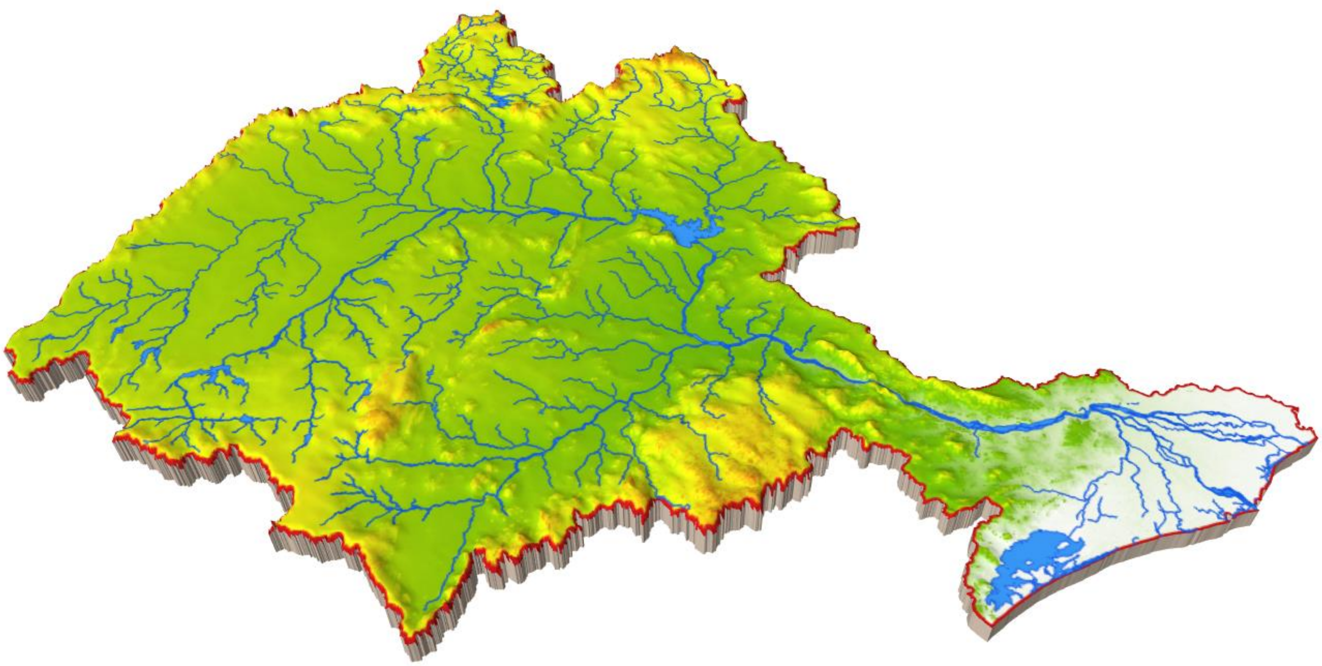
National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development & Ganga Rejuvenation
Government of India

Topographic Maps

Mahanadi River Basin



March 2025

Topographic Maps

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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.

www.nrcd.nic.in

Centres for Mahanadi River Basin Management Studies (cMahanadi)

The Centres 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

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 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.

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

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Abbreviations and Acronyms

ALOS PALSAR	Advanced Land Observing Satellite Phased Array type L-band Synthetic Aperture Radar
ASF	Alaska Satellite Facility
cMahanadi	Centre for Mahanadi River Basin Management and Studies
DAAC	Distributed Active Archive Center
DEM	Digital Elevation Model
GIS	Geographic Information System
GSI	Geological Survey of India
IIT	Indian Institute of Technology
JAXA	Japan Aerospace Exploration Agency
MRB	Mahanadi River Basin
NIT	National Institute of Technology
QGIS	Quantum Geographic Information System
SAGA GIS	System for Automated Geoscientific Analyses
SoI	Survey of India

1. Preamble

The Mahanadi River Basin, located in the eastern region of India, extends across the states of Chhattisgarh and Odisha and holds immense significance for water resource management, agriculture, ecology, and regional planning. Spanning a drainage area of approximately 141,600 square kilometers, the Mahanadi originates from the Sihawa Hills near Pharsiya village in Dhamtari district of Chhattisgarh at an elevation of about 442 meters above mean sea level. It traverses eastwards across diverse physiographic and climatic zones, ultimately discharging into the Bay of Bengal through an extensive deltaic network. The river covers around 851 kilometers in its course, with a substantial portion flowing through Odisha. The basin features a complex mix of mountainous terrains, rolling uplands, and expansive alluvial plains, making it a prime candidate for topographic and hydrological analysis. As the basin supports densely populated and agriculturally intensive regions, understanding the terrain's influence on water flow, flood dynamics, and land use is crucial for integrated river basin management. This report provides a systematic evaluation of the basin's topographic features using high-resolution Digital Elevation Models (DEMs) and GIS-based methods. Key parameters such as elevation, slope, aspect, flow direction, and terrain morphology are analyzed to support hydrological modeling, watershed prioritization, floodplain zoning, and infrastructure development. By leveraging open-access datasets and advanced spatial analysis tools, the study contributes to a scientific framework for informed decision-making and sustainable planning within the Mahanadi River Basin.

2. Data Acquisition and Methodology

Topographic characterization of the Mahanadi River Basin was conducted using two primary data sources: the ALOS PALSAR 12.5-meter Digital Elevation Model (DEM) and Survey of India (SoI) topographic sheets. The ALOS PALSAR DEM, developed by the Japan Aerospace Exploration Agency (JAXA), provides a high-resolution terrain dataset suitable for hydrological and geomorphological assessments. It was downloaded from the Alaska Satellite Facility (ASF) Distributed Active Archive Center (DAAC). The spatial resolution allows for capturing fine-scale topographic variations across the basin. SoI toposheets at 1:50,000 scale were used to validate elevation and drainage patterns. These maps offer critical ground-truth references and supplement remote sensing data with detailed contours, spot heights, and physiographic features. GIS tools such as ArcMap and QGIS were employed for data processing and spatial analysis. Standard workflows were used for generating slope, aspect, hillshade, and contour maps. The Flow Direction and Flow Accumulation functions within the ArcGIS Spatial Analyst toolbox were utilized to extract hydrological parameters, while SAGA GIS was used for terrain classification. Aspect maps were produced to understand slope orientation and solar exposure, which affect vegetation distribution and soil moisture. Hillshade visualization improved three-dimensional terrain interpretation, aiding in visual identification of landforms such as ridges and valleys. DEM-based contour lines at 100 m, 50 m and 10 m intervals were generated for regional and site-specific planning purposes. This methodological framework enabled the derivation of comprehensive topographic datasets, offering reliable spatial references for applications ranging from hydrological modeling to developmental zoning.

3. Topography of the basin

The Mahanadi River Basin displays a diverse range of topographic features that influence its hydrology, sediment transport, and land use dynamics. In the upper catchment within Chhattisgarh, the terrain is characterized by undulating plateaus and forest-covered hill ranges with elevations typically ranging from 300 to 1,000 meters above mean sea level. The region includes the Maikal Hills and Eastern Ghats outcrops that contribute to steep slopes and rapid surface runoff. As the river moves eastward, the topography flattens considerably, transitioning into wide floodplains and deltaic plains of Odisha. These low-gradient areas are interspersed with oxbow lakes, abandoned channels, and natural levees.

3.1 Elevation Distribution and Implications

The Digital Elevation Model (DEM) of the Mahanadi River Basin, generated at a high spatial resolution of 12.5 meters, provides a comprehensive representation of the basin's altitudinal variation. Elevation is a foundational terrain parameter that governs surface runoff, drainage patterns, river gradients, sediment transport, and flood potential. This map categorizes the basin into distinct elevation classes—ranging from below 1 meter to over 1,000 meters above mean sea level—allowing for a nuanced understanding of how elevation influences hydrological and ecological processes across the states of Chhattisgarh and Odisha.

