagar, Nizamabad, Warangal, Adilabad Khammam	Photogrammetry and LiDAR, Remote sensing and GIS
	Catchment Area Assessments	2016	Mallannasagar, Kondapochamma Sagar, and Yellampalli.	LiDAR, Remote sensing and GIS
Telangana State Remote Sensing Applications Centre (TRAC)	Agricultural Monitoring and Land Use Studies.	2016	Agricultural fields and land use patterns within the Godavari basin	LiDAR, Remote sensing and GIS
National Water Development Agency (NWDA)	Unclear	2016-2017	Nanded, Karimnagar, Warangal, and Khammam , Pranhita, Manjira, and Indravati river	Aerial imaging, LiDAR
Central Water Commission (CWC)	Unclear	2019-2020	Unclear	Multi-Spectral Imaging, Aerial imaging, LiDAR
Hyderabad Metropolitan Water Supply and Sewerage Board (HMWSSB)	Unclear	Unclear	Unclear	Unclear
Centre for Water Resources, Jawaharlal Nehru Technological University (JNTU), Hyderabad	Unclear	Unclear	Unclear	Unclear
Department of information technology, electronics and communication	AI for Agricultural Innovation	2020	Unclear	Unclear

Geokno	Godavari-Penna River-Interlinking	Unclear	Unclear	Unclear
Greater Hyderabad Municipal Corporation	Flood Management and Drainage Survey	2020-2021	Unclear	high resolution drones equipped with GIS technology
	Illegal Construction Monitoring	ongoing in recent years	Unclear	
	Waste Management and Dump Yard Monitoring	2020	Unclear	
	Road and Infrastructure Development Projects	various year	Unclear	
	Smart City Project (Hyderabad)	2021	Unclear	
National Remote Sensing Centre (NRSC)	Real-time Operational Spatial Flood Early Warning System Development	2018	Godavari basin	digital elevation models
Contec Pvt ltd	The Sita Rama Lift Irrigation Project (SRLIP)	Unclear	Mulugu	Unclear

2) Chhattisgarh

ORGANIZATION	PROJECT	YEAR	AREA SURVEYED	TECHNOLOGY USED
Chhattisgarh Board of Revenue	Unclear	2015	Baster and nearby villages	Unclear
Forest and climate change department	Unclear	Unclear	Unclear	Unclear
Reelon Air Private Limited	Unclear	Unclear	Unclear	Unclear

3) Andhra Pradesh

ORGANIZATION	PROJECT	YEAR	AREA SURVEYED	TECHNOLOGY USED
Andhra Pradesh State Remote Sensing Applications Centre (APSRAC)	flood monitoring, land cover, environmental and agriculture surveys, infrastructure monitoring, water resource management	various year	Kakinada	Unclear
Government of Andhra Pradesh	YSR Jagananna Shaswata Bhu Hakku mariyu Bhu Raksha Pathakam	2023	Vishakhapatnam	Unclear
WAPCOS PVT Ltd	Drone Survey for Uttarandhra Sujala Sravanthi Project on River Godavari	2023	Godavari river	Unclear
Polavaram Project Authority	Unclear	Unclear	Unclear	Unclear
Andhra Pradesh Pollution Control Board (APPCB)	Unclear	Unclear	Unclear	Unclear
Godavari Institute of Engineering and Technology	crop monitoring by drone	2023	Rajahmundry	high resolution drone

4) Madhya Pradesh

ORGANIZATION	PROJECT	YEAR	AREA SURVEYED	TECHNOLOGY USED
Revenue department	Abadi Survey	2021	Betul, Balaghat, Seoni and Mandla	UTM projection and WGS-84 datum

5) Maharashtra

ORGANIZATION	PROJECT	YEAR	AREA SURVEYED	TECHNOLOGY USED
Maharashtra Remote Sensing Application Centre (MRSAC)	MahaAgriTech project precision, farming plan	2018	All over Maharashtra	RGB Cameras, Thermal Sensors
Marut Drones	Sub-mission on Agricultural Mechanization	Unclear	Buldana	Drones AG365
Aurangabad Smart City Development Corporation Limited (ASCDCL)	Urban planning, land mapping, infrastructure monitoring, and traffic management	2019	Aurangabad	professional survey grade drone
Indian Institute of Technology (IIT), Mumbai	revolutionize drone technology's applications across the state.	2024	All over Maharashtra	professional survey grade drone
Survey of India	Large scale mapping project	2019	Covering more than 40,000 Village	professional survey grade drone

