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(RESEARCH ARTICLE)

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Interplay between Estuarine Geomorphology and Anthropogenic Dependency in the Bichitrapur Mangrove Forest

Mintu Jana [1, *], Dipak Bisai [2] and Taniya Roy [3]

[1] *Coastal Environmental Studies, Egra Sarada Sashi Bhusan College, Egra , Purba Medinipur.*
[2] *Department of Geography, Egra Sarada Sashi Bhusan College, Egra, Purba Medinipur.*
[3] *Department of Geography, Bajkul Milani Mahavidyalaya, Egra, Purba Medinipur.*

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Abstract

The Bichitrapur mangrove ecosystem, situated at the confluence of the Subarnarekha estuary in Odisha, represents a complex interaction between coastal geomorphic processes and socio-economic activities. This study investigates the geomorphological characteristics of the region and evaluates the extent of anthropogenic dependency on its mangrove resources. Utilizing a mixed-method approach, the research integrates geospatial analysis of estuarine landforms, such as beach ridges and cheniers, with primary household surveys across neighboring villages. Results indicate that the unique geomorphic setup fosters a rich biodiversity of mangrove species, including *Avicennia marina* and *Excoecaria agallocha*, which serve as the primary source of livelihood for approximately 50% of the local population through fishing and forest product collection. However, the study reveals a significant socio-economic vulnerability, with 100% of respondents expressing dissatisfaction with current resource management and economic stability. The findings highlight a critical need for sustainable management strategies that balance the preservation of the estuarine geomorphology with the socio-economic development of the dependent communities.

Keywords: Estuarine Geomorphology; Mangrove Ecosystem; Anthropogenic Dependency; Subarnarekha Estuary; Bichitrapur; Coastal Livelihood

1. Introduction

Mangrove ecosystems are among the most productive and biologically diverse biomes on Earth, situated at the dynamic interface between terrestrial and marine environments. These ecosystems play a pivotal role in coastal protection, carbon sequestration, and supporting regional biodiversity. In the context of the East Coast of India, the Subarnarekha estuarine complex serves as a critical geomorphic unit, where the interplay of fluvial and marine processes creates unique landforms such as chenier ridges, mudflats, and sand dunes. The Bichitrapur Mangrove Forest, located at the mouth of the Subarnarekha River in the Balasore district of Odisha, represents a unique ecological niche. This region is characterized by its specific geomorphological evolution, which provides a suitable habitat for mangrove species like *Avicennia marina* and *Excoecaria agallocha*. The formation of the deltaic plain and the constant sediment supply from the Subarnarekha River have historically shaped the spatial distribution of these mangroves. However, the survival and health of these estuarine landforms are increasingly influenced by anthropogenic factors. Coastal communities residing in the fringes of Bichitrapur exhibit a profound dependency on the forest for their daily sustenance. From artisanal fishing to the collection of fuelwood and medicinal plants, the local household economy is intricately tied to the mangrove's health. This dependency often creates a complex socio-ecological tension, where economic necessity meets environmental conservation.

Despite its ecological significance, the Bichitrapur mangrove area faces challenges from shifting estuarine dynamics and increasing human pressure. While previous studies have focused separately on the geomorphology of the Odisha coast