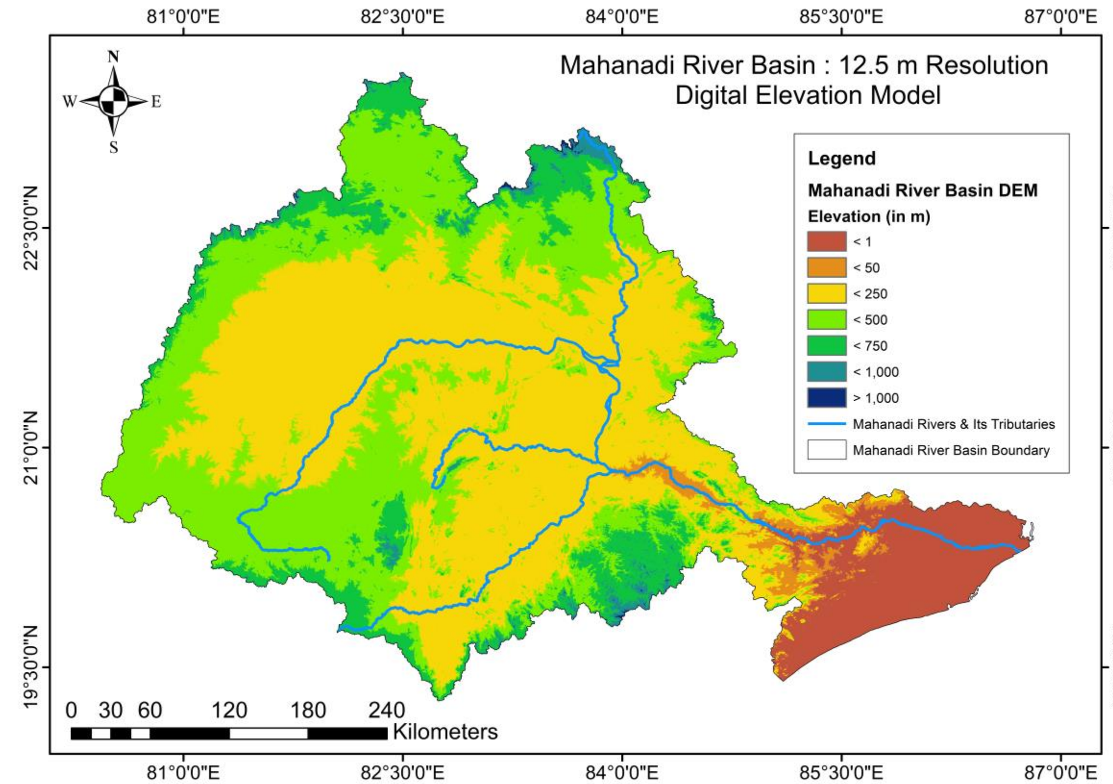

Figure 1. Digital Elevation Model (DEM) of Mahanadi River Basin

In Chhattisgarh, the western and central parts of the basin are dominated by elevations ranging between 250–750 meters, depicted in green to light yellow shades. These areas include districts such as Raigarh, Jashpur, Baloda Bazar, Gariaband, and parts of Dhamtari and Mahasamund. This topographic zone comprises rolling uplands, dissected plateaus, and forested slopes of the Eastern Central Highlands. The higher reaches, particularly in northern Surguja and southern Dantewada, show elevation values exceeding 1,000 meters, marked in dark blue, indicating hilly terrains and steep escarpments that are ecologically sensitive and hydrologically important for base flow generation and biodiversity conservation.

As the river descends into Odisha, the elevation drops significantly, transitioning into plains and lowland floodplains. The elevation class below 250 meters (shown in light green) spans much of western and central Odisha, including districts like Sambalpur, Boudh, Subarnapur, and Nayagarh, which are agriculturally productive and exhibit gentle terrain. The lowest elevation zones, marked in brown and red, are found in the eastern coastal districts of Cuttack, Jagatsinghpur, Khordha, and Puri, where elevation falls below

50 meters and even dips under 1 meter in parts of the Mahanadi Delta. These regions are highly prone to flooding, tidal ingress, and storm surges, especially during cyclonic events. The DEM map also overlays the Mahanadi River and its major tributaries (in blue), showcasing how these watercourses follow natural elevation gradients from highland sources in Chhattisgarh to the low-lying deltaic outfall in Odisha. The topographic transition from high relief to flat plains governs not only the velocity and sediment load of rivers, but also the distribution of agricultural zones, settlement patterns, and groundwater recharge zones.

Overall, this elevation map is a crucial tool for basin-wide planning, including dam siting, floodplain zoning, watershed prioritization, and eco-restoration. It serves as a base layer for integrating other terrain derivatives such as slope, aspect, and flow direction. In both Chhattisgarh and Odisha, understanding elevation variability supports more effective and resilient water resource management, disaster preparedness, and land use planning in the Mahanadi River Basin.

Table 1: Elevation-Area Distribution in the Mahanadi River Basin

S. No	Elevation (m)	Area (sq. km)	% of Total Area
1	<1	12417.55	8.57
2	1 - 10	627.20	0.43
3	10 - 50	2584.60	1.78
4	50 - 100	6711.57	4.63
5	100 - 200	31664.90	21.84
6	200 - 300	45785.63	31.58
7	300 - 400	18360.90	12.67
8	400 - 500	10833.39	7.47
9	500 - 750	13728.79	9.47
10	750 - 1000	2130.67	1.47
11	1000 - 1263	126.53	0.09

The elevation distribution table of the Mahanadi River Basin provides a quantitative summary of terrain heights, showing how elevation zones are spread across the basin's total area. When analysed in conjunction with the high-resolution Digital Elevation Model

(DEM) map, this data offers critical insights into the basin's topographic organization, hydrological behaviour, land use potential, and flood vulnerability across Chhattisgarh and Odisha.

According to the table, the most dominant elevation class is 200–300 meters, covering 45,785.63 sq. km or 31.58% of the basin's area. This zone, primarily distributed across central Chhattisgarh and western Odisha, includes regions such as Raipur, Mahasamund, Gariaband, and parts of Bargarh and Subarnapur. It reflects the transitional upland terrain that serves as the principal catchment area for many tributaries like the Seonath, Jonk, and Tel rivers. The 100–200 m elevation range, which accounts for 21.84% of the area, represents the alluvial plains and middle river valleys of districts like Sambalpur, Nayagarh, Angul, and parts of Cuttack, supporting extensive agriculture and settlement.

At higher altitudes, the 300–400 m and 400–500 m bands together make up over 20% of the basin, located mostly in the dissected plateau regions of northern Chhattisgarh (e.g., Surguja, Jashpur, Kabirdham) and Kandhamal district in Odisha. These elevations, marked in green to blue on the DEM map, represent forested and hilly terrains with high runoff potential and ecological sensitivity. Further upslope, the 500–750 m and 750–1000 m classes contribute 9.47% and 1.47% of the basin, respectively, concentrated along the rugged highlands of southern Chhattisgarh and Eastern Ghats in Odisha, playing a key role in rainwater harvesting, forest cover, and erosion control.

In contrast, the lowest elevation classes—specifically the <1 m and 1–10 m zones—together account for around 9% of the total area and are located in the deltaic and coastal districts of Jagatsinghpur, Kendrapara, Khordha, and Puri. These areas, shown in brown and red on the elevation map, are particularly vulnerable to tidal surges, cyclones, and seasonal flooding, making them critical for coastal zone management and disaster preparedness.

The elevation distribution of the Mahanadi Basin reveals a gradual decline from western Chhattisgarh's highlands to Odisha's coastal plains. Over 31% of the basin falls within the 200–300 m zone, forming the dominant topographic category, followed by 21.8% in the 100–200 m range. Lower elevation classes (<1 m to 50 m), mainly in the eastern delta, account for flood vulnerability, while the upper elevations (>750 m) found in Chhattisgarh's hill districts and Odisha's Ghats represent ecologically fragile terrain. This elevation variability governs hydrological flow, sediment transport, agriculture, and disaster risk management.