6) Karnataka

ORGANIZATION	PROJECT	YEAR	AREA SURVEYED	TECHNOLOGY USED
NeoGeo Infor Pvt ltd	Drone-based Land Parcel Mapping		Bidar, Kalaburagi	CORS and GNSS
Aereo	Drone-based Land Parcel Mapping		Bidar, Kalaburagi	CORS and GNSS

7) Odisha

ORGANIZATION	PROJECT	YEAR	AREA SURVEYED	TECHNOLOGY USED
Orissa Space Application Center	Lidar Survey of Minor irrigation tank	2021	Unclear	GNSS(Global Navigation Satellite System), LiDAR and MX Camera
TP Southern Odisha Distribution Limited (TPSODL)		2024	Rayagada, Koraput, Nabarangpur and Malkangiri	High magnification drone
Housing and Urban Development Department	Geospatial technology to provide land rights to slum dwellers	2017	Malkangiri, Nabrangpur and Rayagada	Quadcopter drones

7. Further description of some drone surveys in the basin

The Godavari River Basin has been surveyed using drone technology by various organizations, focusing on a diverse array of applications such as flood management, agricultural monitoring, land use analysis, and infrastructure assessment.

A drone survey is known to be on the works at the proposed Janampet barrage site, 18^{o} 06' 23" N latitude and 80^{o} 44' 38" E longitude (right bank) near the Bhupathirao pet village in Pinapaka mandal, Bhadradri Kothagudem district of Telangana. Utilizing advanced technologies such as Differential Global Positioning System (DGPS), Total Station, and drone technology, these surveys were outsourced to imaGIS Engineering Solutions Pvt Ltd, Nagpur. The significance of these surveys is underscored by the ongoing efforts of the state government to expedite comprehensive resurvey initiatives, such as 'Jagananna Bhoo Hakku - Boohoo Raksha,' which aims to enhance land surveying through the integration of more drones. Currently, the survey operations are utilizing 52 drones, with plans to increase this number to 172, highlighting a concerted effort to improve land management in the region [6].

Additionally, the a Topographical Drone Survey is planned for the Uttarandhra Sujala Sravanthi Project to harness the waters of the Godavari River for irrigation and water distribution in northern coastal Andhra Pradesh. This project, executed by WAPCOS Limited,

aims to irrigate over 8 lakh acres across Visakhapatnam, Vizianagaram, and Srikakulam districts, ultimately benefiting around 30 lakh people by providing essential drinking and industrial water supply. The detailed topographical maps generated from drone surveys are expected to enhance the design and planning processes for irrigation infrastructure and canal networks.

Drones have been utilized in the Kaleshwaram Lift Irrigation Project (KLIP), for surveying the land cover [7]. This project incorporated LiDAR technology to gather comprehensive data on topography, land use, and water bodies. Another significant project for LiDAR based aerial survey was Sita Rama Lift Irrigation Project (SRLIP), Telangana [8], which aims to irrigate 2.73 lakh hectares, including 1.25 lakh hectares of new command area and 1.38 lakh hectares for stabilization of existing irrigation systems. The project impact area (PIA) spans eight mandals across two districts, including Mulugu.

In Odisha, drone technology has been used to enhance safety in electrical work at heights in Southern Odisha implemented by the TP Southern Odisha Distribution Limited (TPSODL) This initiative covers districts within the Godavari River Basin, such as Rayagada, Koraput, Nabarangpur, and Malkangiri. TPSODL's operational is 48,751 sq. km. which mostly comprises of dense forests, hilly terrain, and tough-reaching geographical areas.

Also in Odisha, in partnership with Tata Trust, advanced drone technology was also used to map 250,000 slum households, which covered area Nabrangpur, Malkangiri and Rayagada, and generated high-resolution images for improved urban planning and infrastructure development (e.g. Fig. 6).

Figure 6. Drone Imagery of Odisha Slum (Source: https://shorturl.at/uFKVj)

In Maharashtra, in an effort to enhance agricultural productivity and increase farmers' income, the Government of Maharashtra has launched a precision farming plan covering 40,913 villages across the state including areas within the Godavari River Basin. As part of this initiative, the Maharashtra government signed a Memorandum of Understanding (MoU) with the Indian Institute of Science (IISc) to utilize drone technology developed by aerospace engineers for estimating crop area, yield, and health, particularly focusing on soybean and cotton [9].

