DISASTER MANAGEMENT *and* ENVIRONMENTAL SUSTAINABILITY



Edited By

Sanjay Kumar, Suraj Kumar Singh,
Shruti Kanga, Gowhar Meraj,
Majid Farooq, and M.S. Nathawat

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Editorial

In an era marked by environmental crises and frequent natural disasters, the urgency to understand and address these issues is palpable. The book *Disaster Management and Environmental Sustainability* enters this crucial dialogue, bringing to light a plethora of interconnected themes, insights, and solutions for tackling these complex challenges, with a specific focus on the diverse context of India.

The authors embark on a meticulous exploration of the key themes surrounding disaster management and environmental sustainability. The book effectively maps the terrain of these topics through fifteen comprehensive chapters. The journey starts with an examination of the geographically vulnerable areas of Madhya Pradesh, laying the groundwork for understanding the significant impact of disasters on communities.

"Disaster Management and Environmental Sustainability" does not shy away from delving into controversial topics. It explores the paradox of development, and its double-edged impact on environmental degradation and human progress. The authors weave together an intricate narrative, exploring the multifaceted nature of sustainability, including the impacts on safety, law enforcement, agriculture, and economic development. It is a testament to the book's strength that it is able to navigate these interwoven themes, providing valuable insights for both the uninitiated and the experienced reader.

As we progress into a digital era, the book also navigates the role of modern technologies such as geographic information systems (GIS) and remote sensing in managing disasters and their potential influence on environmental sustainability. In today's interconnected world, the examination of these digital tools feels both relevant and timely.

However, it is not just about the 'what' but also the 'how'. The book's approach to these complex subjects is evidence-based, rigorous, and comprehensive. Each chapter offers a deep dive into the topic at hand, underpinned by meticulous research and objective analysis. This fact-based approach helps the reader to navigate the often confusing landscape of environmental sustainability and disaster management, providing clarity amidst the complexity.

This book shall serve both a guide and an inspiration for its readers. It calls on us all to become agents of change, making informed decisions for the benefit of our communities and future generations. It is a call that resonates, reminding us of the interconnected nature of our world and our shared responsibility towards it.

From understanding the dangers of illegal sand mining to exploring the potential of solar power as a sustainable energy alternative, from delineating the historical transformation of Berhampur to the detrimental effects of human activities on the environment, and from the geographical aspects of urban crime to the significance of agricultural development, this

book covers a broad spectrum. It also discusses the implications of the recent pandemic on migrant workers, a reality that still resonates across the globe.

"Disaster Management and Environmental Sustainability" is not just a book; it is a blueprint for understanding our relationship with the environment and how we can navigate the challenges that arise from this relationship. It invites us to not only understand the present but to take action for a sustainable future. This book is a valuable resource for anyone interested in environmental sustainability and disaster management, and it is an essential read for those who dare to make a difference.

Editors
Sanjay Kumar
Suraj Kumar Singh
Shruti Kanga
Gowhar Meraj
Majid Farooq
M. S. Nathawat

Preface

In this critical juncture of human history, the importance of an understanding and commitment to environmental sustainability and disaster management cannot be overemphasized. This book, titled *Disaster Management and Environmental Sustainability*, is a significant endeavor towards developing a more in-depth understanding of these complex issues, focusing primarily on the diverse context of India. The chapters herein are designed to serve as a resource for academics, practitioners, policymakers, students, and anyone interested in grasping the intricacies of our natural world and its governance. The book's fifteen chapters explore a range of related themes, each contributing to a holistic understanding of the environmental and disaster management landscape. The earlier chapters provide a foundation in understanding the geography of disaster-prone areas in Bihar and the subsequent impact on its citizens. We delve into the role of urbanization in shaping our environment and analyze both its boons and banes. The book brings to light the paradoxical relationship between development and environmental conservation. While development is seen as a symbol of human progress, it can also lead to environmental degradation, underlining the need for sustainable practices. We also underscore the need for legal measures and regulations to ensure environmental preservation, detailing the evolution of environmental laws in India. In subsequent chapters, the narrative shifts towards the issues of urban crime, agricultural growth, and forest resources, demonstrating the multifaceted nature of environmental sustainability. These chapters show how every aspect of our society is intertwined with the environment, from safety and law enforcement to agriculture and economic development. The later chapters incorporate the use of modern technologies such as geographic information systems (GIS) and remote sensing in managing disasters like urban flooding. We also examine the role of the internet in our lives, a pertinent issue given the digital revolution and the post-pandemic scenario. This chapter will help readers understand how these technological advancements can both aid and pose challenges to environmental sustainability. Each chapter has been meticulously researched and is built on evidence-based facts, aiming to enlighten and engage readers in these crucial topics. It is my hope that this book will not only serve as a comprehensive guide to disaster management and environmental sustainability but also inspire readers to become proactive agents of change in their communities. This book is a testament to the belief that despite the complexity and magnitude of the challenges we face, collective understanding, sustained effort, and persistent innovation can indeed foster a harmonious coexistence between humanity and the environment. It is a call to all of us to tread the path of sustainability, making informed decisions that are beneficial not just for us, but for generations to come.