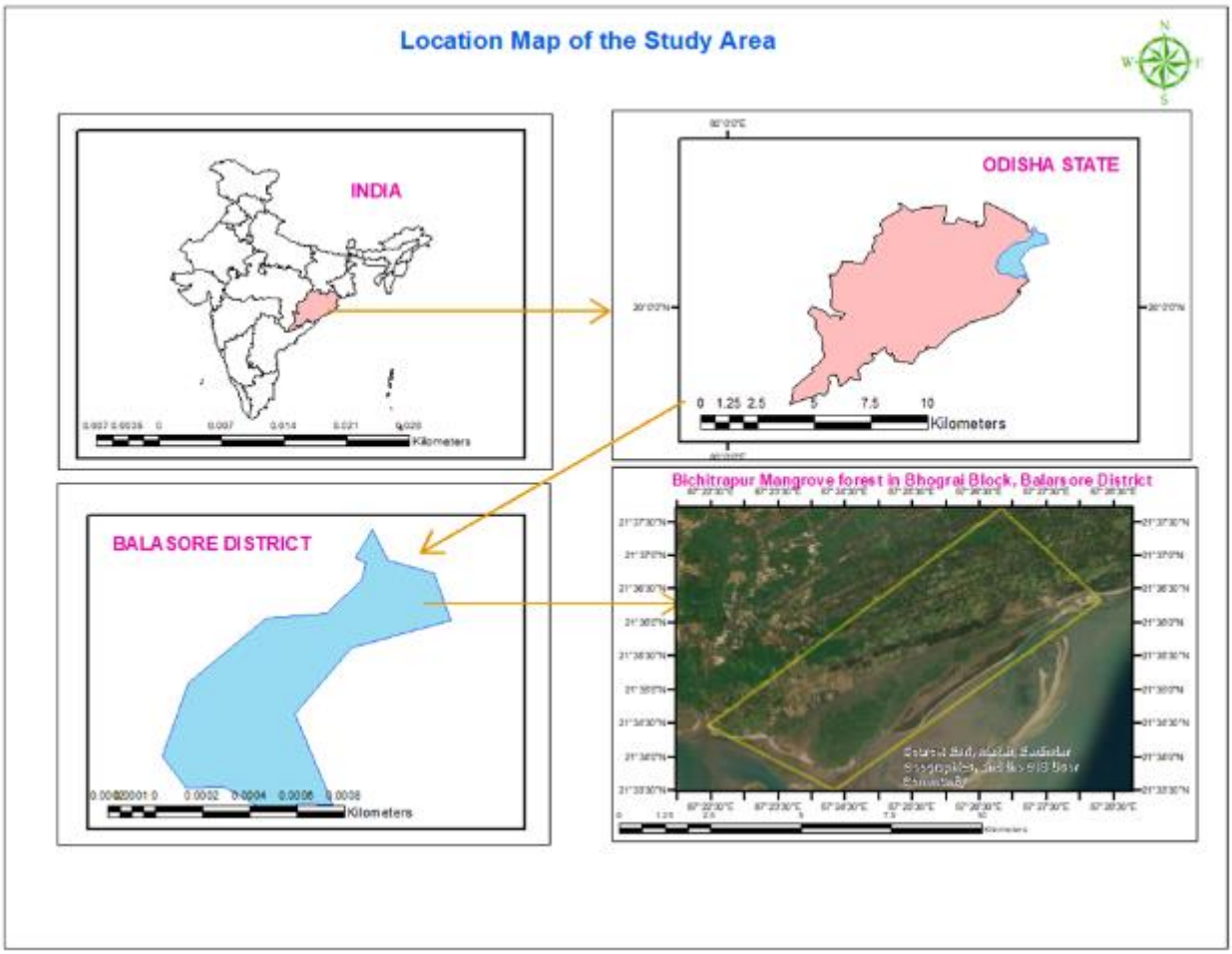
* Corresponding author: Mintu Jana

or the general ecology of mangroves, there is a research gap in understanding the direct "interplay" between the specific landform evolution and the degree of household dependency in this particular estuarine pocket. Therefore, this study aims to bridge this gap by mapping the geomorphological features of the Bichitrapur estuary and analyzing the socio-economic status of the local villagers. By exploring this relationship, the research seeks to provide a scientific basis for sustainable coastal management that integrates both geomorphic preservation and community livelihood security.

2. Study Area Description

2.1. Geographical Location

The study was conducted in the Bichitrapur Mangrove Forest, which is situated at the confluence of the Subarnarekha River with the Bay of Bengal. Geographically, it is located in the Bhograi Block of Balasore district, Odisha, on the eastern coast of India. The area lies approximately 18 km from Digha (West Bengal) and 59 km from the district headquarters, Balasore. The study site is positioned at an average elevation of 3 meters (9.8 ft) above mean sea level.



2.2. Geomorphological Setting

The region is a part of the Subarnarekha deltaic plain, characterized by a complex network of estuarine channels, mudflats, and sand dunes. The geomorphology is dominated by Chenier ridges and beach ridges, which have been shaped by both fluvial (riverine) deposits from the Subarnarekha and marine processes from the Bay of Bengal. These landforms provide the necessary substrate for the development of a unique mangrove ecosystem.

