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 MAHANADI RIVER BASIN

September 2024

cMahanadi

cGanga

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National River Conservation Directorate (NRCD)

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

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Centres for Mahanadi River Basin Management and Studies (cMahanadi)

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

www.cmahanadi.org

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

www.cganga.org

Acknowledgment

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

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Preface

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

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

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

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

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

Centres for Mahanadi River Basin
Management and Studies (cMahanadi)
NIT Raipur & NIT Rourkela

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Abbreviations and Acronyms

cMahanadi	Centre for Mahanadi River Basin Management and Studies
MRB	Mahanadi River Basin
UAV	Unmanned Aerial Vehicles
DGCA	Directorate General of Civil Aviation
CAPF	Central Armed Police Forces
NTPC	National Thermal Power Corporation
RSCL	Raipur Smart City Limited
GIS	Geographic Information System
PHC	Public Health Centre
NIT	National Institute of Technology
IIT	Indian Institute of Technology
IGKV	Indira Gandhi Krishi Vishwavidyalaya
ICAR	Indian Council of Agricultural Research
AHP	Analytical Hierarchy Process

1. Executive Summary

This gap report examines the potential applications of drones, UAVs, and aerial surveys for assessing river conditions and provides a comprehensive evaluation of drone and aerial surveys conducted or planned by various authorities and stakeholders, with a particular focus on the Mahanadi River Basin. Its primary objective is to identify areas that require additional surveying for future river condition assessments.

The report also discusses the Drone Rules, 2021, which define operational flying zones for the basin area, and integrates these regulations into the gap analysis. This analysis helps in recommending specific regions for future aerial or drone surveys by considering potential hazard zones, historical flood-prone areas, restricted flying zones, and previously surveyed regions. Additionally, the report includes an estimate of data acquisition costs and provides relevant recommendations.

2. Introduction

A drone/UAV/aerial survey involves the use of unmanned aerial vehicles (UAVs) or drones to capture high-resolution images and data from the air. These surveys can provide detailed geographic, topographic, and spatial information over large areas quickly and efficiently, making them essential tools in various engineering, environmental, and planning applications (Turner et al., 2012). The collected data can be used to create 3D maps, models, and orthophotos, which are crucial for informed decision-making in these fields.

In the Mahanadi River Basin, drone/UAV/aerial surveys are particularly important for advancing water resources engineering. These surveys provide high-resolution topographical and hydrological data, essential for flood management, irrigation planning, and water quality monitoring (Zhang & Kovacs, 2012). Given the basin's susceptibility to seasonal flooding, drones enable real-time monitoring of water levels and flood-prone areas, aiding in the design of effective flood control measures (Turner et al., 2012).

In irrigation, drones facilitate the precise mapping of agricultural fields, ensuring optimal water distribution and reducing waste (Zhang & Kovacs, 2012). They also support sedimentation studies in rivers and reservoirs, helping to maintain storage capacity and water quality (Zhang & Kovacs, 2012). Additionally, drones monitor environmental changes, such as deforestation and wetland degradation, contributing to sustainable water resource management (Anderson & Gaston, 2013).

For infrastructure development, including dam construction and canal excavation, drone surveys offer accurate data, ensuring structures are built in optimal locations (Turner et al., 2012). Moreover, drones help identify potential groundwater recharge areas, which is essential for addressing water scarcity in the region (Zhang & Kovacs, 2012).

Overall, drone/UAV/aerial surveys are vital for informed decision-making and sustainable management of the Mahanadi River Basin's water resources, supporting both environmental conservation and regional development. In the Chhattisgarh region, drone-based surveys have become pivotal across various sectors, driving advancements in land management, environmental conservation, and agricultural optimization. For instance, the Chhattisgarh Government's Revenue Department, under the Svamitva Scheme, utilizes drones to map rural populated areas, issuing land ownership certificates to residents and monitoring critical tiger corridors to combat encroachment (Government of India, 2021).

Simultaneously, research institutions like the National Institute of Technology Raipur (NIT Raipur) and Indian Institute of Technology Kanpur (IIT Kanpur) employ RGB drone surveys for air pollutant monitoring, soil moisture assessment, and agricultural applications, significantly reducing production costs and enhancing precision farming (Anderson & Gaston, 2013). Additionally, tender projects involving agencies like Raipur Smart City Limited and the Chhattisgarh Mineral Development Corporation focus on using drone surveys for mining activities, forest mapping, and infrastructure development, including topographical surveys for a major thermal power plant (Government of India, 2021). These initiatives underscore the diverse and transformative role of drone technology in the Chhattisgarh region, contributing to sustainable development and efficient resource management.

2.1 Potential Use of Drone/UAV/Aerial Survey in Condition Assessment of the River Basin

Drones/UAVs offer significant potential across various sectors in the Mahanadi River, particularly in the context of Condition Assessment of the River Basin. In flood management, drones can provide real-time data on water levels and flood-prone areas (Karamuz et al., 2020; Govedarica et al., 2018) enabling accurate modelling and early warning systems. For irrigation planning, UAVs help map agricultural fields with high precision, ensuring efficient water distribution and minimizing waste.

In water quality monitoring, drones equipped with sensors can detect pollutants and monitor sediment levels, ensuring the health of aquatic ecosystems (Yang et al., 2022; Kieu et al., 2021). Sedimentation studies are another critical area where drones can track sediment accumulation in rivers and reservoirs, aiding in maintaining storage capacity and water quality.

For groundwater management, drones can identify potential recharge areas, which is essential for addressing water scarcity (Tampubolon and Reinhardt, 2014; Barnes and Volkmann, 2015). Additionally, in infrastructure development, such as dam construction and canal excavation, UAVs provide accurate topographical data, ensuring that projects are executed in optimal locations.

Lastly, drones contribute to environmental monitoring by mapping land use changes and deforestation, helping to protect the basin's ecosystems. Overall, drone technology enhances the efficiency, precision, and sustainability of water resource management in the Mahanadi River Basin.

Table 1. Applications of Drone/UAV/Aerial Survey in Condition Assessment of the River Basin

S. No.	Purpose	Descriptions
1	Mapping River Course and Tributaries	Documenting the river's flow, tributaries, and surrounding landscape to track geographical changes.
2	Monitoring Landscape Changes	Identifying alterations in the river basin due to natural or human activities over time.
3	Estimating Bank Erosion and Morphological Changes	Assessing the rate and impact of erosion and other changes in river morphology.
4	Planning Water Resource Management	Analyzing topography and drainage patterns to support flood prediction and water resource planning.
5	Identifying Environmental Degradation	Detecting areas over-exploited or at risk, guiding conservation and sustainable land use strategies.
6	Land Use and Land Cover Analysis	Assessing current land uses and detecting changes to guide urban planning, agriculture, and conservation.
7	Topographic Mapping	Creating detailed elevation maps to understand drainage patterns, flow characteristics, and flood zones.
8	Waterbody Monitoring	Mapping the location and spread of reservoirs, lakes, ponds, and wetlands to support water resource management.
9	Floodplain and Erosion Mapping	Identifying flood-prone areas and analyzing bank erosion rates to inform flood management strategies.

2.2 Flying Zones Under the Drone Rules, 2021

The Drone Rules, 2021, have divided Indian airspace into three primary zones based on the level of restrictions for drone operations:

- Green Zone
  - Least restricted area.
  - Drones can fly up to a height of 400 feet (120 meters) without specific permission.
  - Most of India is categorized as a green zone.
- Yellow Zone
  - Controlled airspace.
  - Requires specific permissions to operate drones.
  - Typically, areas near airports, military installations, and other sensitive areas.
  - Height restrictions and other limitations may apply.
- Red Zone
  - No-fly zone.
  - Drone operations are strictly prohibited unless under exceptional circumstances with specific government approval.

❖ Includes high-security areas and critical infrastructure.