The Government of Maharashtra has also planned the "**Maharashtra Drone Mission**" (MDM), aimed at positioning Maharashtra as a global leader in drone technology [10]. The MahaAgriTech project, initiated by the Maharashtra Department of Agriculture in collaboration with Maharashtra Remote Sensing Application Centre (MRSAC), focuses on using drones, equipped with thermal sensors and RGB cameras to enhance agriculture decision-making.

In the Buldhana district, a collaboration between the Maharashtra government and Marut Drones to assist in irrigation assessments [11]. Drone technology was also used in water and irrigation sector for measuring area of irrigated land and identifying the type of crop by the Water Resources Department at Pune to help increase are under irrigation from 10.71 lakh hectares to 13.884 lakh hectares, contributing an estimated additional ₹50 crores in value. The types of drones used in Maharashtra, and their specifications are given below in Table 3. An example photo (unrelated to the Maharashtrian study is presented in Figure 7.

Table 2. Specifications of drones used in Maharashtra for measuring irrigated land and identifying crop types

Sr. No.	Item	Fixed Wing Drone	Quad Copter
1.	Weight	2.5 to 6 kg	1.5 to 5 kg
2.	Speed	11 to 17 m/s	8 to 10 m/s
3.	Battery Type	Lithium Polymer	Lithium Polymer
4.	Photo Capture Capacity	3 photos / second	3 photos / second
5.	Flight altitude	150 m	90 m
6.	Flight duration	90 min	45 min
7.	Area covered in single flight	4 to 5 sq. km	2 to 4 sq. km
8.	Camera	Sony Alfa 600 R, Resolution -24 Megapixel	Sony Alfa 600 R, Resolution -24 Megapixel
9	Type of terrain	Plain area	Hilly area

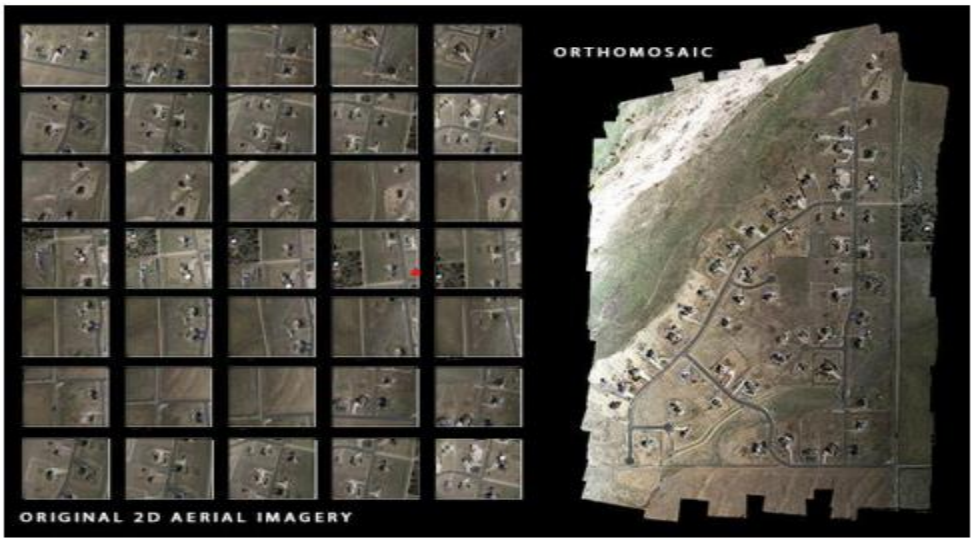

Figure 7. An example ortho mosaic image is prepared using photogrammetry software (Source: https://medium.com/new-farmer/what-is-an-orthomosaic-photo-11140c0601pdf)

On a broader scale, the Ministry of Home and Urban Affairs (MoHUA) has launched the **Smart City Mission** (SCM) to drive economic growth and improve the quality of life through technology-driven urban planning. Drones are proposed to play an important part in supporting this initiative. The city of **Aurangabad** in Maharashtra has been selected as part of this mission, with the goal of retrofitting existing areas, redeveloping slums, and creating new areas to accommodate the growing urban population.