3.2 Slope Characteristics and Distribution

The slope map of the Mahanadi River Basin offers a comprehensive spatial understanding of terrain variability across the states of Chhattisgarh and Odisha, which together encompass the majority of the basin's geographical extent. Classified into eight categories—ranging from nearly level to very steep slopes- the map captures the influence of geomorphic structure, elevation, and underlying lithology on surface gradients. The slope classes include Nearly level (0°–1°), Very gently sloping (1°–3°), Gently sloping (3°–5°), Moderately sloping (5°–10°), Strongly sloping (10°–15°), Moderately steep (15°–30°), Steep sloping (30°–35°) and Very steep (>35°). In Chhattisgarh, the western and central regions of the basin, including Raipur, Dhamtari, Mahasamund, and parts of Gariaband and Baloda Bazar, are predominantly marked by very gently to gently sloping terrain (3°–5°), shown in green shades. These areas form the core agricultural belt of the state and are favorable for irrigation, infrastructure development, and rural settlement. The northern and southern fringes of Chhattisgarh, such as parts of Kabirdham, Durg, and Dantewada, exhibit moderately steep to steep slopes, indicating dissected plateaus and forested uplands that require slope-sensitive land and water management interventions.

In Odisha, the slope characteristics change notably as the river enters the middle and lower basin. The western and central Odisha districts like Bargarh, Subarnapur, Boudh, and Angul show a mixed slope pattern, with both moderate slopes in upland forested zones and gentler gradients along major river valleys and agricultural plains. Moving eastward, the coastal and deltaic districts such as Cuttack, Jagatsinghpur, Khordha, and Puri are characterized by nearly level to very gently sloping terrain (<3°), which supports extensive rice cultivation but also poses high vulnerability to flooding, especially during monsoonal events and cyclonic surges. Notably, the southern part of Odisha, including Gajapati and Kandhamal, reveals zones of very steep slopes (>35°), corresponding to the Eastern Ghats' rugged terrain, which are ecologically sensitive and susceptible to landslides and erosion.

Overall, the slope map reflects the transition from elevated plateau regions in Chhattisgarh to deltaic plains in Odisha, illustrating the terrain's critical role in determining hydrological flow, erosion patterns, and land use suitability. The insights from this map are vital for watershed prioritization, afforestation planning, infrastructure alignment, and flood risk reduction across both states. Integrating this slope information into basin-level planning ensures terrain-sensitive and region-specific development strategies, contributing to the sustainable management of the Mahanadi River Basin.

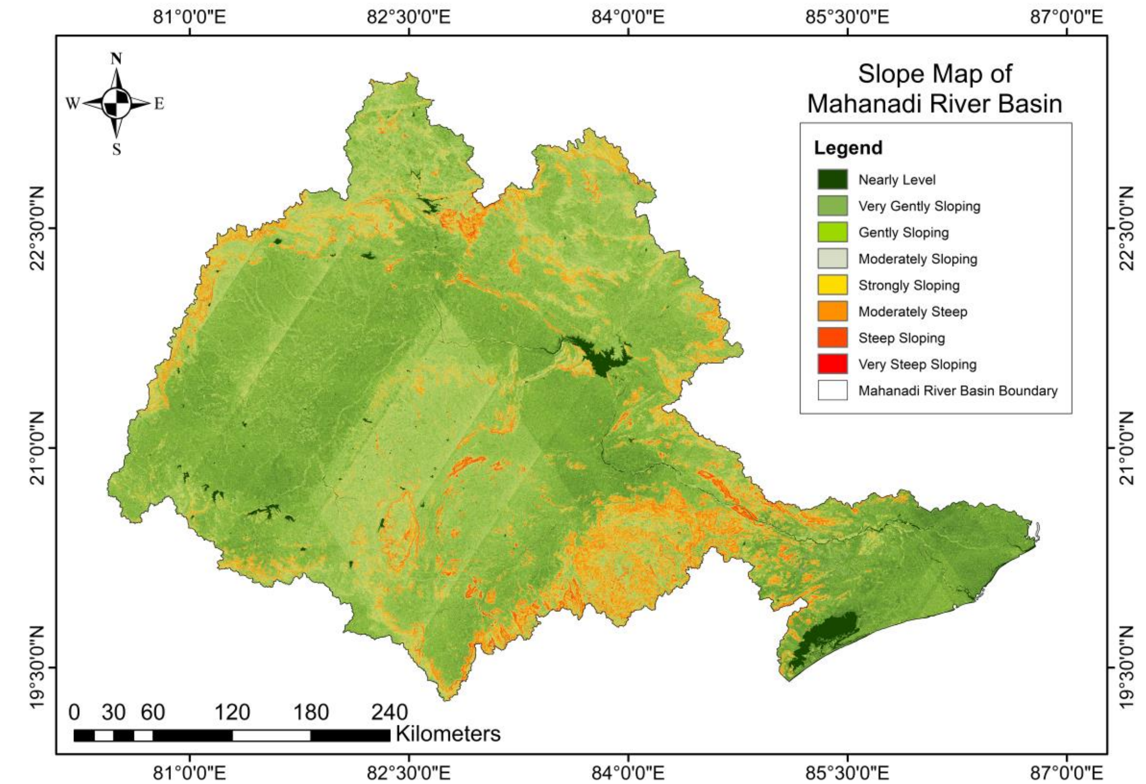

Figure 2. Slope Map of Mahanadi River Basin

3.3 Flow Direction Dynamics

The flow direction map of the Mahanadi River Basin illustrates the pathways along which surface runoff travels across the basin's diverse terrain. Derived from high-resolution Digital Elevation Model (DEM) data using the D8 (eight-direction) algorithm, this map provides essential insight into the orientation of overland water movement—crucial for watershed delineation, stream network generation, flood routing, and drainage design. Each raster cell on the map is assigned a value indicating the steepest downslope direction to an adjacent cell, producing a matrix of directional water flow. The legend on the map categorizes these directions into ranges, visualized using a color gradient from green to blue, which helps in identifying both local and regional flow patterns.

In Chhattisgarh, the upper reaches of the Mahanadi Basin—including districts like Raipur, Dhamtari, Kabirdham, Bilaspur, and Gariaband—exhibit strong directional flow patterns emerging from the upland and plateau zones. These areas are characterized by clearly defined east- and southeast-flowing drainage lines that correspond with major tributaries such as the Seonath, Hasdeo, Mand, and Jonk rivers. The flow direction mapping in this region reflects the natural eastward slope of the terrain, facilitating rapid runoff movement during monsoons and shaping the region's dense dendritic drainage network. This information is critical for sub-watershed planning, erosion control, and irrigation design.

As the river system moves eastward into Odisha, the flow patterns continue to align with the general eastward and southeastward slope of the basin. Districts such as Boudh, Subarnapur, Angul, and Nayagarh display relatively convergent flow directions toward the central trunk of the Mahanadi. In the coastal and deltaic areas—including Cuttack, Jagatsinghpur, and Puri—the flow direction becomes more diffuse and complex due to low-gradient terrain and the influence of distributary networks. The map shows high variability in flow directions in these zones, reflecting the braided river morphology and extensive floodplain dynamics that dominate the delta.

This flow direction map serves multiple planning and environmental applications. It is indispensable for drainage basin demarcation, runoff modeling, flood forecasting, and infrastructure siting—including roads, canals, embankments, and wastewater outfalls. It also provides a foundational layer for combining with slope and flow accumulation maps to generate accurate stream networks, predict overland flow paths, and prioritize intervention zones. In both Chhattisgarh and Odisha, the map supports integrated watershed management and climate-resilient planning by offering terrain-sensitive hydrological intelligence that aligns with the physical realities of the Mahanadi River Basin. The flow direction map reveals overland flow paths across the Mahanadi Basin. Chhattisgarh's terrain drives water eastward into Odisha, with flow alignment influenced by local topography. The pattern becomes more complex in Odisha's deltaic stretch due to low gradients and distributary systems. Understanding flow direction is essential for sub-basin delineation, runoff routing, and flood risk reduction.