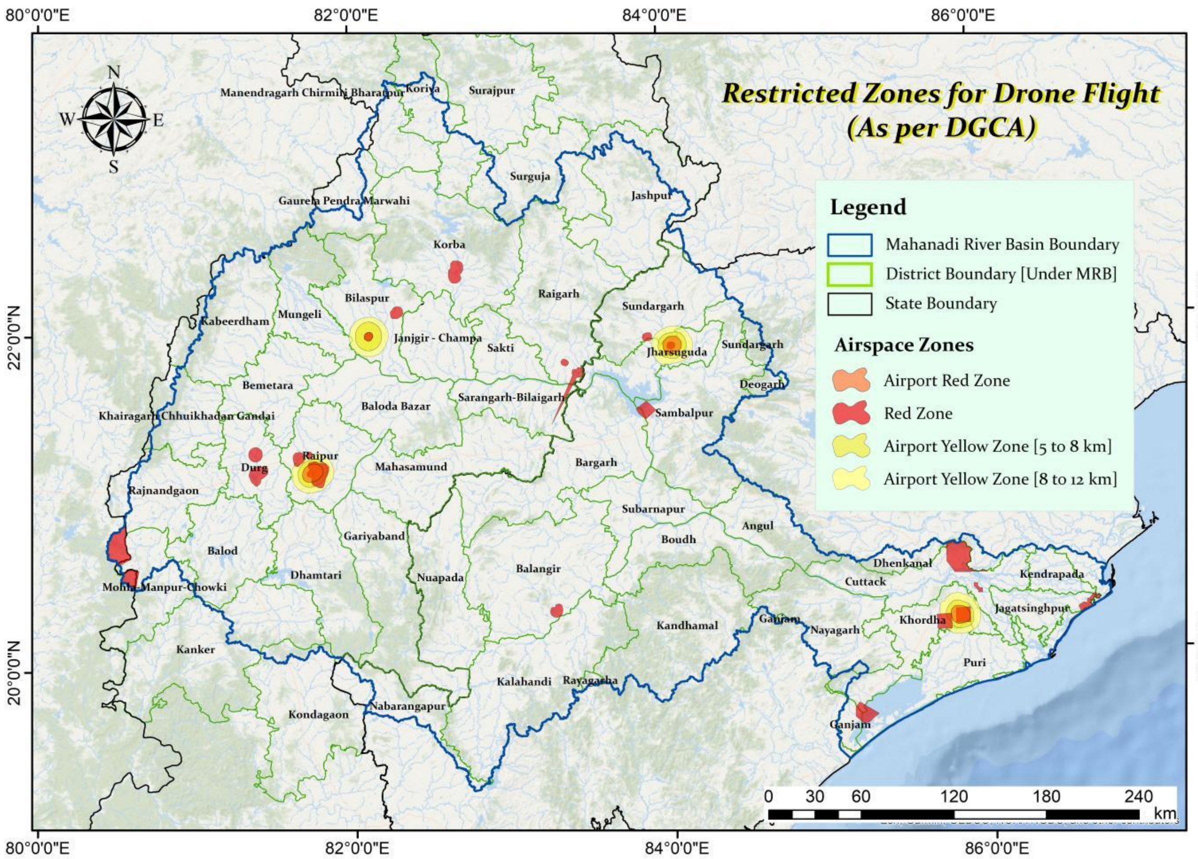


Figure 1: Restricted Zones for Drone Operations under the Drone Rules, 2021
(Data Source: Digital Sky Platform | https://digitalsky.dgca.gov.in/airspace-map/#/app)

(Prepared by cMahanadi Team)

It's important to know that, the specific boundaries of these zones can vary and are subject to change. The Digital Sky platform (https://digitalsky.dgca.gov.in) provides up-to-date information on zone classifications and restrictions.

The portion of the Mahanadi River Basin within Chhattisgarh state faces significant geographical, strategic, and security challenges. As a result, several restricted zones for drone operations exist as shown in Figure 1 under the Drone Rules, 2021. These zones primarily fall into the following categories as shown in Figure 2:

a. **Airport Zones**

Swami Vivekananda Airport - Raipur, Bilasa Devi Kevat Airport - Bilaspur and Defence Airports: Red zone over the airport vicinity and Yellow Zone surrounding the airport, restricting drone operations within a certain radius.

Biju Patnaik International Airport, Bhubaneswar: A critical no-fly zone extending up to a specific radius around the airport. This includes areas like Patia, Jaydev Vihar, and the central region of Bhubaneswar.

b. **Security Force Zones**

Central Armed Police Forces (CAPF) Camps: Given the Nasal-Affected areas in southern parts of MRB in Chhattisgarh, CAPF camps and installations are Generally located in Red Zones.

State Police Headquarters and Units: These are typically designated as Yellow/Red Zones due to security concerns.

CRPF Group Centre, Bhubaneswar: The area surrounding the CRPF camp in Bhubaneswar is restricted for drone activities.

Chilika Naval Base: A significant naval base located on the eastern shore of Chilika Lake. The surrounding areas are heavily restricted.

c. Industrial Zones

Industrial zones such as the Bhilai Steel Plant and NTPC Power Plants in Korba, Bilaspur, and Raigarh districts of Chhattisgarh could have restrictions due to safety or security reasons.

d. Critical Infrastructure

Hirakud Dam, Sambalpur: One of the largest dams in India, located on the Mahanadi River, is a sensitive area with strict restrictions on drone flights.

Paradip Port, Jagatsinghpur: A major port on the eastern coast, including its surrounding areas, is restricted for drone activities.

e. Religious Sites

Lingaraj Temple, Bhubaneswar: A prominent temple in the capital city, where drone operations are not allowed.

Understanding the intricate network of restricted zones in Chhattisgarh, particularly within the Mahanadi River Basin, is crucial for a successful drone survey for water quality, hazard assessment, and river conservation etc. Prioritizing areas outside restricted zones for initial data gathering is essential to optimize survey efficiency in terms of both time and money. Moreover, obtaining necessary permissions for operations within or near restricted zones should be a proactive step.

3. Data Sources, and Methodology

The data sources and methodology section outlines the various Datasets, tools, and approaches used for the gap analysis of the Drone survey for the condition assessment of the Mahanadi River Basin. Table 2 and Figure 2 shows the integration of diverse data types, including government reports, remote sensing data, and restricted flying zone information, to identify a comprehensive plan for the aerial/drone survey.

Table 2: Datasets Used

S. No.	Purpose	Data Type	Source
1	Literature Review	Research Paper	Online sources
		Government Schemes/Reports	Online source
		Tender Documents	Online source
		News Articled	Online source
2	Restricted Flying Zones	Red and Yellow Zones	Digital Sky Platform
3	Hazard Map	LULC	ESRI Sentinel
		Rainfall (mm)	IMD
		Slope (%)	JAXA (Derived from DEM)
		River Buffer (Meters)	JAXA (Derived from DEM)
4	Historical Flood Prone Areas	Report (CG State Disaster Management Plan 2019)	Revenue & Disaster Management Department, Govt. of CG
5	Secondary Data	Information regarding the conducted and planned drone surveys via. Google form (Questionnaire)	NIC, CHiPs, Revenue and Disaster Mgmt. Dept., Forest Dept. Etc.