Chapter 1 delves into the alarming consequences of illegal sand mining on river ecosystems, with an in-depth focus on the Chambal River. The researchers leverage advanced geospatial techniques to map the changes in river morphology due to unlawful extraction activities. The findings illuminate the pressing need for sustainable sand mining practices to safeguard our rivers and their delicate ecosystems. **Chapter 2** shifts our attention to the energy sector, focusing on the enormous potential of solar power as a green energy alternative. The research identifies suitable areas for solar power plant installation in four districts of Himachal Pradesh, India, with the help of geospatial technology. It spotlights the role of solar energy in relieving the increasing pressure on exhaustible resources, like coal and petroleum, imposed by population growth and industrial expansion. **Chapter 3** is the third chapter in our journey. It deals with the essential role of potable water in households and takes a close look at the consumption patterns in Idah LGA, Kogi State. It presents an analysis of water sources, household water demand, and influential factors, underpinned by a scientific method involving questionnaires, interviews, and observations. The findings provide a basis for effective water supply planning.

Chapter 4 presents a broad overview of disasters, emphasizing their omnipresence and destructive nature. It underscores the necessity of comprehensive knowledge about disasters to manage their risks and impacts effectively. The chapter elucidates the concept of disasters, frequency of occurrences, and how to build resilience against these calamities, drawing from the author's vast expertise in the field. **Chapter 5** focuses on the detrimental effects of human activities on the environment. Detailing various types of pollution, it underlines their consequences on human health. Stressing the need for environmental education, the chapter calls for simple techniques to measure pollution and appropriate remedies to mitigate their effects. **Chapter 6** discusses the interplay between environmental degradation and human progress. Using an allegory from mythology, it stresses the necessity of balancing development and environmental preservation. The chapter emphasizes the urgency to address environmental issues while ensuring economic growth and poverty eradication.

Chapter 7 addresses the effects of the pandemic and the ensuing lockdown on migrants in India. Using Rohtak, a significant migrant destination, as a case study, it provides insights into the experiences of migrant laborers during these trying times. This chapter paints a vivid picture of the human toll of the pandemic, extending beyond health issues to include broader socio-economic implications. **Chapter 8** delves into the geography of crime, a social issue whose variable nature provides geographers with a dynamic field to study. Despite its relevance, this discipline has struggled to capture the attention of mainstream geographers. Taking the city of Patna as a case study, we explore how urban transformations and economic, political, and social changes influence the city's crime rates, with a specific focus on crimes against women. The intricate and layered nature of urban crime is discussed, alongside the impacts of fear perception and gender differences in such contexts. **Chapter 9** discusses the significance of cropping intensity as an indicator of agricultural development. The potential of multiple cropping as a solution to maximize agricultural production and augment farmer incomes in India is examined, taking into account irrigation impacts on cropping intensity. Analyzing secondary data from 1991–92 to 2017–18 in Haryana, we delve into how higher degrees of cropping intensity can signify a higher level of agricultural development. **Chapter 10** underlines the importance of forests as crucial ecological resources, detailing the direct and indirect uses they serve. With Bihar's forest

cover at a mere 7.75%, we discuss the reasons behind forest cover disappearance and the prospects of forest resources in the state. Measures to improve and sustain forest cover are suggested, all based on an empirical study conducted via secondary data, literature surveys, and self-observation.

Chapter 11 emphasizes the profound challenges of environmental degradation in the modern century, a result of population growth and the overexploitation of natural resources. It introduces sustainable development as a crucial solution, stressing the need for a rational and equitable balance between economic growth and environmental conservation for the sake of future generations. **Chapter 12** provides a historical overview of environmental laws in India, beginning with the single law of the colonial era—the Indian Forest Act (1927)—and tracing the evolution to the current comprehensive suite of laws and regulatory bodies that protect and improve the environment. **Chapter 13** explores how remote sensing and GIS have revolutionized the approach to flood management, mapping flood risks and defining flood zones. The chapter evaluates various techniques, methodologies, and models used globally for urban flood management, underscoring the role of technology in keeping hazards under control. **Chapter 14** dissects the unique challenges of urbanization in Bihar, where a rapidly growing urban population grapples with environmental degradation and social disparities. The focus lies on the cities of Patna, Gaya, Bhagalpur, Muzaffarpur, and Darbhanga, as we explore how unchecked migration, illegal settlements, socio-cultural disparities, and infrastructure shortcomings contribute to environmental deterioration and threaten the quality of life.

Chapter 15 presents an in-depth analysis of the Network—the Internet—and its profound effects on our social life. As the world increasingly shifts online, we examine how this digital realm shapes our daily interactions, from shopping to learning, and the ramifications of this transformation on our societal structures, especially in the wake of the COVID-19 pandemic. **Chapter 16** unveils the grave reality of natural and man-made disasters affecting both developed and developing nations. It emphasizes the dire need for tools and methodologies to mitigate the disastrous impacts on human life, economy, infrastructure, and the environment. Highlighting the importance of technological advancements, the chapter delves into the role of remote sensing and GIS in disaster management, drawing from comprehensive reviews of existing research. In **Chapter 17,** the reader is taken through the historical transformation of Berhampur from an army cantonment chosen by the British to a bustling town. It underlines the interplay between politics, trade, and demography, leading to increased demand for quality water for various uses. The chapter provides insights into the complex dynamics of urban growth and the consequential strain on resources.