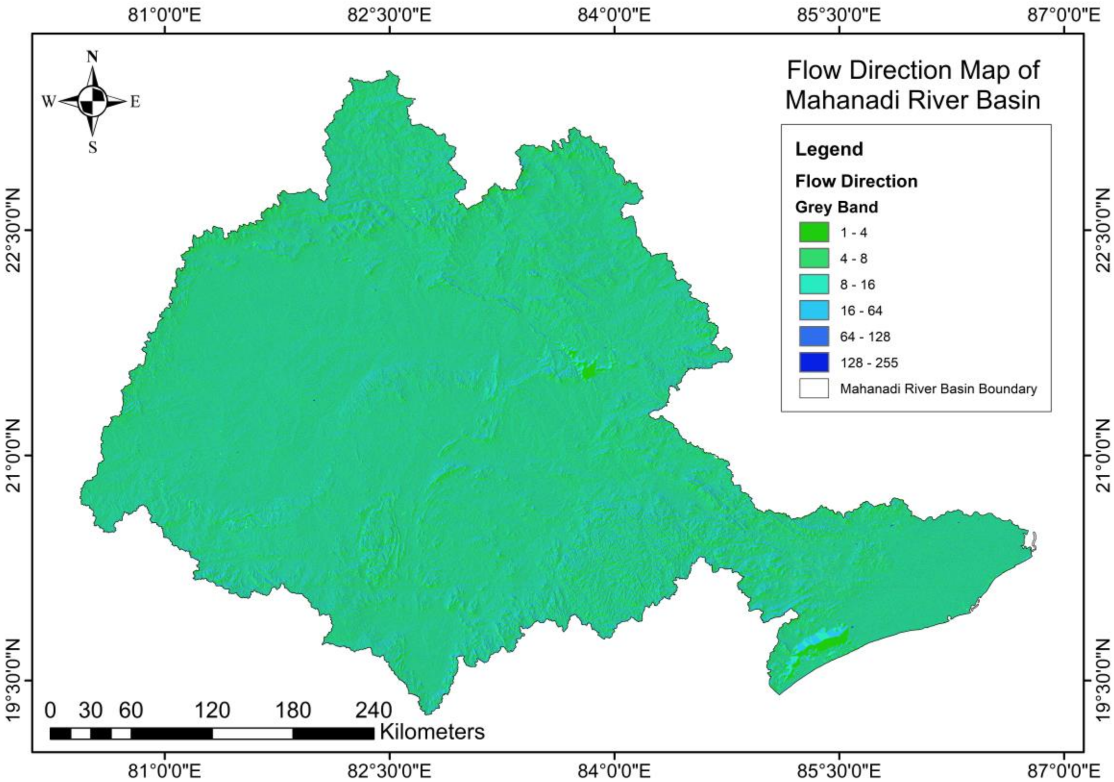

Figure 3. Flow Direction Map of Mahanadi River Basin

3.4 Flow Accumulation Patterns

The flow accumulation map of the Mahanadi River Basin visualizes the spatial patterns of surface water convergence based on digital elevation data, providing critical insights into hydrological behavior, drainage intensity, and watershed dynamics across both Chhattisgarh and Odisha. Flow accumulation represents the number of upstream cells draining into each cell in a raster grid, effectively identifying stream channels, drainage paths, and potential zones of runoff concentration. In this map, areas with no or negligible accumulation are depicted in white, while cells with flow accumulation greater than zero are highlighted in blue, signifying zones where surface runoff begins to coalesce and form drainage lines.

In Chhattisgarh, the upper and central catchments of the Mahanadi Basin—including districts like Dhamtari, Raigarh, Janjgir-Champa, Bilaspur, and Mahasamund—display numerous well-defined flow accumulation paths. These align with tributaries such as the Seonath, Hasdeo, Mand, and Jonk rivers, which originate from forested uplands and dissected plateaus. The high density of accumulation lines in these regions indicates intense surface runoff and efficient drainage networks, particularly in areas with moderate to steep slopes. These flow channels are critical for delineating micro-watersheds and planning structures such as check dams, percolation tanks, and soil conservation trenches.

As the river enters Odisha, the flow accumulation pattern evolves, with major flow lines becoming broader and more interconnected. In districts like Boudh, Subarnapur, Angul, Nayagarh, and Cuttack, the accumulation zones coincide with the Mahanadi's principal course and its major tributaries, including the Tel, Ong, and IB rivers. Further east, in the deltaic stretches of Khordha, Jagatsinghpur, and Puri, the accumulation map reveals a dense web of distributaries and drainage outlets, particularly in the coastal plains. These low-gradient areas collect significant runoff from upstream regions and are thus highly susceptible to flooding, waterlogging, and sediment deposition during the monsoon.

This map is vital for flood modeling, catchment prioritization, and hydrological infrastructure planning, such as reservoir sitting, floodplain demarcation, and drainage design. It also supports ecological planning, as flow convergence zones often sustain riparian habitats and groundwater recharge zones. By combining this flow accumulation analysis with slope and land use data, planners and researchers can more effectively manage runoff, control erosion, and design adaptive strategies to enhance water availability and reduce flood risk across the Mahanadi River Basin in both Chhattisgarh and Odisha.

The flow accumulation map visualizes how surface runoff converges across terrain. In Chhattisgarh, well-defined accumulation paths reflect efficient drainage systems in upland plateaus. Major tributaries such as Seonath, Hasdeo, and Jonk are captured prominently. In Odisha, convergence patterns intensify, particularly in the flood-prone deltas of Cuttack and Jagatsinghpur. This map supports floodplain mapping, micro-watershed planning, and hydrological modeling.

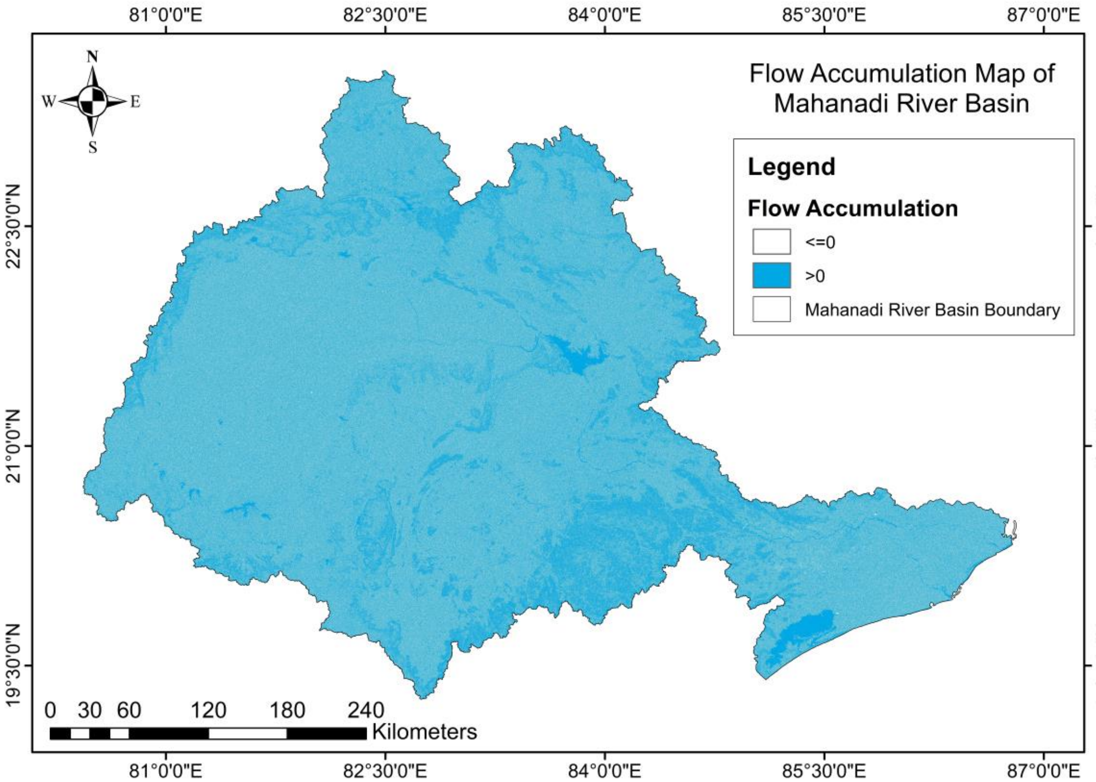

Figure 4. Flow Accumulation Map of Mahanadi River Basin

3.5 Aspect Orientation Analysis

The aspect map of the Mahanadi River Basin presents a spatial distribution of slope orientations, which is essential for interpreting solar exposure, moisture retention, vegetation patterns, and microclimatic conditions across the basin. Aspect refers to the compass direction that a terrain surface faces and is classified here into nine directional categories—ranging from north-facing to northwest-facing slopes—along with a tenth category for flat or near-horizontal areas. The map reveals a highly heterogeneous terrain orientation across the basin, reflecting the influence of varied landforms, geological structures, and erosional processes that shape the region's physiography.