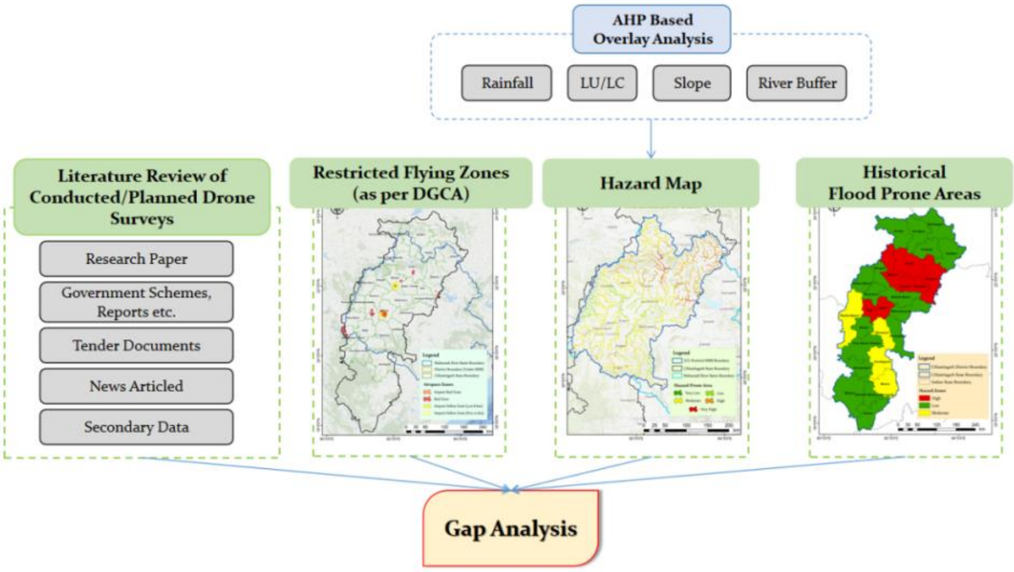


Figure 2: Methodology adopted for Gap Analysis

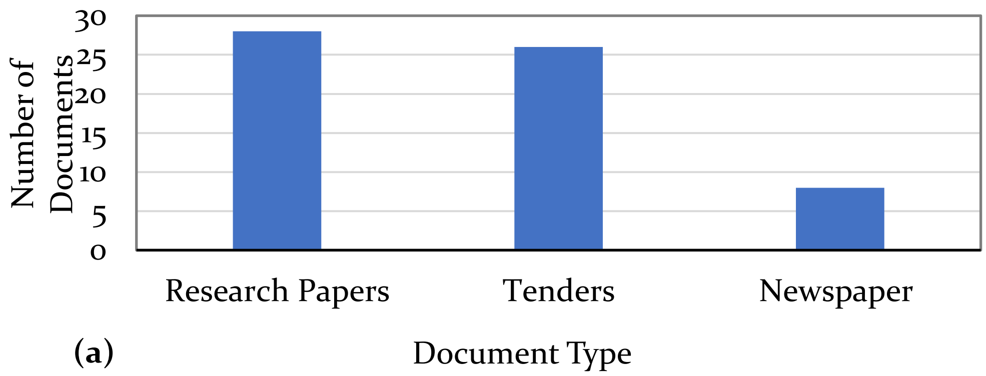
4. Review of Drone Survey over Mahanadi River Basin

Newspapers, research articles, and government tenders have extensively covered the aerial and drone surveys over the Mahanadi River Basin, highlighting their critical role in regional development and environmental management as shown in Figure 3. These surveys have significantly contributed to understanding the basin's complex topography, hydrology, and land use (Table 1 & 2 of Appendix.). Hence, the overall aerial and drone surveys over the Mahanadi River Basin are vital to sustainable development, offering insights that drive informed decision-making and effective resource management.

4.1 Summary of Existing Drone/UAV/Aerial Survey

Government Schemes/Reports -The Chhattisgarh Government's Revenue Department, under the Svamitva Scheme, has initiated a drone-based survey to map populated rural areas and issue land ownership certificates to residents. The survey is being conducted across various districts, including Raigarh, Korba, Mahasamund, Balod, and Dallirajhara. The initiative aims to create digital maps of populated lands, aiding in the distribution of leases and providing legal documentation to property owners. Additionally, the project addresses environmental concerns by monitoring tiger corridors and detecting land and water changes to combat encroachment and enhance anti-poaching efforts. The total project cost is Rs 285,000. High-resolution imagery from the drone surveys will be accessible to the public, supporting further land management and conservation activities.

Research Paper - Majorly the use of RGB drone surveys by institutions like NIT Raipur, IGKV Raipur, IIT Kanpur, ICAR New Delhi, and others for various environmental and agricultural research applications is found. These drones are used for air pollutant monitoring, soil moisture determination, optimal crop planning, and the rejuvenation of small rivers. UAVs have proven effective in detecting vertical and horizontal air pollution, measuring soil moisture content, and estimating groundwater recharge potential. In agriculture, drones are employed for tasks like farm surveying, mapping plantation crops, spraying agrochemicals, and calculating field areas, resulting in a 25-30% reduction in production costs through early pest detection and precise spraying. Drones also play a crucial role in monitoring containment zones during curfews, maintaining social distancing, and enforcing restrictions. The integration of technologies like LiDAR and thermal imaging enhances the accuracy and efficiency of these operations. Additionally, drones can automate much of the farming process, including seeding, fertilizing, and harvesting, allowing for more precise and efficient agricultural management.



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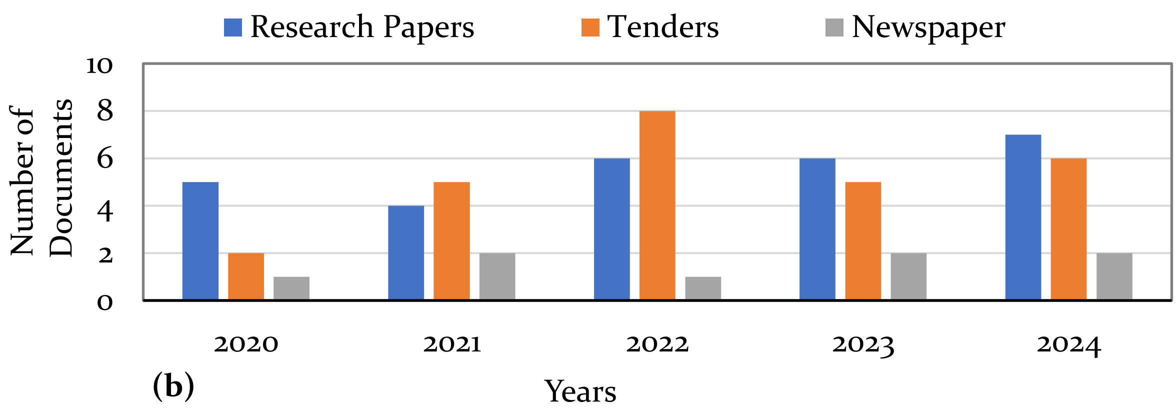

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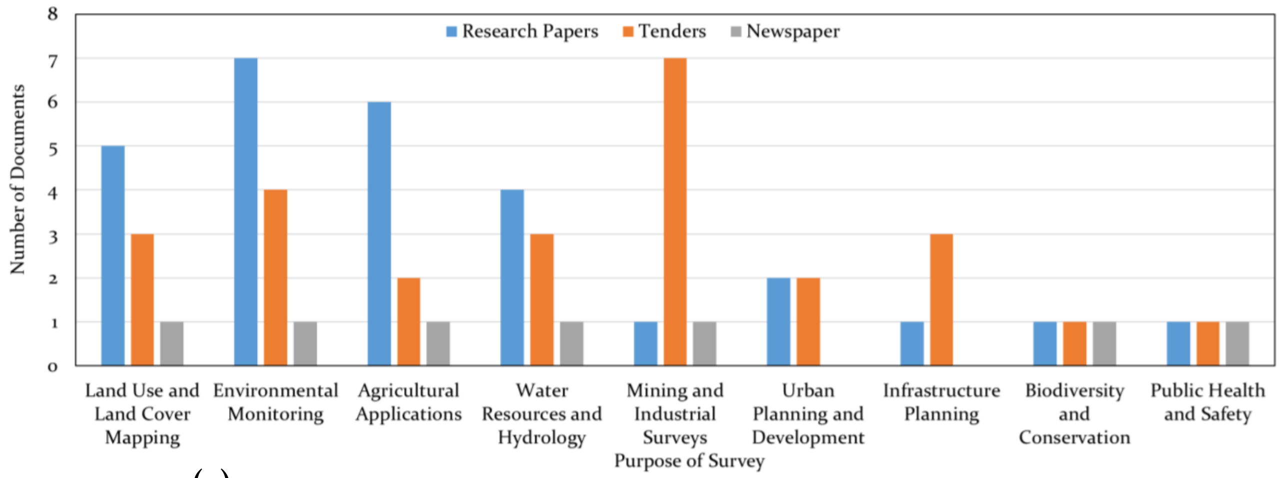


(c)

Figure 3: Graphical representation of (a) Number of Documents Found by Source Type (Tender, Research Paper, News Articles), (b) Yearly Distribution of Documents by Source Type, and (c) Number of Documents Found by Source Type Across Different Application Field

Tender Documents - Outlines the involvement of Raipur Smart City Limited (RSCL), Chhattisgarh Mineral Development Corporation Limited, the Department of Forest and Climate Change, Chhattisgarh State Power Generation Company, and other agencies in various drone-based surveys in Chhattisgarh. The surveys aim to aid mining activities, map forest areas, and conduct topographical and contour surveys for the proposed 2x660 MW Thermal Power Plant at Korba West. The drone (UAV) surveys are intended to create a detailed base map covering properties, road networks, water bodies, and tree census within the Raipur Municipal Corporation's jurisdiction, assist in property tax assessment, and manage assets. The surveys also cover additional mineral blocks and forest boundaries, with the flight path including a range of infrastructure elements such as canals, ponds, roads, buildings, and electrical lines, ensuring thorough coverage of the areas surveyed.