In **Chapter 18**, the researchers apply the genetic algorithm (GA) technique to optimize reservoir operation rule curves. The application was implemented in the KLRS Pulichintala project in India, resulting in operational insights and effectiveness projections under varying climate scenarios. **Chapter 19** examines the essential role of rivers in human well-being and the threats they face from sub-optimal investment decisions. It presents a conceptual framework explaining the connections between rivers and their societal, economic, and strategic benefits, emphasizing the importance of sustainable river management. Lastly, **Chapter 20** explores the issue of water shortage, focusing on groundwater availability for agriculture in the Pisangan Watershed. The researchers combine remote sensing data and GIS to identify potential groundwater zones, underscoring the necessity of modern techniques in water resource management.

Acknowledgments

The completion of this book, *Disaster Management and Environmental Sustainability*, is the culmination of numerous contributions from various individuals and institutions, without whom this monumental task could not have been realized. We would first and foremost like to extend our deepest appreciation to the reviewers who invested their time and expertise to refine the quality of our work. Their feedback and constructive criticism played an indispensable role in sharpening our arguments and illuminating the nuances of the complex topics we tackled. Their meticulous reviews not only ensured the accuracy of the presented information but also significantly enhanced its readability and accessibility. We also owe a significant debt of gratitude to our families, who provided us with the much-needed support, both emotionally and practically, throughout this demanding journey. Their patience, understanding, and unwavering belief in our efforts provided the constant encouragement that propelled us through the challenges and late nights. Their role in the creation of this book is as crucial as ours.

Our institutional heads deserve a special note of thanks. Their leadership, guidance, and vision were critical in providing the conducive environment necessary for undertaking a project of such a vast scale. They supported us unconditionally, lending us resources and fostering an atmosphere of intellectual curiosity that was critical for our work.

To our graduate students, we express our heartfelt gratitude. Their tireless efforts, spirited discussions, and intellectual vigor greatly enriched our research. Their fresh perspectives often led us to reconsider established notions and explore new directions. Their enthusiasm and dedication served as a constant reminder of why we embarked on this journey in the first place.

We would also like to extend our thanks to the support staff at our institutions. Their administrative, technical, and logistical assistance was invaluable in facilitating our research and ensuring our focus remained undivided on the intellectual tasks at hand. Lastly, we want to express our gratitude to our readers for embarking on this journey with us. We sincerely hope this book brings value to your understanding of environmental sustainability and disaster management.

Thank you, everyone, for making "Disaster Management and Environmental Sustainability" a reality. The journey has been as rewarding as the outcome, and we are glad to have undertaken it with all of you by our side.

Monday, 26 June 2023

Sanjay Kumar
Suraj Kumar Singh
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Editors

1

Assessment of Changes in River Morphology Due to Illegal Sand Mining by Geospatial Techniques

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Abstract

Illegal sand mining poses a significant threat to river ecosystems, causing detrimental impacts on river morphology and ecological balance. This chapter presents a comprehensive assessment of the changes in river morphology resulting from illegal sand mining on the Chambal River using advanced geospatial techniques. The study focused on the Aandva Purani site, heavily affected by illegal sand mining, and employed the end point rate (EPR) methodology to evaluate erosion and accretion processes. The analysis involved the examination of satellite data from Landsat 5 OLI (1990), Landsat 5 OLI (2000), Landsat 7 ETM+ (2010), and Landsat 8 OLI (2020) to track changes over time. Geometric correction and digitization techniques were applied to accurately delineate the river shoreline and identify illegal sand mining sites. The results revealed a significant proportion of erosional transects (52.17%) and accretional transects (47.83%) within the study area. The average erosion rate was calculated as –0.16 m/y, indicating the adverse effects of sand extraction on the river's morphology. Conversely, the average accretion rate was estimated as 0.19 m/y, highlighting the deposition of sediments resulting from altered flow patterns caused by illegal sand mining activities. Visual representations of the changes in river morphology between different time intervals were provided, emphasizing the temporal dynamics and trends observed. The findings underscore the urgency of implementing sustainable sand mining practices and regulations to preserve the Chambal River's integrity and protect its delicate ecosystems. This research serves as a valuable resource for policymakers, environmental agencies, and local communities in formulating strategies and policies to mitigate the adverse impacts of illegal sand mining on river systems and promote sustainable management practices.

***Keywords*:** Illegal sand mining, geospatial techniques, end point rate (EPR), erosion and accretion, sustainable sand mining practices, river morphology, average erosion rate, average accretion rate