In Chhattisgarh, the upper and central parts of the basin display a wide range of aspects due to the presence of dissected plateaus and hill ranges, especially in districts such as Kabirdham, Dhamtari, Gariaband, and Kanker. Slopes in these areas show a significant presence of south- and southeast-facing aspects, which receive more solar radiation and therefore experience higher evapotranspiration rates. This can affect crop water requirements, forest types, and soil moisture dynamics. The western districts also feature northeast and northwest aspects, particularly on forested uplands, influencing local biodiversity niches and erosion susceptibility.

Moving into Odisha, the middle and lower portions of the basin—especially in Sambalpur, Angul, Boudh, and Kandhamal—demonstrate a dominant mix of east-, southeast-, and south-facing slopes, reflecting the broader eastward drainage direction and structural slope controls. These aspects are especially important in agricultural planning as they influence the thermal regime and productivity of croplands. In the deltaic plains of Cuttack, Khordha, Jagatsinghpur, and Puri, large tracts are classified as flat terrain due to their negligible slope. These areas are highly fertile but susceptible to waterlogging, requiring careful drainage and land management strategies.

Overall, the aspect map complements the slope and elevation analyses by adding directional context to terrain features. It is particularly useful in ecological zoning, irrigation scheduling, afforestation planning, and solar infrastructure placement. When integrated with climatic data and soil types, aspect analysis enables refined site selection for agriculture, reforestation, and watershed development in both Chhattisgarh and Odisha, thereby enhancing the environmental sustainability and resilience of interventions across the Mahanadi River Basin.

The aspect map of the Mahanadi River Basin highlights the orientation of slope faces. In Chhattisgarh, dissected plateaus show dominant south- and southeast-facing aspects, affecting microclimates and soil moisture. In Odisha, east- and southeast-facing slopes are prevalent in middle catchments, aiding solar exposure for crops. Flat terrains dominate the delta region, where the aspect is less influential but still relevant for water retention. This analysis aids ecological zoning, irrigation planning, and land management strategies.

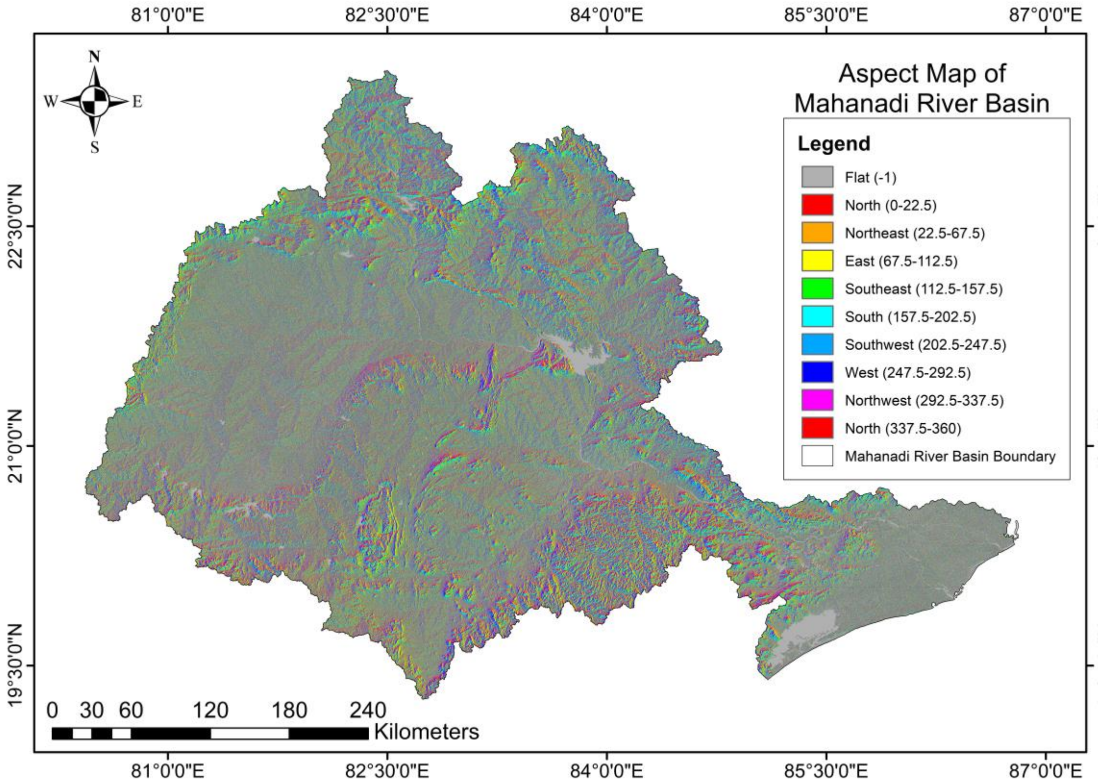

Figure 5. Aspect Orientation Map of Mahanadi River Basin

3.6 Hill shade and Terrain Visualization

The hill shade map of the Mahanadi River Basin provides a visually enhanced representation of terrain relief by simulating how sunlight interacts with the landscape. This map is derived from a high-resolution Digital Elevation Model (DEM) using a hill shading algorithm, which models the illumination of terrain based on a hypothetical light source—typically from the northwest at 315° azimuth. The grayscale and coloured shading patterns reflect variations in slope and aspect, making it easier to interpret topographic features such as ridges, valleys, escarpments, and plateaus across both Chhattisgarh and Odisha.

In Chhattisgarh, particularly in the districts of Kabirdham, Surguja, Jashpur, and Dantewada, the map displays rugged hill systems and deeply dissected plateaus, highlighted by strong shadow contrasts. These areas, marked in darker hues and sharp textural variation, indicate steep slopes and elevated features such as the Maikal and Satpura hill ranges. These landforms play a crucial role in shaping runoff dynamics, biodiversity corridors, and erosion processes. The central basin regions, including Raipur, Mahasamund, and Janjgir-Champa, show relatively smoother hill shading with gradual topographic transitions, reflecting the presence of gently rolling uplands and broad alluvial valleys.

As the river flows eastward into Odisha, the terrain becomes more varied. The western and central districts such as Boudh, Kandhamal, Angul, and Nayagarh are marked by moderate relief with visible slope breaks and undulating topography, evident from intermediate shading tones. In contrast, the eastern deltaic region—covering Cuttack, Khordha, Jagatsinghpur, and Puri—exhibits light and nearly uniform shading, characteristic of flat floodplains and coastal plains. This part of the basin is less affected by topographic obstruction and supports extensive agricultural activity, albeit with increased flood vulnerability.

Hill shade maps are not only aesthetic but serve practical purposes in terrain analysis and spatial planning. They enhance the interpretation of hydrological features, guide site selection for civil infrastructure, and support environmental modelling and visualization. When integrated with thematic layers such as slope, aspect, and land use, hill shade visualization enables better communication of spatial patterns in landscape morphology, drainage alignment, and geomorphic processes. In the context of the Mahanadi River Basin, this map aids in recognizing terrain-driven challenges and opportunities, facilitating informed watershed planning, ecological assessment, and development interventions across both Chhattisgarh and Odisha.

The hill shade map simulates sunlight on terrain, enhancing visual interpretation of landforms. In Chhattisgarh, strong shadows and contrast highlight dissected hills and steep escarpments, notably in Kabirdham and Dantewada. In Odisha, moderate shading is seen in Kandhamal and Angul, while smooth gradients dominate the delta. Hill shade mapping improves interpretation of slopes, ridges, and valleys, supporting watershed planning, terrain-sensitive infrastructure design, and erosion risk assessments.