The Word Cloud shown in the Figure 4illustrates the wide-ranging applications of drone surveys in Chhattisgarh, emphasizing their significance across multiple sectors. In land management, drones are instrumental in creating digital maps, conducting GIS-based surveys, and mapping populated areas. These activities help combat encroachment, enhance anti-poaching efforts, and support accurate property rights documentation for village owners through Records of Rights.

Figure 4. Word cloud presenting prominent features of drone survey.

In agriculture, drones facilitate smart farming by surveying farms, mapping plantation crops, and geo-tagging fields. They are also used for spraying agro-chemicals, optimizing crop planning, and calculating agricultural field areas. Additionally, drones play a critical role in soil moisture determination and monitoring, ensuring efficient water use and improved crop yields.

The Word Cloud also highlights specialized uses of drones in mining-related activities, aerial monitoring of containment areas, and rejuvenating small rivers. Overall, it captures the diverse and impactful roles of drone surveys in enhancing governance, agriculture, and environmental management.

5. Gap Analysis

This section presents a comprehensive analysis aimed at identifying key hotspots for detailed aerial or drone surveys within the Mahanadi River Basin. By employing an Analytical Hierarchy Process (AHP)based overlay analysis, the study integrates various data layers such as LULC, river buffers, rainfall, and slope data to categorize the region into five distinct hazard zones. These zones are crucial for prioritizing drone surveys, specifically for the areas identified as having high hazard levels.

In addition to current data, historical or observed hazard-prone areas, particularly flood-affected zones, are also considered. This approach ensures that both historically vulnerable areas and high-risk zones identified through the Geospatial analysis are covered. Detailed district-wise information is provided, focusing on rivers in Chhattisgarh that are particularly susceptible to flooding. Special attention is given to urban areas affected by floods, as outlined in the CG State Disaster Management Plan, 2019.

5.1 Hazard Mapping using Overlay Analysis

The Analytical Hierarchy Process (AHP) was employed to determine hazard-prone areas in the Mahanadi River Basin (Chhattisgarh) for the purpose of proposing a drone survey. The analysis categorized the region into five hazard zones: Very Low, Low, Moderate, High, and Very High. The methodology involved the following steps:

Criteria Selection and Rating Assignment

Four key criteria were selected for the hazard-prone area mapping: Land Use Land Cover (LULC), River Buffer, Rainfall, and Slope. Each criterion was divided into sub-categories, and a rating was assigned based on the level of hazard associated with each sub-category as shown in Table 3 of Appendix.

The ratings have been done between 1 to 5. When we consider LULC, highest ratings were assigned to water bodies and built-up areas as they are linked to causing floods in most regions. For rainfall, the region with highest rainfall was assigned the highest rating while classifying the annual rainfall variability map. In case of slope analysis, the regions with higher slope ,though do not have much effect on flooding, but it might cause other hazards like

Landslide and gully erosions. To further study the probable regions of flood around rivers, river buffer was done, and the buffer regions are assigned the highest ratings.

Weight Assignment for Criteria

The relative importance of each criterion in the hazard analysis was determined through weight assignment. The weightages were calculated based on the significance of each criterion in contributing to the overall hazard risk as shown in Table 3 of Appendix.

AHP-Based Pairwise Comparison

A pairwise comparison matrix was developed using the assigned ratings and weightages. The matrix was used to calculate the normalized weights for each criterion, ensuring that the combined weight of all criteria equals 100%. This step involved consistency checks to ensure reliable results.

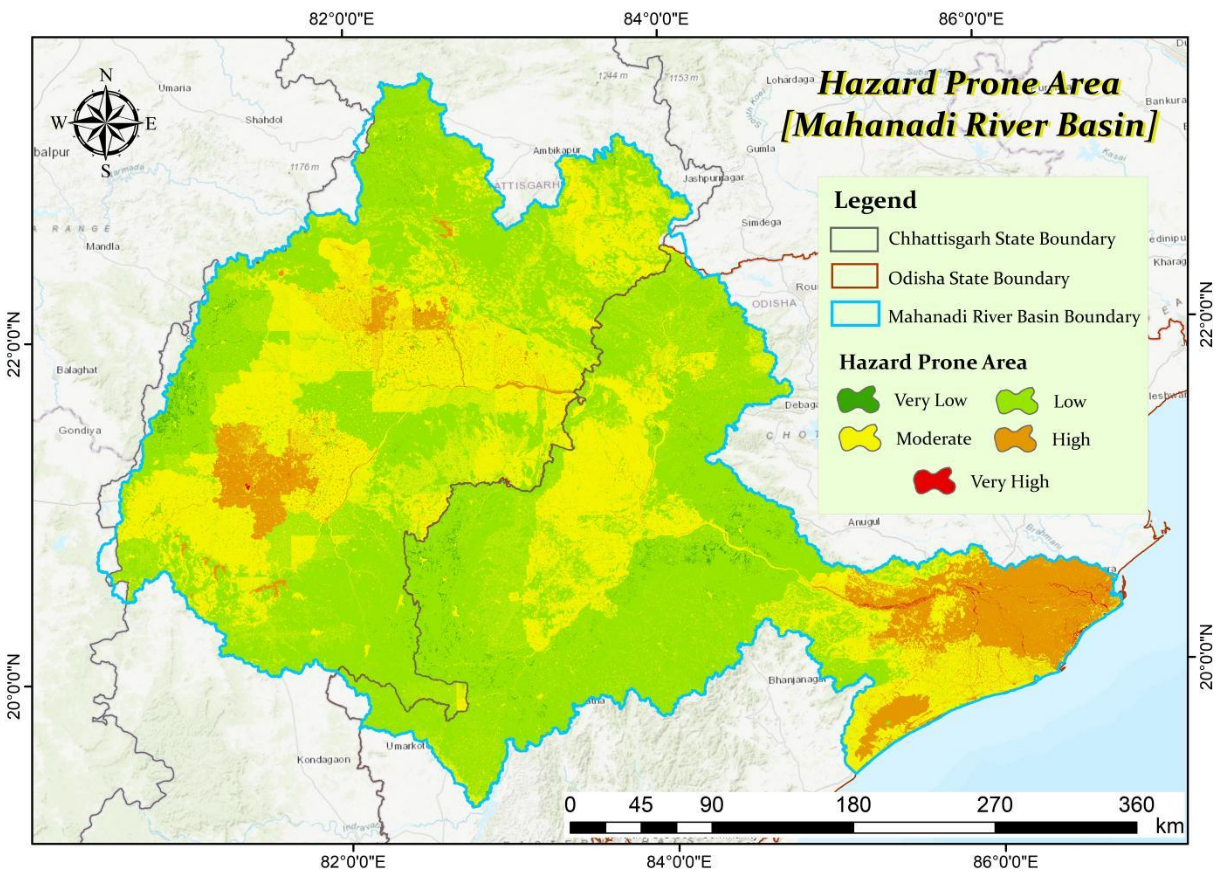


Figure 5: Hazard Prone Area Map for Mahanadi River Basin

Composite Hazard Index Calculation

A composite hazard index was computed by overlaying the weighted criteria layers. Each grid cell in the study area was assigned a hazard score based on the weighted sum of its ratings across all criteria.

Hazard Zone Classification

The calculated hazard index was used to classify the study area into five hazard zones: Very Low Hazard Zone, Low Hazard Zone, Moderate Hazard Zone, High Hazard Zone, and Very High Hazard Zone as shown in Figure 5.

Prioritized Drone Survey

Based on the classified hazard zones, a targeted drone survey plan can be proposed along with the other historical river caused Hazard Hotspot area identification. The focus of the survey will be on areas identified as High and Very High hazard zones to conduct detailed assessments and management strategies for the Mahanadi River Basin. This systematic approach ensures that the most vulnerable areas are identified and prioritized for intervention, enabling more efficient and effective disaster management planning under the Mahanadi River Basin.