In Karnataka, the Allterra and NeoGeo won the largest-ever drone-based land parcel mapping contract, covering 68,000 sq. km and ten districts, including the Bidar district which lies in the Godavari River Basin [12]. Using a fleet of approximately 60 survey-grade drones, the project aims to map around 1.75 lakh acres per day, generating high-resolution maps with a pixel

resolution better than 5 cm. The digital maps will be used by the SSLR department to update land ownership records and enable infrastructure development across the state.

in Chattisgarh, the Revenue Department of Chhattisgarh, in partnership with the National Remote Sensing Agency (NRSA), has conducted aerial surveys of 237 villages in the Bastar division, covering a total area of 5,852 sq. km.

8. Gap Analysis

This section presents a detailed GAP analysis of the current aerial imaging and drone-based surveys being employed **for** Godavari River Basin, with a focus on areas such as flood risk monitoring, water quality monitoring, deforestation and soil erosion monitoring, and irrigation optimization.

It may be noted that to enhance our data collection efforts, we have reached out to various organizations, but only a few have responded positively. Despite our in-person visits and meetings, we encountered challenges in gathering the necessary data due to lengthy procedural steps within these organizations. **This highlights the need for streamlined processes that can facilitate better collaboration and data sharing related to drone surveys in particular, and other information in general.**

Based on the analysis of available data or information, we have identified many gaps in current implementation of drones. These gaps guide us towards areas for improvement. One significant issue is the insufficient coverage of drone surveys in most flood prone districts (Fig. 8) such as the East Godavari, West Godavari, and Konaseema, Kakinada, Eluru, Parvathipuram Manyam and Alluri Sitharamaraju, Mancherial, Mulugu, Jayashankar Bhupalpally, and Khammam. **This lack of coverage limits our ability to effectively collect data on flood risks monitoring.**