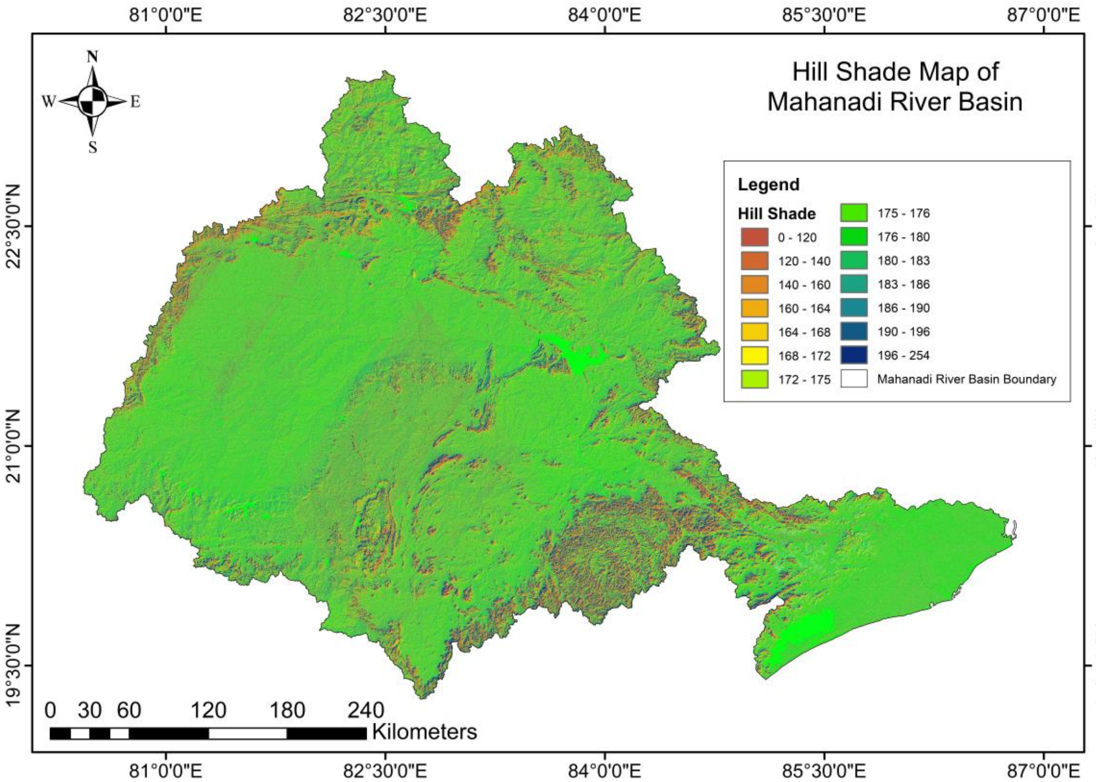

Figure 6. Hill Shade Map of Mahanadi River Basin

3.6 Geomorphological Landforms of the Mahanadi River Basin

The geomorphological landform map of the Mahanadi River Basin presents a highly detailed classification of surface landforms and terrain features, as interpreted at a 1:250,000 scale from the Geological Survey of India (GSI). This thematic map integrates fluvial, structural, denudation, and coastal geomorphic units, offering crucial insights into basin evolution, sediment dynamics, and landform processes across both Chhattisgarh and Odisha.

In Chhattisgarh, the western and northern regions—especially in Raigarh, Janjgir-Champa, Raipur, and Baloda Bazar districts—are dominated by denudation hills and valleys, with landform types such as DenH5 – Highly Dissected Hills and Valleys and DenL5 – Highly Dissected Lower Plateaus. These terrain types are products of long-term weathering, fluvial incision, and tectonic uplift, marking the rugged highlands of the basin. The central plains of Chhattisgarh (including Durg and Mahasamund) are represented by Pediments, Younger Alluvial Plains, and Residual Hills, illustrating zones of lower slope gradient with depositional influence and moderate erosion.

Moving east into Odisha, the geomorphological diversity increases significantly. The middle basin exhibits a mosaic of Alluvial Plains, Floodplains (FluOF and FluYF), and Natural Levees along the Mahanadi and its major tributaries like the Tel and Ib. The coastal delta region, especially in Cuttack, Jagatsinghpur, Khordha, and Puri, is composed of Coastal Plains (CsoOf, CsoYf), Tidal Flats, Beach Ridges, Swales, and Back Swamps. These landforms reflect active sedimentation, tidal dynamics, and fluvial-coastal interaction, making the area sensitive to climate change and sea-level rise.

This geomorphological map is invaluable for identifying zones susceptible to erosion, flooding, groundwater recharge, and tectonic activity. It supports spatial planning for agriculture, infrastructure, mining, and ecological conservation. Recognizing and managing these diverse landforms is essential for maintaining geomorphic equilibrium, sustaining livelihoods, and enhancing disaster preparedness across the Mahanadi Basin.

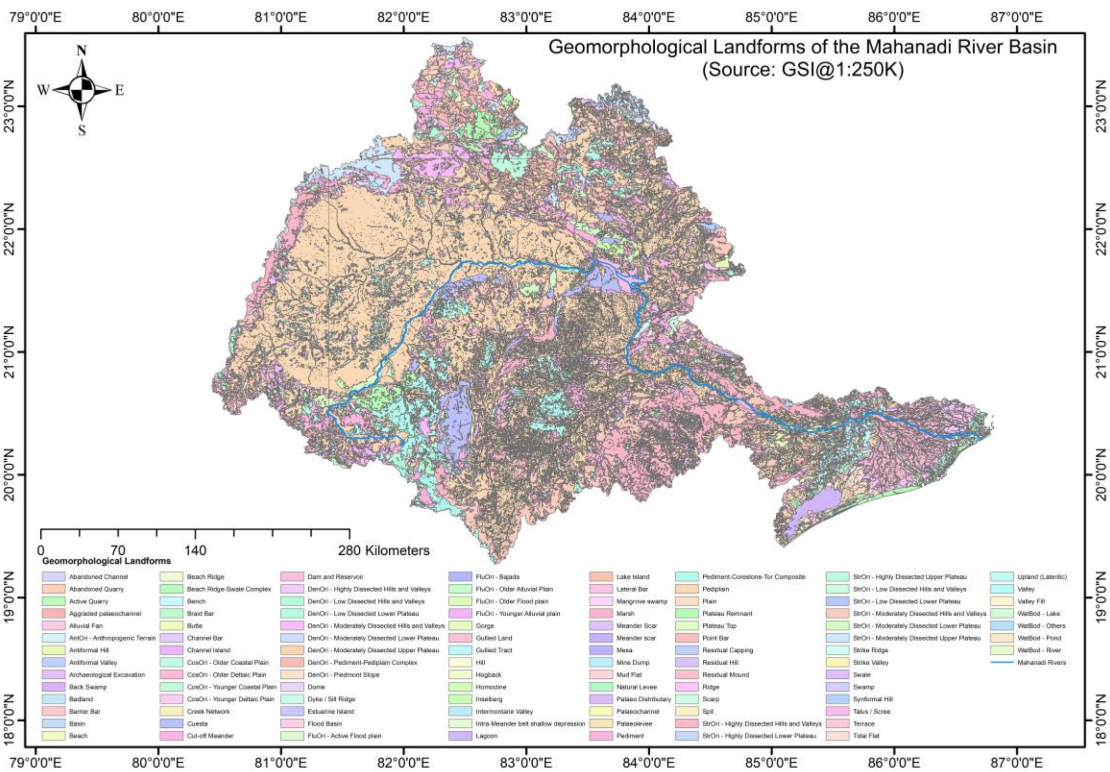

Figure 7. Geomorphological Landforms of the Mahanadi River Basin

4. Contour Mapping and Applications

Contours provide an essential perspective on terrain morphology and hydrological gradients. Using the ALOS PALSAR DEM, contour lines were generated at four intervals—100 meters and 50 meters for regional elevation variation and 10 meters for micro-scale planning. In Chhattisgarh's uplands, 100 m and 50 m contours delineate ridgelines and high-relief features such as escarpments and dissected plateaus. These help in regional planning, delineation of sub-basins, and understanding sediment transport pathways. In contrast, Odisha's lowlands were mapped using 10 m contours to capture floodplain undulations and backwater effects near distributary channels. The dense contouring in delta regions helps in the precise zoning of flood-prone areas and in modeling potential inundation under extreme weather events. Such detailed contouring shall also support irrigation command planning, tank restoration, and groundwater recharge structure sitting. Beyond hydrology, contour datasets are useful in civil engineering and transportation planning by offering elevation data for roads, bridges, and urban layouts. They also guide land suitability analysis in rural development programs, watershed development missions, and eco-restoration projects. When used in conjunction with slope and aspect data, contour layers enable terrain-sensitive designs that respect natural flow paths and ecological boundaries. Thus, the application of DEM-derived contour maps extends from academic research to real-world planning scenarios, reinforcing their value for multidisciplinary stakeholders across the Mahanadi River Basin.