5.2 Historical Hazard Prone Areas

Chhattisgarh

In the context of flood vulnerability, certain regions within Chhattisgarh are identified as highly susceptible to disasters, particularly flooding. The State Disaster Management Plan (SDMP) provides a detailed analysis of these areas. Table 3 highlights the rivers across various districts that are prone to flooding, along with the number of affected villages. Key districts include Sukma, Jagdalpur, Narayanpur, Bijapur, Dantewada, Kanker, Surajpur, Raipur, Gariyaband, Dhamtari, Balodabazar, Durg, Balod, Bemetara, and Rajnandgaon. Among these, Bijapur and Balodabazar stand out with the highest numbers of affected villages, indicating critical zones for targeted aerial surveys.

Furthermore, the urban flooding has become a growing concern in rapidly urbanizing districts such as Raipur, Dhamtari, Durg, Rajnandgaon, Bilaspur, Mungeli, Janjgir-Champa, Raigarh, and Bastar as shown in Table 4.

Table 3: Rivers of the CG state which Susceptible to Flooding
(Source: CG State Disaster Management Plan 2019)

S. No.	District	Tehsil	River	Total No. of Village
1	Sukma	Sukma, Chhindgarh, Konta	Shabri river	50
2	Jagdalpur	Jagdalpur, Lohandhiguda, Bastar, Bakawand	Indrawati, Narangi river	37
3	Narayanpur	Narayanpur	Kukur river, Orchha river	14
4	Bijapur	Bijapur, Bhopalpatnam Bhairamgarh	Mingachal river, Irandravati river, Chintabagu river, Godavari river, Marahi river, Berudi river, Talperu river	90
5	Dantewada	Gidam, Dantewada	Indravati, Sankini, Dankini river	17
6	Kanker	Kanker, Narharpur, Charama, Bhanupratappur Pankhajur, Antagad, Durgukondal	Dudh River, Mahanadi, Khandi River, Kotari River, Mendhaki River	79
7	Surajpur	Premnagar, Surajpur Bhatgaon, Bhaiyathan, Pratappur, Odhgi	Atem, Gej, Hasdeo, Rend River, Mahan River, Baanki River, Andhruva River	64
8	Raipur	Raipur, Arang, Abhanpur, Tilda	Kharun River, Mahanadi	69
9	Gariyaband	Gariyaband, Rajim, Chhura, Mainpur, Devbhog	Pairi River, Sondhur River, Mahanadi	39
10	Dhamtari	Dhamtari, Kurud, Magarlod, Nagari	Mahanadi, Jonk River,	77

11	Balodabazar	Kasdol, Simga, Bilayigarh, Baloda bazaar, Palari, Bhatapara, Simga	Jonk river, Mahanadi, Shivnath river	101
12	Durg	Durg, Dhamdha, Patan	Shivnath river, Tandula reservoir, Amner river, Kharun river	92
13	Balod	Balod	Tandula river	3
14	Bemetara	Bemetara, Navagarh, Berla, Saza, Thankhamharia	Shivnath river, Haaf river, Kharun river	110
15	Rajnandgaon	Rajnandgaon, Ambagarh chowki, Khairagarh, Chhuria, Dongargaon, Mohala	Shivnath river, Bhanpuri river, Amner river, Muskaan river	75

In these areas, drainage failures, overwhelmed stormwater systems, and inadequate sewerage management have exacerbated flood risks, impacting numerous municipal wards. For instance, Raipur, Bilaspur, and Raigarh municipalities have multiple flood-affected wards, making them prime candidates for detailed drone surveys to assess and mitigate flood risks.

This district-wise identification of flood-prone areas provides a strategic foundation for conducting targeted aerial and drone surveys, enabling more focused and effective flood risk management interventions across Chhattisgarh.

Table 4:CG State's Urban Flood Affected Areas under Mahanadi Basin
(Source: CG State Disaster Management Plan 2019)

S.No.	Name of District	Flood Affected Area	Flood Affected Ward
1	Raipur	Municipal Corporation Raipur	26, 27

		Municipal Corporation Birgaon	20, 21, 34, 36
2	Balodabazar	Municipality Balodabazar	10
		Nagar Panchayat Simga	1, 2, 15
3	Dhamtari	Nagar Panchayat Kurud	8, 10
4	Mahasamund	Nagar Panchayat Pithaura	3, 5, 8, 12
5	Durg	Municipal Corporation Durg	55 Phoolgaon, 36
			Ganjpara, 54 Potiya
		Municipality Kumhari	16 Parsada, 13 Area on the banks of the Kharun River on the Ganganagar
6	Rajnandgaon	Municipal Corporation Rajnandgaon	47, Mohara and 50 Singdai
		Municipality Khairagarh	Ward 03 Ganji Para, 04 Raj Family, 05 Thakur Para, 09 Itavari Bazar, 16 Dau Chaira, 18 Ambedkar
7	Bilaspur	Municipal Corporation Bilaspur	9, 34, 35, 36, 43
		Municipality Takhatpur	4, 5, 9,12, 13
		Nagar Panchayat Kota	5,13
8	Mungeli	Municipality Mungeli	Tilak Ward, Androj Ward
		Nagar Panchayat Lorami	4, 6,14,15
9	Janjgir-Champa	Municipality Champa	1, 2, 39, 10
		Nagar Panchayat Kharaud	1, 3, 4, 9, 15,
		Nagar Panchayat Shivrinarayan	1, 2, 3, 4, 9, 12,13,14,15
		Nagar Panchayat Chandrapur	1, 2, 3, 4, 5, 14, 15
10	Raigarh	Municipal Corporation Raigarh	4, 5, 6, 19, 24, 25
11	Bastar	Municipal Corporation Jagdalpur	Praveer 01, Vijay 02, Shiv Temple 03, Bhairamdev 04, Veerasavarkar 05, Bhagat Singh 06, Chandrashekhar Azad 41, Shyamaprasad Mukherjee 39, Vallabh Bhai Patel 46, Lal Bahadur Shastri 08
12	Kanker	Municipality Kanker	Bhandaripara 10, Mahadev ward no. 11, Subhash 13, MG 15, Rajpara 21

		Nagar Panchayat Antagarh	Maharani Laxmi bai 09, Devni Dokari 12, Chandra Shekhar 14, Indira Gandhi 15
		Nagar Panchayat Pakhanjur	Subhash Chandra Bose 07, Dr. Bhim Rao Ambedkar 15
		Nagar Panchayat Charama	Mahatma Gandhi 13 Pt. Jawaharlal Nehru 01

Table 5: District wise Hazard Analysis Summary of Chhattisgarh

(Source: CG State Disaster Management Plan 2019)

District wise Hazard Analysis Summary of Chhattisgarh							
S.No.	**District Name**	**Flood**	**Drought**	**Lightning**	**MAH Units(industrial)**	**Accident**	**Over all Hazards**
1	Raipur	High	Moderate	Low	High	High	High
2	Dhamatri	High	Moderate	Low	Low	Low	Moderate
3	Durg	Moderate	Moderate	Moderate	Moderate	High	High
4	Rajnanadgaon	High	Moderate	Moderate	Low	Moderate	Moderate
5	Mahasamund	Low	Moderate	High	Low	Low	Low
6	Balod	Moderate	Moderate	Low	Low	Low	Low
7	Baloda bazar	Moderate	High	Low	Low	Moderate	Low
8	Sukma	High	Moderate	Moderate	Low	Low	Low
9	Dantewada	Moderate	Low	Moderate	Low	Low	Low
10	Narayanpur	Low	Moderate	Low	Low	Low	Low
11	Kondagaon	Low	Moderate	Low	Low	Low	Moderate
12	Kanker	Moderate	Moderate	High	Low	Low	Low
13	Jagdalpur	High	Low	High	Low	Low	Moderate
14	Bijapur	Moderate	Moderate	Moderate	Low	Low	Low
15	Kabirdham	Low	High	Low	Low	Low	Low
16	Bilaspur	Low	Moderate	Low	Low	High	High
17	Korba	High	Moderate	High	Low	Low	High
18	Janjgir-Champa	Moderate	Moderate	Low	Low	Moderate	High
19	Jashpur	Low	Moderate	Moderate	Low	Low	Low
20	Sarguja	Low	Low	Moderate	Low	Low	Low
21	Korea	Low	Moderate	Moderate	Low	Low	Low
22	Surajapur	Moderate	Low	Moderate	Low	Moderate	Low
23	Balrampur	Low	Low	Moderate	Low	Low	Low
24	Raigarh	Low	Moderate	High	Low	High	High
25	Mungeli	Low	High	Low	Low	Low	Low
26	Gariyaband	Moderate	Moderate	Moderate	Low	Low	Low
27	Bemetara	Moderate	High	Low	Low	Low	Low

The District-wise Hazard Analysis Summary as shown in Table 5 and Figure 6 for Chhattisgarh highlights varying levels of risk across different districts. Raipur, Durg, and Korba face high overall hazards due to a combination of flood, industrial (MAH Units), and accident risks. Districts like Dhamtari and Rajnandgaon have moderate overall hazards, while districts like Mahasamund and Mungeli face lower overall risks.