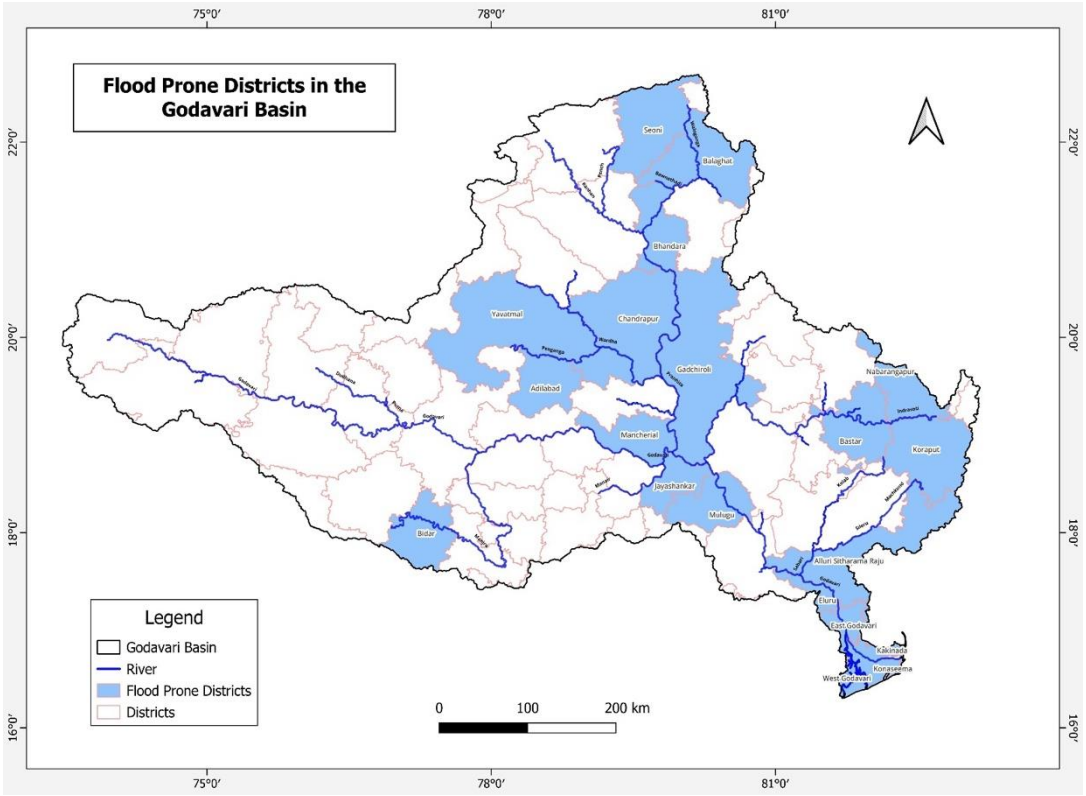

Figure 8. Flood affected districts under Godavari river basin

Furthermore, there is a pressing need to bolster disaster management efforts. **Currently, proactive drone surveying for flood and drought responses is quite limited**. Covering drought events through targeted drone surveys in vulnerable regions (Fig. 9) like Aurangabad, Jalna, Bid, Mahabubabad, Nizamabad, Ranga Reddy, Karimnagar And Warangal is essential for safeguarding communities during challenging times.

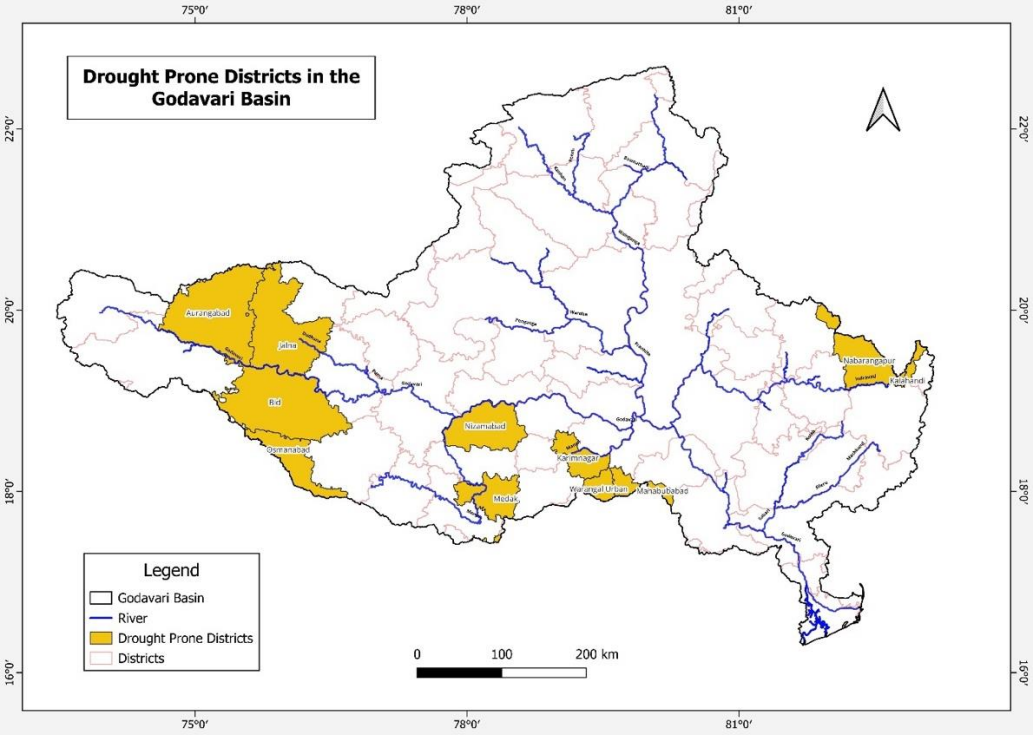

Figure 9. Drought affected districts under Godavari River basin

Another important aspect is the **integration of drone-generated data with existing state databases for forest cover** (Fig. 10), which remains inadequate. Rapid urban growth can lead to deforestation around cities like Gadchiroli, Nagpur, Thane, Nashik, Amravati, Chandarpur, Yavatmal, Chhatrapati Sambhaji Nagar, Pune, Aurangabad and Ahmednagar; areas around which covers more than 70% of forest in Maharashtra. This underscores the necessity for comprehensive drone mapping to support overall health of our ecosystems. By establishing protocols for this data integration, we can enhance decision-making processes related to forest management and urban planning.