The 100-meter interval contour map of the Mahanadi River Basin provides a generalized overview of the elevation changes and topographic configuration across the entire basin area in Chhattisgarh and Odisha. These contours, spaced at every 100-meter rise in elevation, are particularly useful for broader landscape-scale planning, watershed zoning, and erosion-prone area delineation.

In Chhattisgarh, the northern districts such as Surguja, Jashpur, and Balrampur exhibit dense and tightly spaced 100 m contour lines, indicating rugged terrains and pronounced topographic relief. These highland areas form the headwaters for several tributaries of the Mahanadi and are critical for runoff generation and orographic rainfall influence.

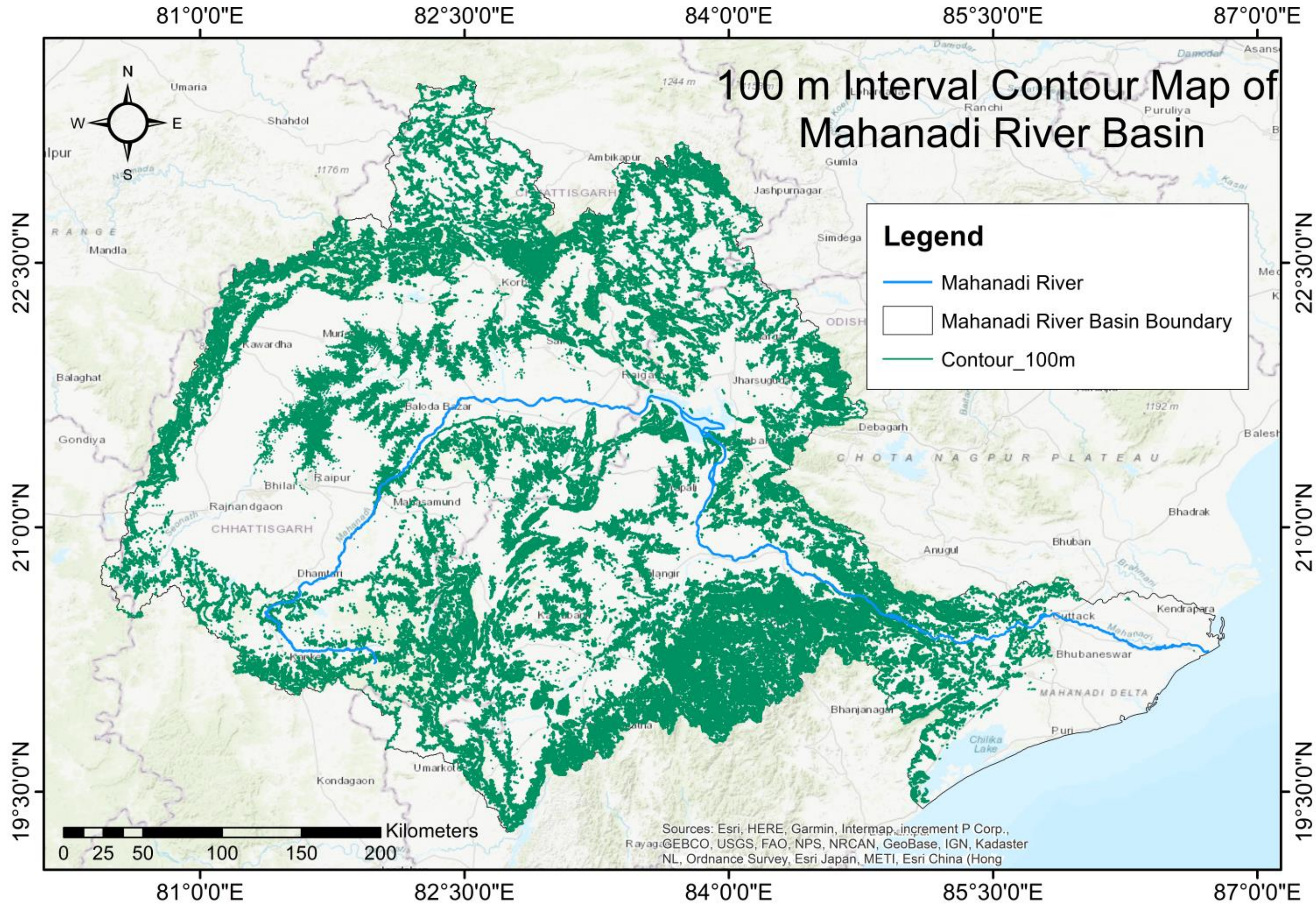

Figure 8. Contour Mapping (100 m interval) of the Mahanadi River Basin

Central districts like Raipur, Dhamtari, and Mahasamund have more open contour spacing, indicative of gentle plains and valley regions. Southern parts like Kondagaon and Bastar show alternating steep ridges and moderate elevations, reflecting plateau features and dissected landforms.

In Odisha, western and central upland districts such as Kalahandi, Nuapada, and Kandhamal show significant topographic variation with notable clustering of 100 m contours. These areas form mid-basin zones that gradually transition into flatter plains. As the river moves toward the deltaic region in coastal Odisha, including Cuttack, Jagatsinghpur, Puri, and Khordha, the contours become sparse or nearly absent, revealing a flat, low-lying terrain characteristic of the alluvial floodplains and estuarine systems.

The 50-meter interval contour map of the Mahanadi River Basin presents a high-resolution visualization of the basin's surface elevation variations using equidistant contour lines. These lines, spaced at every 50-meter elevation change, provide an insightful representation of the terrain complexity and topographic gradient across Chhattisgarh and Odisha.

In Chhattisgarh, particularly in the central and northern regions (such as Raipur, Dhamtari, Kanker, and Mahasamund), the contour lines are more widely spaced, indicating areas of relatively low relief and gentle slopes. These zones coincide with the expansive alluvial plains and valley floors that support agriculture, human settlements, and major transport corridors. In contrast, districts like Jashpur, Balrampur, and Surguja in the north and Kondagaon and Bastar in the south show a dense clustering of contours, reflecting steeper slopes and dissected terrains formed by upland plateaus and river incisions.

As the river progresses into Odisha, the contour spacing varies considerably. The upper catchment areas in districts such as Nuapada, Kalahandi, and Kandhamal exhibit closely spaced contours, characteristic of hilly and plateau regions. These are geomorphological significant zones for surface runoff, groundwater recharge, and forest conservation. In the middle and lower basin areas, including Boudh, Angul, Cuttack, and Jagatsinghpur, the contours become sparse, indicating a transition to flat alluvial plains and the deltaic zone. The eastern edge near Puri and Khordha, which borders the Bay of Bengal, shows minimal elevation change, corroborating with floodplain and tidal influence.