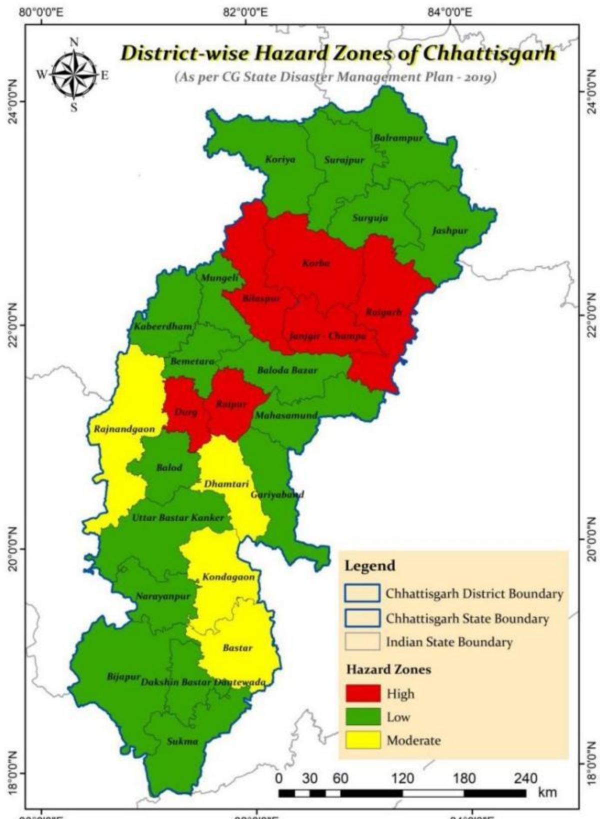


Figure 6: District-wise Hazard Zones of Chhattisgarh

Odisha

Odisha has been affected by nearly 35% of all the cyclonic and severe cyclonic storms that have crossed the eastern coast and associated storm surges that have often inundated large tracts of the coastal districts. Similarly, the Mahanadi and her tributaries have the potential to cause very severe floods. Odisha has 10 other major river systems which cause flood in regular intervals. Out of a total geographical area of 15, 571 lakh hectares, 1.40 lakh hectares are very flood prone. The State is also vulnerable to flash floods and landslides. The frequency, intensity and extent of droughts in the State are gradually on the rise. This is leading to crop failure, decline in surface and groundwater level, increasing unemployment and under-employment, migration and indebtedness. Drought is particularly frequent and severe in the Western districts of the State.

Table 6: % Area Prone to hazard in Odisha portion of the MRB (Source: Vulnerability Atlas of India, 1997)

Type of hazard	Particulars	% of area Vulnerable
Flood	Flood Prone	1.9 %
	Flood Protected	2.4 %
	Outside Flood Area	95.7 %
Cyclone	198-180 km/h	24.1%
	169.2 km/h	3.3 %
	158.140.9 km/h	72.6 %
Earthquake	Low damage risk zone	84.2 %
	Moderate damage risk Zone	15.8 %

The table below indicates the occurrence of major disaster in the Odisha state during last 20 years.

Table 7: Types of Occurrences of hazard in Odisha portion of the MRB (Source: Office of the Special Relief Commissioner)

Year	Calamity
1996	Drought
1997	Drought
1998	Drought, Heat Wave
1999	Super Cyclone
2000	Drought
2001	Floods
2002	Drought
2003	Floods
2004	Floods
2005	Floods
2006	Floods
2007	Floods (July, August, Sept)
2008	Floods (June & September)
2009	Flood & Heavy rain, Drought
2010	Flood & Heavy rain, Drought, Unusual cyclic rain

2011	Drought & Flood
2012	Drought & Flood
2013	Very severe Cyclonic Storm, Flood
2014	Very severe Cyclonic Storm
2015	Drought, Flood and Heavy rain

5.3 Proposed area for Aerial/Drone survey

Based on the prepared hazard map and flood-prone areas identified from the Chhattisgarh State Disaster Management Plan (SDMP) 2019, certain regions have been prioritized for river condition assessment under the Mahanadi Basin project. Additionally, restricted flying zones, as per the DGCA Drone Rules 2021, have been taken into consideration while planning the aerial surveys.

The areas identified for the river condition assessment task have been selected based on their susceptibility to flooding, pollution from industrial discharge, and other environmental hazards as shown in Figure 7.

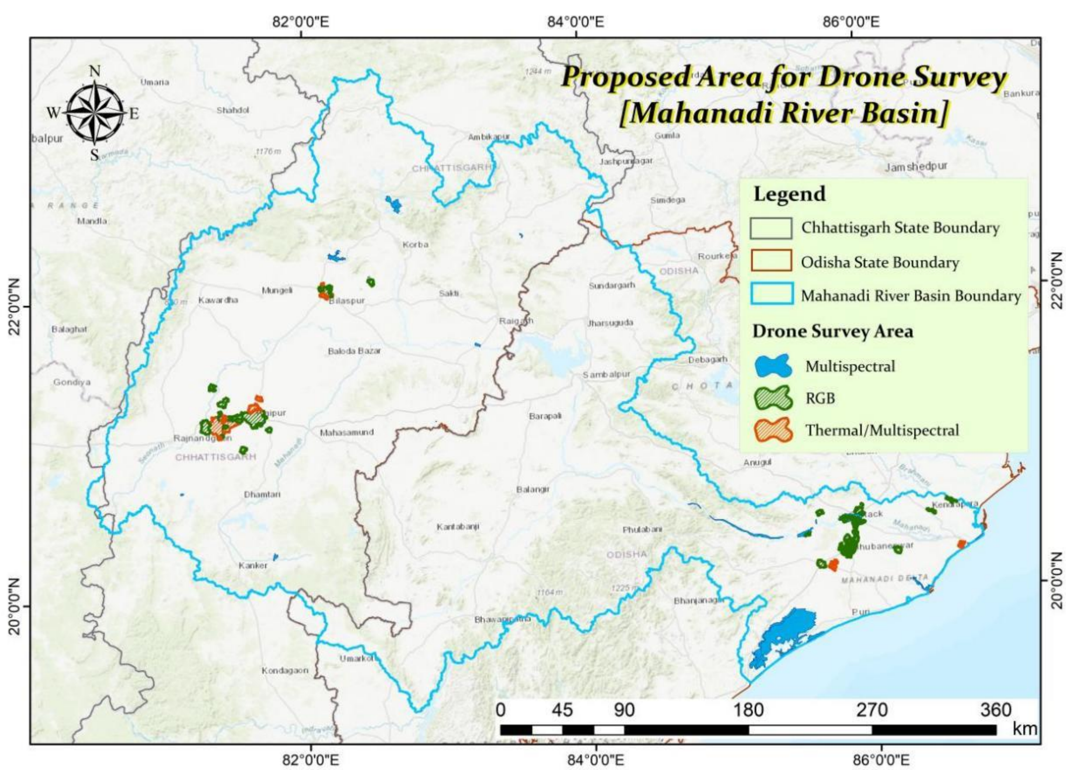


Figure 7: Proposed area for drone survey under MRB

The specific types of sensors/technology, along with their spatial coverage and unit costs for the proposed survey area, are outlined in Table 8.