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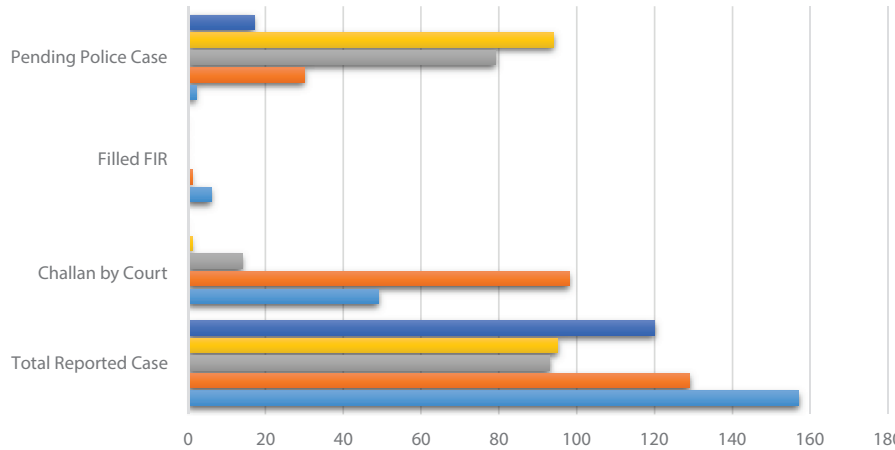
1.1 Introduction

According to the sand mining framework, India has an annual sand requirement of 70 million tons, predominantly driven by the booming construction industry. With each passing year, the demand for sand continues to rise steadily at a significant growth rate of 7% (Singh *et al.,* 2022a; Singh *et al.,* 2023b). This surge in demand can be attributed to the escalating construction activities across the country. As the construction sector expands, sand mining plays a vital role in meeting the soaring demand for this essential resource. Sand and gravel are crucial components used in various construction processes, including the production of concrete, mortar, and other building materials. The reliance on sand for construction purposes has transformed it into a highly sought-after commodity. Due to the tremendous demand–supply gap, sand has become a valuable resource, both economically and environmentally. The scarcity of quality sand reserves, coupled with the need for sustainable extraction Practices, has further contributed to the increasing value of sand. The escalating prices and the competition for limited sand resources have led to intensified efforts to regulate and manage the sand mining industry (Upadhyay *et al.,* 2023; Debnath *et al.,* 2022a). Efforts are being made to promote alternative materials and construction techniques to reduce the dependence on sand (Singh *et al.,* 2023b; Debnath *et al.,* 2022a). Additionally, governments and regulatory bodies are implementing stricter guidelines and policies to ensure responsible sand mining practices, safeguarding the environment, and mitigating the adverse impacts associated with excessive extraction. As India continues its rapid urbanization and infrastructure development, the demand for sand is expected to persistently rise. Balancing this growing demand with sustainable extraction practices and exploring alternatives will be crucial in ensuring the availability of this essential resource for construction activities while minimizing environmental consequences. Sand mining has adverse impacts on the lives and livelihoods of the people, especially those staying in close proximity to the river banks (Joy *et al.,* 2020; Debnath *et al.,* 2023b). One of the common problems faced due to sand extraction is river bank erosion. During heavy rains, water enters into the fields and other areas, destroying the crops. It also pollutes the local drinking water resources in the village. Sand mining has affected the ground water tables significantly, which has caused shortage of drinking water (Singh *et al.,* 2023; Debnath *et al.,* 2023c). When the rate of extraction of sand, gravel, and other materials surpasses the natural replenishment rate, it leads to a range of environmental issues. Sand mining, in particular, has been known to have detrimental effects on ecosystems, disrupting the natural cycle of sedimentation and impacting various habitats. The extraction of sand and gravel often involves the removal of topsoil, vegetation, and the alteration of landscapes (Farooq *et al.,* 2022b). This process not only leads to the loss of biodiversity but also disrupts the intricate balance within ecosystems. The morphological changes caused by mining activities can have long-lasting consequences on the surrounding environment. One of the primary impacts of sand mining is the alteration of riverbeds and coastal areas. Excessive extraction of sand from river channels and coastal regions can disrupt the natural flow of water, affecting sediment transport and leading to erosion and flooding in some cases. These changes in hydrological patterns can adversely impact aquatic ecosystems and the organisms that rely on them. Furthermore, sand mining can result in the destruction of habitats for various plant and animal species. Wetlands, dunes, and riverbanks often harbor unique ecosystems that are highly sensitive to disturbances. The removal of sand disrupts these habitats, displacing

organisms and reducing biodiversity. Additionally, the excavation and transportation of sand can cause air and noise pollution. Dust emissions during the mining process can have adverse effects on air quality, potentially leading to respiratory problems for both humans and wildlife. The operation of heavy machinery and transportation vehicles can generate noise pollution, further disturbing local ecosystems and wildlife. To address these environmental concerns, it is crucial to implement sustainable sand mining practices (Farooq *et al.,* 2022c). This includes the implementation of regulations and monitoring mechanisms to ensure responsible extraction, restoration of mined areas, and the promotion of alternatives such as recycled materials or artificial substitutes for sand in certain applications. By striking a balance between the demand for sand and the preservation of ecosystems, it is possible to mitigate the negative impacts of sand mining. Collaboration among stakeholders, including government bodies, mining companies, environmental organizations, and local communities, is essential to develop and enforce sustainable practices that protect the environment while meeting the needs of construction and development activities (Rafiq *et al.,* 2022).

A case has been filed against illegal sand mining in the Chambal National Sanctuary (Figure 1.1) to address violations, hold responsible parties accountable, and protect endangered species. Illegal sand mining disrupts the river's morphology and threatens the sanctuary's delicate ecosystems.