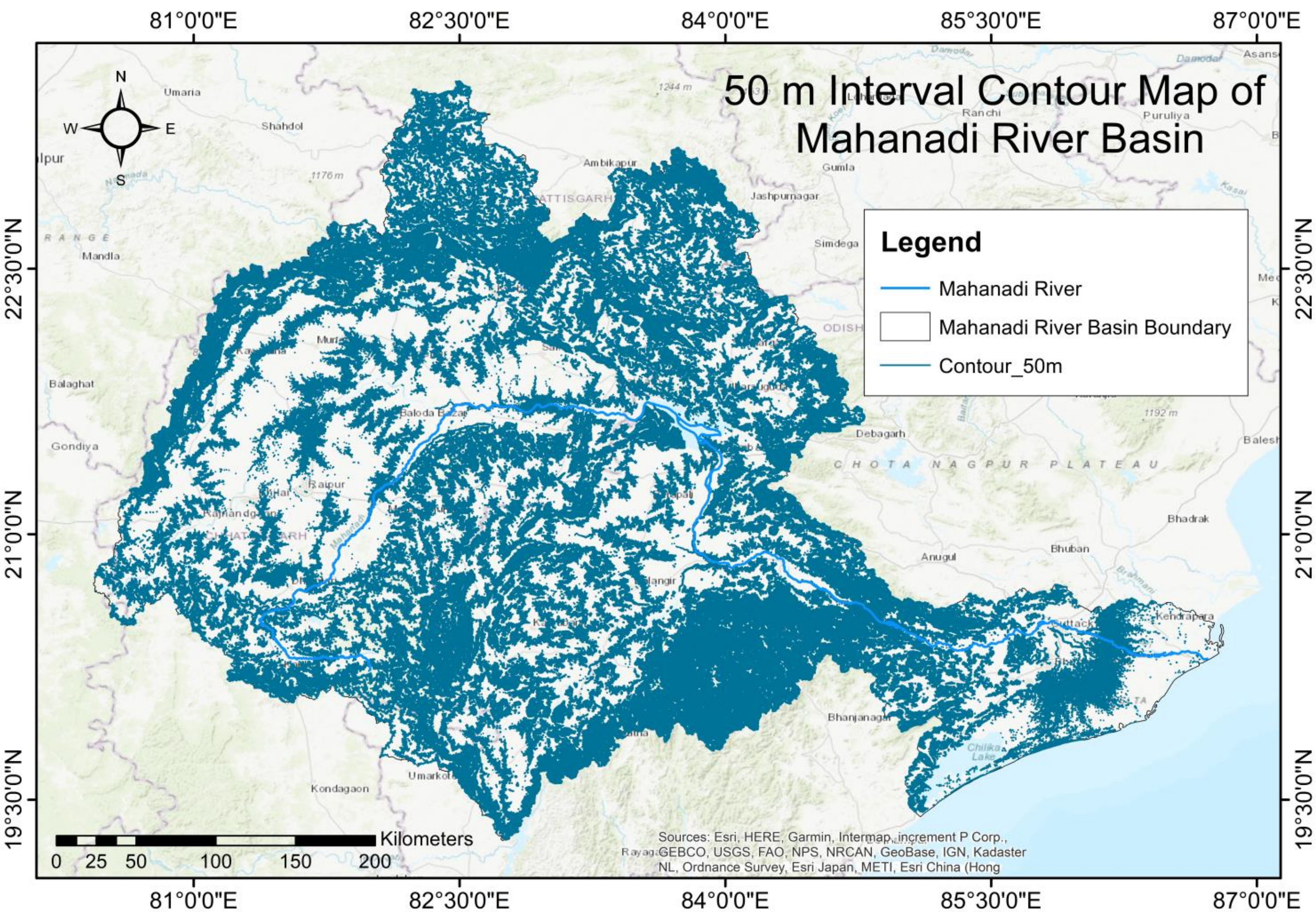

Figure 9. Contour Mapping (50 m interval) of the Mahanadi River Basin

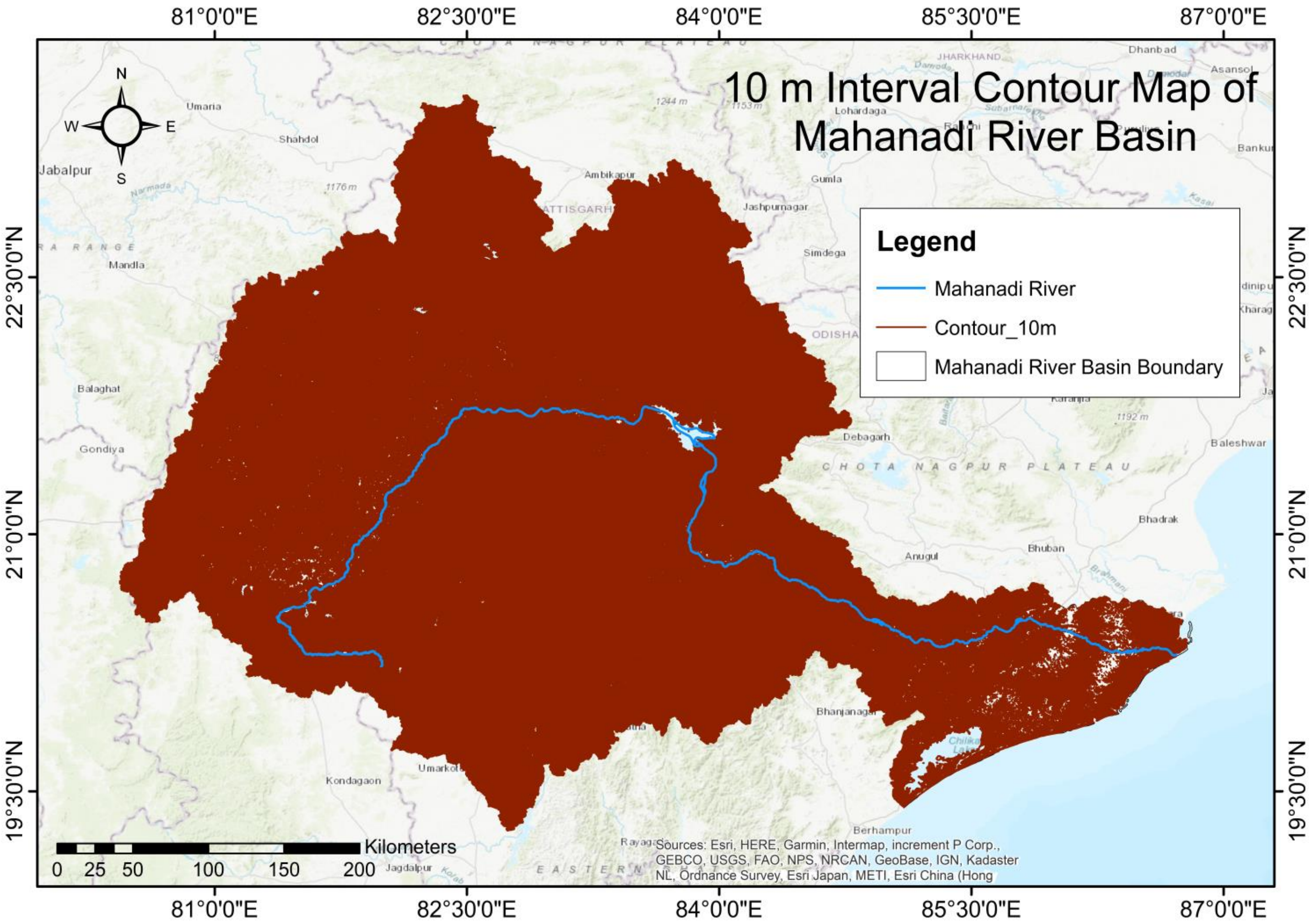

Figure 10. Contour Mapping (10 m interval) of the Mahanadi River Basin

5. Conclusion and Recommendations

This report presents a spatially resolved topographic assessment of the Mahanadi River Basin in Chhattisgarh and Odisha, emphasizing its varied geomorphology and hydrological significance. Following are the **major findings** of the report:

- Using high-resolution ALOS PALSAR DEM and validated by Survey of India maps, it captures key terrain metrics such as elevation distribution, slope gradient, aspect orientation, and flow dynamics. The basin reveals three broad physiographic zones: upland hills and plateaus in Chhattisgarh; the central alluvial corridor of the river's mainstream; and the low-lying deltaic floodplains of coastal Odisha. These zones collectively influence river discharge, erosion, groundwater recharge, and human settlement.
- Slope analysis shows that nearly one-third of the basin is gently sloped, favoring agriculture and infrastructure development, while hillier zones require soil conservation and afforestation measures.
- Flow accumulation and direction maps delineate the basin's hydrological behavior, indicating strategic zones for runoff harvesting and flood control. Contour mapping at both macro and micro scales enhances zoning precision and design optimization.

Recommendations:

- The insights from this report can support multiple domains: state planning departments, irrigation and water resources authorities, disaster management agencies, and conservationists.
- Future work should integrate land use, soil data, and climate projections to build a dynamic topography-hydrology interaction model. The study reinforces that topographic intelligence is central to sustainable and resilient river basin management, especially in data-scarce or hazard-prone landscapes like the Mahanadi Basin.

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- Survey of India (SoI) for providing topographical sheets and the related data.
- The ALOS PALSAR DEM, developed by the Japan Aerospace Exploration Agency (JAXA), provides a high-resolution (12.5 m DEM) terrain dataset suitable for hydrological and geomorphological assessments. It was downloaded from the Alaska Satellite Facility (ASF) Distributed Active Archive Center (DAAC).