Table 8: Details of Proposed Aerial/Drone Survey

Type of Technology	Purpose	Spatial Coverage (Area_Km2)		Unit Cost (Rs/Km²)	Total Cost
		Chhattisgarh	Odisha		
RGB	Land Cover and Floodplain Mapping	111.48	961.76	3000/- +GST	3,219,720
Multispectral	Water Quality Assessment and Studies	413.87	314.97	4500/- +GST	3,279,780
Thermal/Multispectral	Industrial Pollution Monitoring and Analysis	257.22	39.06	5000/- +GST	1,481,400
Total		782.57	1315.79		7,980,900

6. Observations and Recommendations

Observation over the MRB covering Chhattisgarh state

Flood-Prone Areas in Chhattisgarh: In Chhattisgarh, districts such as Raipur, Bilaspur, Janjgir-Champa, Raigarh, Durg, and Mahasamund located in the Mahanadi basin are particularly vulnerable to flooding during the monsoon season. The Mahanadi River and its tributaries, like the Seonath, Hasdeo, and Jonk, tend to swell, impacting villages and towns in close proximity to the river. This flooding is exacerbated by rapid water discharge from upstream regions during heavy rains.

Changes in Land Use and Land Cover (LULC): Over the past few decades, Chhattisgarh has experienced significant changes in land use and land cover due to industrialization, mining, urban expansion, and agricultural intensification. These changes have led to encroachment into floodplains and increased vulnerability to floods. The expansion of coal mining activities in districts such as Korba and Raigarh has led to the degradation of catchment areas, exacerbating erosion and siltation in the river.

Poor River Basin Management: The current river basin management practices in Chhattisgarh, particularly in terms of flood control and siltation, are inadequate. Embankments in certain regions are either poorly maintained or insufficient to manage the floodwaters during peak monsoon seasons. With increasing urban development along riverbanks, the risk of riverbank erosion and embankment breaches is high.

Need for Updated Survey Data: Traditional surveying methods have been insufficient to provide real-time, high-resolution data on the river's health and flood management issues. As a result, there is a significant gap in up-to-date data on sediment load, river morphology, floodplain encroachment, and siltation in the Mahanadi and its tributaries in Chhattisgarh and Odisha.

Observation over the MRB covering Odisha state

The Mahanadi and its tributaries tend to swell up in Sambalpur, Jharsuguda, Deogarh, Bargarh, Angul, Boudh, Subarnapur, Bolangir, Nuapada, Kalahandi, Cuttack, Kendrapara and

Jagatsinghpur districts during monsson seasons causing flood in villages close to river proximity.

Moreover, the coastal plains are very flat, the slopes in the inlands are precipitous. This leads to heavy siltation, flash floods and poor discharge of flood waters into the sea and thus the embankments are breached with alarming frequency.

Besides, when we consider the changes in LULC from past decades, the change is quite drastic. The high population densities in the flood-prone coastal and delta regions, increased encroachment in the flood plains because of comparatively better livelihood opportunities and development have triggered urban flooding ultimately becoming one of the most important contributors to the increased vulnerability to flood in the basin.

Recommendations

Floodplain Encroachment Monitoring: Utilize drone imagery to monitor and map changes in land use and land cover, particularly in flood-prone areas. Drone surveys can track urbanization and encroachment into the floodplains, providing data to inform decisions on zoning regulations and urban planning to reduce flood vulnerability. These surveys can also detect illegal construction or encroachment along riverbanks.

Embankment Monitoring and Maintenance: Drone technology can be utilized to regularly inspect the integrity of embankments and flood protection structures in vulnerable districts. This would enable authorities to identify weak points or damage that needs urgent attention. A comprehensive mapping of these structures will help prioritize areas for strengthening or reconstruction.

Enhance Flood Management Practices: By integrating drone-collected data with hydrological models, authorities can develop better flood prediction models for Chhattisgarh. These models can provide early warnings for downstream areas and help mitigate the risk of flash floods and embankment breaches. Improved flood management practices will ensure that water release schedules from dams like the Hasdeo Bango and Hirakud (shared with Odisha) are better regulated to prevent flooding downstream.

Catchment Area Conservation: Drone surveys can be instrumental in monitoring the condition of the upper catchment areas in Chhattisgarh, particularly in the Maikal Hills region.

This would provide insights into deforestation, soil erosion, and land degradation. Based on the survey results, catchment area treatment plans such as reforestation or soil conservation measures can be initiated to reduce runoff and sediment flow into the Mahanadi basin.

Siltation and Sediment Flow Assessment: Drones should be used to assess the levels of siltation in river channels, dams, and reservoirs in Chhattisgarh. This will help authorities gauge the sediment load and identify critical points where dredging or river channel restoration is required. Additionally, drone surveys can assist in studying the sediment flow patterns from mining areas such as Korba, which contribute significantly to river siltation.

6.1 Approximate Cost of Data Acquisition.

This section provides an estimated breakdown of the costs associated with acquiring drone survey data for the proposed drone survey.

Table 9: Financial Overview/ Price Estimates for Drone Survey

<table>
<tr><th rowspan="2">S. No.</th><th rowspan="2">Type of data processing</th><th rowspan="2">Specific data</th><th>Rate per sq. km</th><th>Rate per sq. km</th><th>Rate per sq. km</th></tr>
<tr><th>x Company</th><th>y Company</th><th>z Company</th></tr>
<tr><td>1.</td><td>DEM Creation:</td><td>DEM Creation: Generating Digital Elevation Models (DEMs) from classified point clouds to represent the terrain.</td><td>2500 + 18% GST</td><td>3000+ 18% GST</td><td rowspan="4">Rs. 59,280/-</td></tr>
<tr><td>2.</td><td>DSM Creation:</td><td>DSM Creation: Creating Digital Surface Models (DSMs) to capture the surface of objects (e.g., buildings, vegetation) above the ground.</td><td>2000 + 18% GST</td><td>3000+ 18% GST</td></tr>
<tr><td>3.</td><td>Contour Generation:</td><td>Contour Generation: Producing contour lines from DEMs for topographic analysis.</td><td>1000 +18% GST</td><td>-</td></tr>
<tr><td>4.</td><td>Topographical Survey DGPS and Drone with centimeter accuracy. (For more than 100 SQKM km)</td><td>• Orthomosaic
• Dense Point Cloud (. laz/.las)
• RSME Report
• 3D Surface Model
• GIS-Based Map / .dwg
• Shape File / KML File
• GCP CSV Data with Both Projections (GCS & PCS)</td><td>-</td><td>-</td></tr>
<tr><td>5.</td><td>Point Cloud Data (LiDAR)</td><td>Point Cloud Classification: Distinguishing different types of points (e.g., ground, vegetation, buildings) to improve the accuracy of subsequent analyses.</td><td>7000 + 18% GST</td><td>-</td><td>Rs. 4,19,900</td></tr>
</table>