Demand for sand is increasing non-linearly, particularly in Asia, and especially for concrete production. China used more sand for concrete production in 2011 and 2013 than what the United States used during the entire 20th century. The scale of the problem can be better assessed if one considers the fact that 1 ton of cement can require up



	Total Reported Case	Challan by Court	Filled FIR	Pending Police Case
2022-23	120	0	0	17
2021-22	95	1	0	94
2020-21	93	14	0	79
2019-20	129	98	1	30
2018-19	157	49	6	2

Figure 1.1 Filed case against illegal sand mining in the Chambal National Sanctuary.

to 10 tons of sand to make concrete (Singh *et al.,* 2022b). In order to put an end to river and mining, The Ministry of Environment, Forest and Climate Change formulated the Sustainable Sand Management Guidelines 2016 (Singh *et al.,* 2023b), which focuses on the management of sand mining in the country. The study, The Monitoring of Riverbank Erosion and Shoreline Movement at Amu River Using Remote Sensing and GIS, found that the river movement was toward the Afghanistan side, *i.e.*, southward. The threat of losing Afghanistan land was estimated to be ca. 362.4 ha/y. The total eroded area was calculated to be 1984 ha, 1410 ha, and 1680 ha during the period of 2000–2005, 2005–2010, and 2010–2014, respectively. The shoreline was demarcated in each image and the area was categorized into three zones, corresponding to the erosion trend, *i.e.*, lower as moderate eroded zone, central as high eroded zone, and upper as lower eroded zone (Singh *et al.,* 2022). Figure 1.2 illustrates the direct and indirect impacts of the Chambal River, which have far-reaching consequences on both the natural environment and human communities. The Chambal River serves as a lifeline for the surrounding regions, providing water for irrigation, drinking, and other domestic purposes. Its fertile banks support agriculture and contribute to the livelihoods of local communities. However, the illegal sand mining activities taking place along the Chambal River have unleashed a series of detrimental effects. The extraction of sand disrupts the river's natural flow and alters its morphological characteristics. This leads to changes in sediment transport, erosion patterns, and overall river dynamics, negatively impacting the river's ecosystem.

The Chambal River, selected as the study area for assessing changes in river morphology due to illegal sand mining, is a significant river system located in central India. With a total length of approximately 960 km, it traverses through the states of Madhya Pradesh, Rajasthan, and Uttar Pradesh. As a tributary of the Yamuna River, it eventually joins the Ganges River, forming an essential part of the larger river network in the region.

Figure 1.2 Illustration of the direct and indirect impacts of illegal sand mining on the Chambal River.

1.2 Materials and Methods

The study incorporated satellite data from multiple time periods, including Landsat 5 OLI (1990), Landsat 5 OLI (2000), Landsat 7 ETM+ (2010), and Landsat 8 OLI (2020). These satellite images were used to assess the changes in the Chambal River over the course of several years. To begin the image processing, geometric correction was applied to the satellite images. This process involved rectifying any distortions or misalignments in the images to ensure accurate spatial representation. The next step involved the digitization of the baseline of the Chambal River using a topographic sheet from the survey of India. This provided a reference for the river's original position. Subsequently, the river shoreline was digitized using the satellite data from each respective year (1990, 2000, 2010, and 2020). This entailed delineating the water boundary along the river's edges in the satellite images. Figure 1.3 Study area map. (a) Map of India, illustrates the geographic context of the study area, (b) map showcases the state of Rajasthan in India, emphasizing the district divisions within the state, and (c) map focuses on the specific sites of illegal sand mining along the Chambal River.