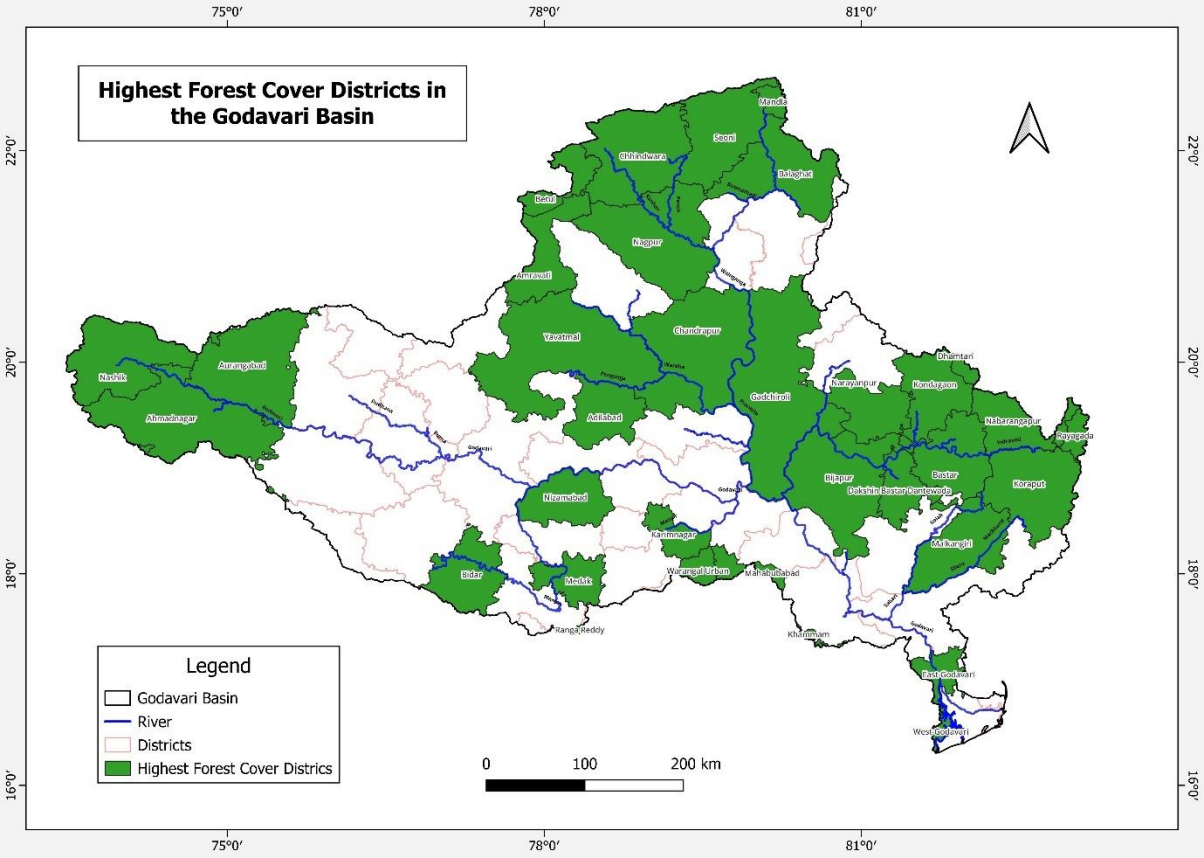

Figure 10. High forest cover districts in the Godavari River Basin

Drone technology is vital for tracking environmental factors in the Godavari River Basin, particularly when it comes to water quality. However, based on secondary data water quality monitoring is still quite **limited, especially in smaller water bodies and reservoir.** Conducting assessments in areas like East Godavari and West Godavari could provide visual confirmation of **the number and types of water bodies (ponds, tanks, lakes, reservoir) provides a baseline for assessing pollution levels.**

The heat map presented in Fig. 11 below represents the importance of drone surveys across multiple regions with districts with a high or low density of different water body types. High water body-districts need to be covered to safeguard and account for the total water availability, and low water-body districts need to be surveyed to protect whatever little water that is stored and may become at risk.