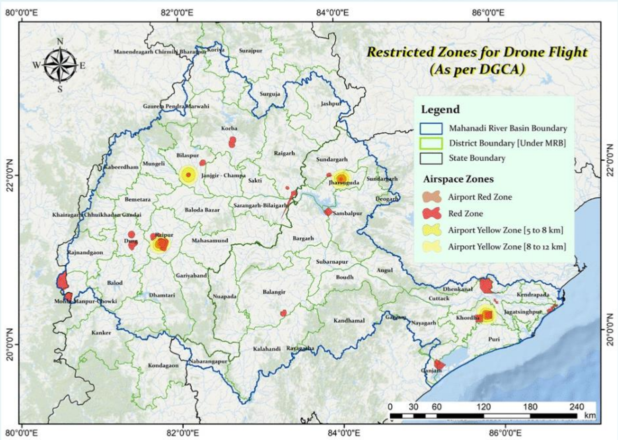
6.	**Feature Extraction Object Detection:**	**Object Detection:** Identifying and classifying objects such as buildings, roads, and vegetation from LiDAR or photogrammetric data. Change Detection: Analyzing temporal changes in the landscape by comparing current data with historical datasets. Topographic Analysis: Identifying landforms, slopes, and drainage patterns for environmental and planning purposes.	5000 +18% GST	4000+ 18% GST	
7.	**GIS Integration**	**Georeferencing:** Aligning drone and LiDAR data with spatial reference systems to ensure proper location accuracy. Spatial Analysis: Performing operations like buffering, overlay analysis, and proximity analysis to derive insights from geospatial data. Data Visualization: Creating maps, charts, and other visual aids to effectively communicate findings.	5000 + 18% GST	4000+ 18% GST	
8.	**Lidar Survey**	• DTM/ DEM/ DSM • Tile Photos • RSME Report • Contour • 3D Surface Model	-	-	
9.	**Thematic Mapping Land Use/Cover Mapping:**	Identifying and classifying land use or land cover types based on remote sensing data. Vegetation Analysis: Assessing vegetation health, density, and distribution using spectral and LiDAR data. Understanding these types of GIS processing tasks can help you effectively scope out and execute drone and LiDAR mapping projects. Each type of data and processing method contributes to a comprehensive understanding of the surveyed area, aiding in decision-making for planning, analysis, and management.	4000 + 18% GST	4000+ 18% GST	-
10.	**Data Management and Quality Control**	Removing noise and erroneous data points from LiDAR point clouds or imagery. Data Fusion: Combining data	5000 + 18% GST	4000+ 18% GST	-

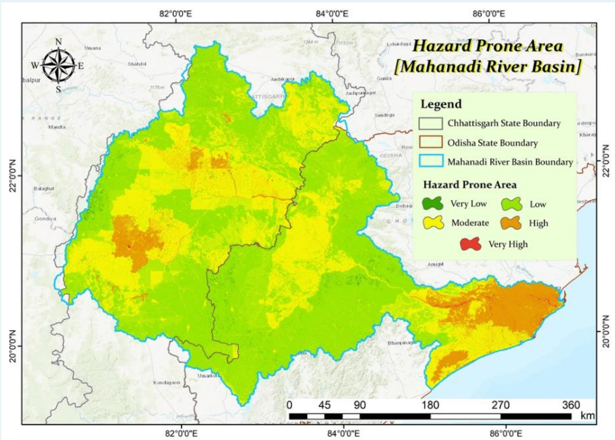
	Data Cleaning:	from multiple sources (e.g., different drone flights or sensors) to create a comprehensive dataset. Metadata Management: Ensuring that all data is properly documented with metadata for future reference and use			
11.	**Data Acquisition**	with PPK VTOL	-	7000+ 18% GST	-
12.		with PPK Multirotor	-	5000+ 18% GST	-

Note: The Rate provided by Y company is for a Topographical Survey using DGPS and Drone with centimetre accuracy (For more than 100 SQKM).

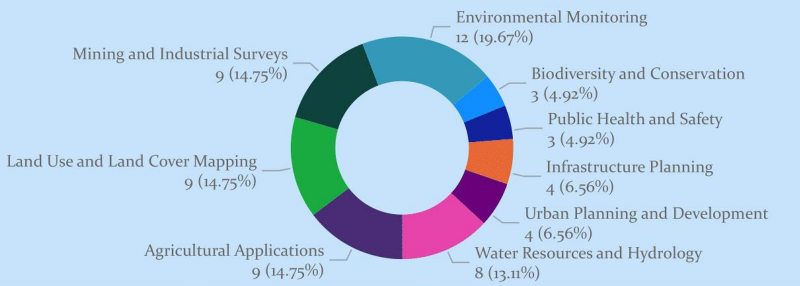
7. Graphical Summary

Glimpse of Aerial/ drone surveys, Aerial photographs over MRB

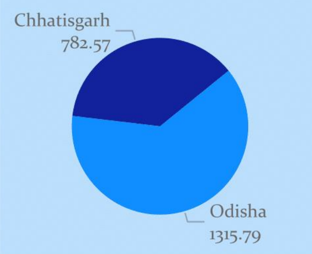




Purpose of Existing Survey



Propsed Area to be Surveyed [Sq. Km]

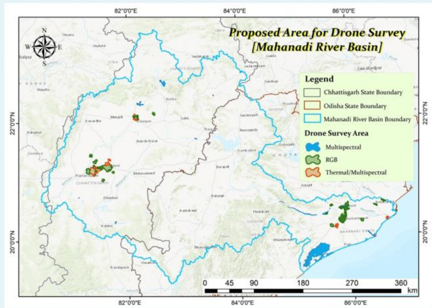


Summary

- This summary provides an overview of completed and ongoing aerial/drone surveys in the Mahanadi River Basin (MRB), covering 52.65% of the area in Chhattisgarh and 47.35% in Odisha. It details the costs and types of surveys (RGB, Thermal, Multispectral) conducted across various locations.
- These surveys serve multiple purposes, including land use, environmental monitoring, agriculture, water resources, mining, urban planning, infrastructure, biodiversity, and public health.
- The proposed survey will cover 782.57 sq. km in Chhattisgarh and 1,315.79 sq. km in Odisha, focusing on land cover and floodplain mapping, water quality assessments, and industrial pollution monitoring, with an estimated cost of ₹7,980,900 (₹34,82,955 in Chhattisgarh and ₹44,97,945 in Odisha)

Approximate cost of Proposed Aerial/Drone Survey

Type of Technology	Purpose	Area [Sq. Km]	Unit Cost [Rs]	Total Cost [Rs]
Thermal/Multi spectral	Industrial Pollution Monitoring and Analysis	296.28	5000/-+GST	1481400
RGB	Land Cover and Floodplain Mapping	1073.24	3000/-+GST	3219720
Multispectral	Water Quality Assessment and Studies	728.84	4500/-+GST	3279780
			Grand Total	7980900



*Mentioned estimates for the drone survey are based on quotations received from multiple companies (as mentioned in section 6.1).

Figure 8: Status of Aerial/ Drone Surveys & Aerial photographs in Mahanadi River Basin

8. Conclusion

The previous drone surveys conducted by various agencies, departments, and institutes over the Mahanadi River Basin have provided valuable insights into the river's health and surrounding environment. However, gaps in coverage remain, especially in critical areas that were not surveyed in sufficient detail, limiting a comprehensive assessment of the river's condition. These gaps affect understanding of water quality, erosion patterns, and biodiversity impacts. Among previous surveys, the SVAMITVA Scheme (Survey of Villages Abadi and Mapping with Improvised Technology in Village Areas), funded by the Ministry of Panchayati Raj and executed by the Chhattisgarh Geospatial Data Centre, Survey of India, successfully covered 15,794 notified villages in Chhattisgarh. Each village, mostly within the Mahanadi Basin, had an average of 0.25 square kilometres surveyed (Abadi Bhoomi), totalling an approximate survey area of 3,948.5 sq. km.

The proposed area for the Aerial/Drone survey includes regions identified through the hazard map and historical flood-prone areas, while also accounting for restricted flying zones as per the DGCA Drone Rules 2021. The proposed survey will cover 782.57 sq. km in Chhattisgarh and 1,315.79 sq. km in Odisha, with an estimated cost of ₹7,980,900 (₹34,82,955 in Chhattisgarh and ₹44,97,945 in Odisha). The areas identified for the river condition assessment task have been selected based on their susceptibility to flooding, pollution from industrial discharge, and other environmental hazards.

Future aerial and drone surveys by the Chhattisgarh Geospatial Data Centre, Survey of India are planned for urban centers with populations between 50,000 and 100,000 in Chhattisgarh under the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) which is funded by the Ministry of Housing and Urban Affairs. This upcoming survey, along with previously gathered data, will significantly contribute to more accurate flood zonation, environmental analysis, and overall river basin management and effective planning.

Surveys in the study area have largely focused on rural regions, leaving gaps in urban zones and areas critical to assessing the river basin's health. Although upcoming surveys under various government schemes aim to cover urban areas are still pending. It is therefore recommended that the cMahanadi may conduct targeted Aerial/Drone surveys in the identified zones as needed to meet project objectives. This approach will close data gaps, enhance understanding of the Mahanadi Basin's environmental challenges, and support effective river health management for comprehensive project outcomes.

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- Environment and Forest Department, Government of Chhattisgarh
- Chhattisgarh Council of Science and Technology (CCOST)
- National Informatics Centre (NIC)

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