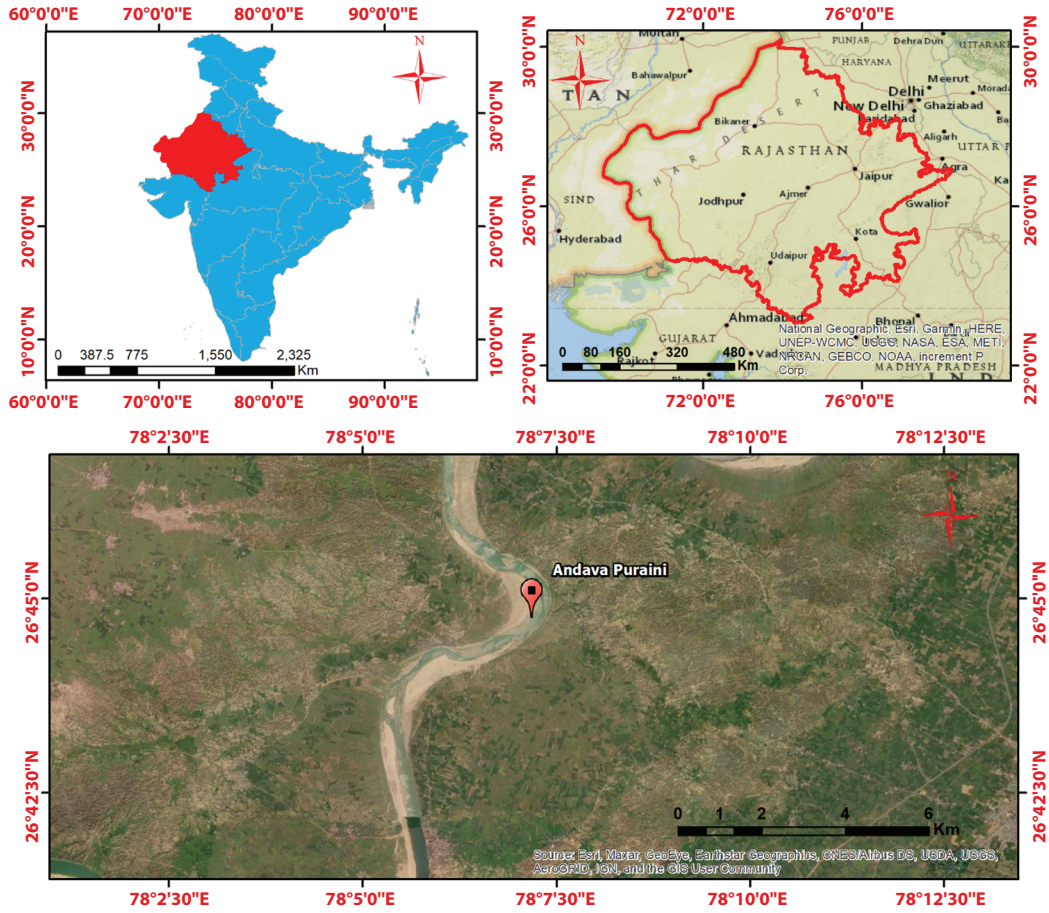


Figure 1.3 Study area map. (a) Map of India, illustrates the geographic context of the study area, (b) map showcases the state of Rajasthan in India, emphasizing the district divisions within the state, and (c) map focuses on the specific sites of illegal sand mining along the Chambal River.

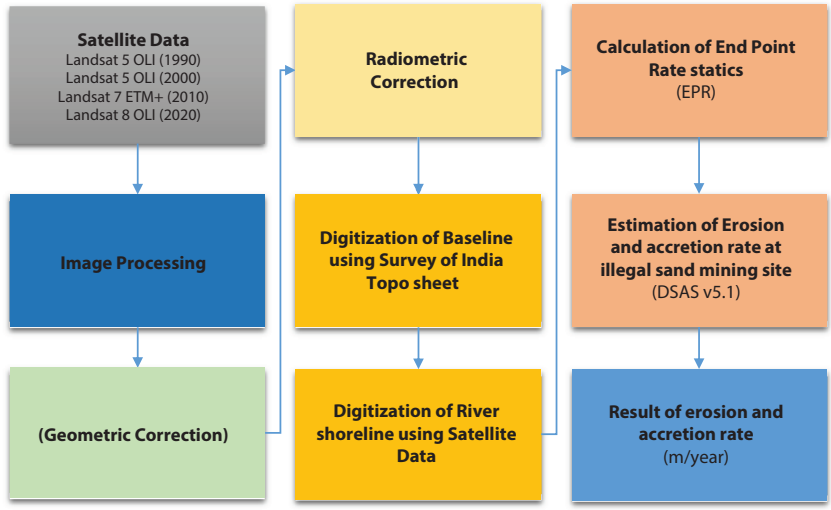


Figure 1.4 Methodology flow chart for assessing changes in river morphology due to illegal sand mining on the Chambal River using geospatial techniques.

To calculate the end point rate (EPR) statistics, a comparative analysis of the digitized shoreline data from different years was performed. The EPR measures the net change in the shoreline position over a specific time frame. By analyzing the changes in the shoreline, the rates of erosion (negative EPR values) and accretion (positive EPR values) (Singh *et al.,* 2023a; Sud *et al.,* 2023) were determined. The estimation of erosion and accretion rates at the illegal sand mining site was conducted using the DSAS v5.1 (Digital Shoreline Analysis System) software. This software enables quantitative analysis of shoreline changes. The digitized shoreline data from the different years were inputted into the software, which calculated the erosion and accretion rates specifically for the area affected by illegal sand mining. The results of the erosion and accretion rates were reported in meters per year (m/y), indicating the amount of erosion and accretion occurring over time.

1.3 Results and Discussion

By presenting the changes in river shoreline over different time intervals, Figure 1.5 allows for a comprehensive visual assessment of the Chambal River's erosion and accretion. The analysis focused on the Aandva Purani area and employed the EPR methodology to evaluate erosion and accretion processes. The results revealed a total of 23 transects analyzed, among these, 12 transects exhibited erosional characteristics, representing 52.17% of the total transects. The average erosion rate was calculated to be –0.16 m/y, indicating erosion on the illegal sand mining sites of Aandva Purani. Conversely, 11 transects showed signs of accretion, accounting for 47.83% of the transects, with an average accretion rate of 0.19 m/y, as show in in Table 1.1.