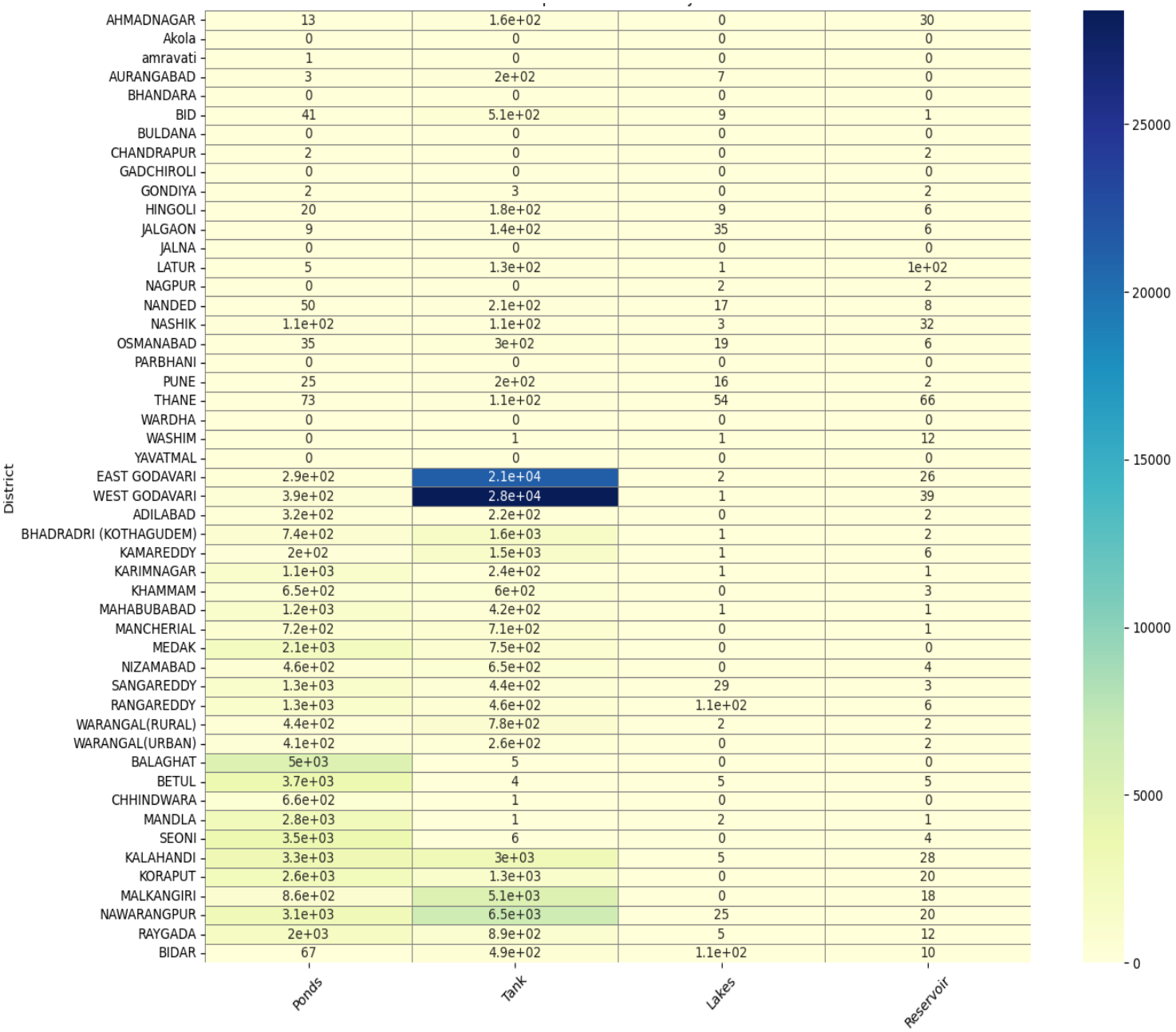

Figure 11. Heatmap visually representing the count of different types of water bodies (ponds, tanks, lakes, and reservoirs) across various districts
(Note: a.e+m = a. 10 m, m=1,2,3,……..)

Overall, it is to be noted that the **majority of the basin faces issues related to droughts, floods, pollution and ecological and economic losses (as also highlighted in the River at a Glance report for the Godavari River Basin).** Thus, there is an urgent need to cover as much of the basin as possible.

9. Conclusion

The Godavari River Basin is a critical resource for India, but it faces environmental challenges such as flooding, pollution, and deforestation. This report examines how drone technology can enhance the management of these issues. Drones can gather high-resolution data for flood risk assessment, water quality monitoring, and deforestation control. **Although the prospects of utilization of drone in monitoring and protecting the river basin are promising, this study highlights the many gaps in actual coverage**. For example, limited geographical coverage, lack of real-time integration with disaster management systems, and insufficient public involvement. Expanding drone usage and improving collaboration with local authorities and decision systems could greatly enhance environmental monitoring and resource management in the region.

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