Figure 1.5 depicts the changes in river morphology over time, highlighting the alterations observed during different periods. Subfigure (a) specifically focuses on the changes that occurred between 1990 and 2000, providing insights into the river's morphology

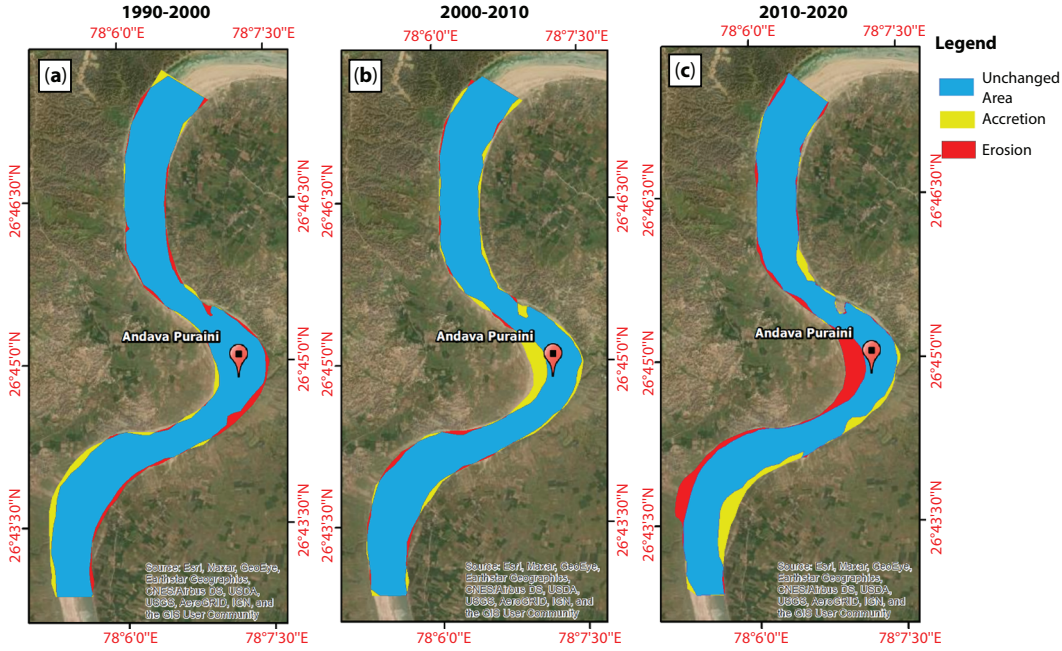


Figure 1.5 Changes in river morphology. (a) Showing the changes between 1990 and 2000, (b) showing the changes between 1990 and 2000, and (c) showing the changes between 2010 and 2020.

Table 1.1 End point rate of Aandva Purani.

Total number of transects 23
Number of erosional transects 12
Percent of all transects that are erosional 52.17%
Average of all erosional rates –0.16
Number of accretional transects 11
Percent of all transects that are accretional 47.83%
Average of all accretional rates 0.19

during that decade. Subfigure (b) presents the changes in river morphology between 2000 and 2010, shedding light on the transformations that took place during this period. By examining this subfigure, one can observe any shifts in channel alignment, changes in the river's shape, and alterations in sediment distribution. Comparing the river's morphology between these two time periods helps to identify any significant trends or patterns in river behavior and geomorphological changes. Lastly, subfigure (c) focuses on the changes in river morphology between 2010 and 2020, providing a more recent perspective on the river's evolution. This subfigure enables the examination of any recent developments, including changes in river course, erosion or deposition hotspots, and overall modifications in channel characteristics. Understanding the river's morphology during this period helps to

assess the current state of the river and identify any ongoing trends or potential concerns regarding illegal sand mining activities.

The findings suggest that illegal sand mining significantly impacted the river shoreline at illegal mining sites and it also impacted the Chambal River's morphology at the Aandva Purani site, as shown in Figure 1.6. The occurrence of erosional transects highlights the detrimental effects of sand extraction, leading to sediment removal and subsequent erosion. These visual representations aid researchers, policymakers, and stakeholders in

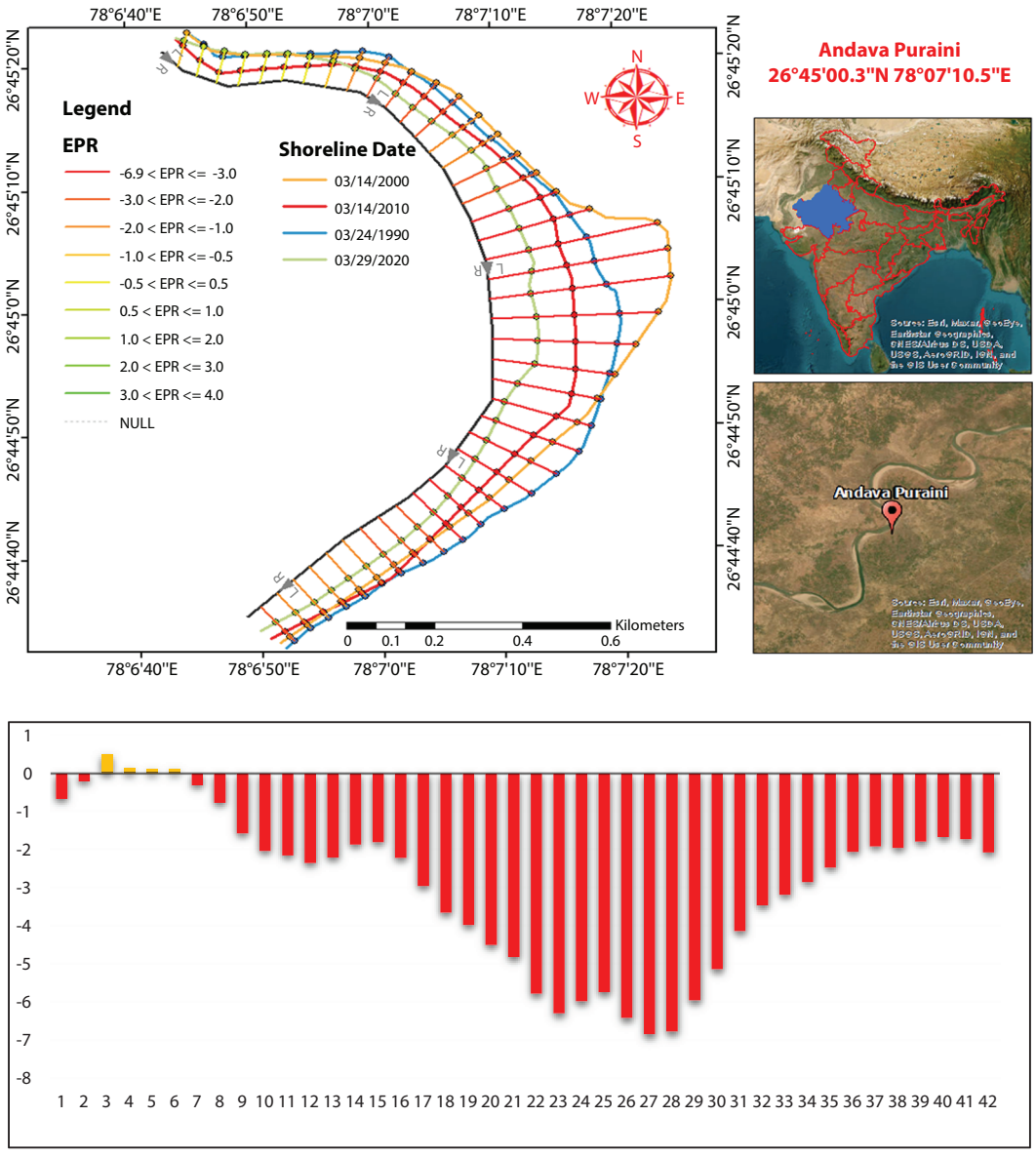


Figure 1.6 The erosion and accretion map by DSAS. (a) Showing end point rate of each transects and (b) showing rate of erosion and accretions of each transects in m/y.

understanding the temporal dynamics of the river, highlighting the need for sustainable management strategies to preserve the integrity and ecological balance of the Chambal River system. This phenomenon disrupts the river's natural equilibrium, resulting in channel instability and alterations to the riverbed. On the other hand, the presence of accretional transects indicates sediment deposition, potentially caused by altered river flow patterns resulting from illegal sand mining activities. Accretion can lead to the formation of sandbars, affecting the river's course and the overall dynamics of the ecosystem. The results emphasize the urgency of implementing effective measures to regulate and combat illegal sand mining within the Chambal River. It is crucial to safeguard the river's morphology and preserve its delicate ecosystem by enforcing sustainable sand mining practices. The findings of this study can serve as a valuable resource for policymakers, environmental agencies, and local communities in formulating appropriate strategies and policies to mitigate the adverse impacts of illegal sand mining on river systems.

1.4 Conclusion

In this study, we conducted a comprehensive assessment of the changes in river morphology resulting from illegal sand mining on the Chambal River using advanced geospatial techniques. Our findings provide compelling evidence of the direct and indirect impacts of this destructive activity on the river ecosystem. The analysis focused on the Aandva Purani site, which has been heavily affected by illegal sand mining. By employing the EPR methodology, we evaluated the erosion and accretion processes occurring in this area. The results revealed alarming trends, with a significant proportion of transects exhibiting erosional characteristics. Approximately 52.17% of the analyzed transects experienced erosion, indicating the detrimental effects of sand extraction on the river's morphology. Furthermore, our study identified 11 transects showing signs of accretion, representing 47.83% of the total transects. This suggests that sediment deposition is occurring, potentially due to altered flow patterns resulting from illegal sand mining activities. The average accretion rate of 0.19 m/y underscores the importance of understanding the dynamics of sedimentation in mitigating the impacts of sand mining.

This study emphasizes the severe impacts of illegal sand mining on the Chambal River shoreline. Erosion caused by sand extraction can disrupt the river's natural equilibrium, leading to channel instability and the destruction of the riverbed. Conversely, accretion can result in the formation of sandbars, altering the river's course and affecting the delicate balance of the ecosystem.

The implications of our findings are significant for policymakers, environmental agencies, and local communities. It is crucial to develop and enforce sustainable sand mining practices that prioritize the preservation of the Chambal River's morphology and ecological integrity. By implementing effective regulations and interventions, we can mitigate the adverse impacts of illegal sand mining and ensure the long-term sustainability of this invaluable river system.

Overall, our research highlights the urgent need to address the challenges posed by illegal sand mining on the Chambal River. By protecting the river's morphology and ecosystem, we can safeguard the diverse range of species, including endangered gharials, dolphins, turtles, and migratory birds, that rely on the river for their survival.