2.3. Climate and Hydrology

The area experiences a tropical monsoon climate. The hydrological regime is influenced by the semi-diurnal tidal cycles of the Bay of Bengal, which ensures a regular supply of saline and brackish water, essential for mangrove survival. The Subarnarekha river mouth acts as a primary source of freshwater and nutrient-rich sediments, particularly during the monsoon season.

2.4. Flora and Fauna

The Bichitrapur sanctuary is a biodiversity hotspot. The forest is dominated by mangrove species such as *Avicennia marina*, *Excoecaria agallocha*, and *Phoenix paludosa*. These species exhibit climax characteristics suited to the saline estuarine environment. The ecosystem supports various marine and pelagic species, including crabs, mollusks, and diverse fish fauna, which form the ecological backbone of the region.

2.5. Socio-Economic Context

The fringe areas of the mangrove forest are inhabited by local communities who are primarily dependent on the estuary for their livelihood. The villages under study show a high prevalence of traditional housing (approx. 50% *Kancha* houses) and a demographic heavily reliant on artisanal fishing and the collection of non-timber forest products (NTFP) such as fuel-wood and medicinal plants.

3. Objectives of the Study

The primary goal of this research is to evaluate the relationship between the physical environment of the Bichitrapur mangrove and the socio-economic structure of the surrounding population. The specific objectives are:

- To map and analyze the geomorphological features of the Subarnarekha estuarine mouth and the Bichitrapur mangrove ecosystem.
- To identify the dominant mangrove species and assess their ecological characteristics within the study area.
- To investigate the nature and extent of household dependency on mangrove resources for livelihood, including food, fuel, and timber.
- To evaluate the socio-economic status of the local villagers and their perception of current forest management and sustainability.

4. Methodology

To achieve the aforementioned objectives, a systematic methodology was adopted, integrating both spatial and socio-economic data. The study was conducted in three major phases:

4.1. Pre-Field Work

- Literature Review: Extensive review of existing research on the Subarnarekha delta, geomorphology by D. Niyogi (1970), and mangrove ecology.
- Data Acquisition: Collection of secondary data from government reports, District Census Handbooks (2011), and topographical maps.
- Geospatial Data: Procurement of satellite imagery (Google Earth and Sentinel-2) to identify the spatial extent of mangroves and estuarine landforms.

4.2. Field Work (Primary Data Collection)

- Geomorphic Observation: Direct field observation and photography were used to document landforms like beach ridges, cheniers, and tidal mudflats.
- Household Survey: A structured questionnaire was administered to the local villagers in the fringe areas of Bichitrapur. Random sampling was used to select households to capture diverse socio-economic backgrounds.
- Biological Survey: Identification of mangrove flora (e.g., *Avicennia marina*, *Excoecaria agallocha*) and fauna through on-site forest visits and interaction with local forest dwellers.

4.3. Post-Field Work (Data Processing & Analysis)

- Statistical Analysis: The collected household data were tabulated and analyzed using descriptive statistics to understand dependency patterns and income levels.
- Cartographic Representation: Maps were generated to show the study area location and the distribution of geomorphic features.
- Diagrammatic Representation: Quantitative data were represented through various charts (Bar charts, Pie diagrams) to interpret satisfaction levels, occupation patterns, and housing types.

5. Results and Discussion

5.1. Geomorphological Observations

The study identifies the Bichitrapur region as a highly dynamic estuarine environment. The mouth of the Subarnarekha river facilitates the formation of Chenier ridges and beach ridges, which are the primary geomorphic units.

- Tidal Mudflats: These areas are enriched with fine-grained sediments, providing an ideal substrate for mangrove colonization.
- Estuarine Dynamics: The continuous supply of sediment from the Subarnarekha river, coupled with tidal ingress from the Bay of Bengal, maintains the brackish water environment necessary for the climax character of the mangrove species.

5.2. Analysis of Mangrove Biodiversity

Field investigations reveal a rich floral diversity. The dominant species identified are *Avicennia marina* and *Excoecaria agallocha*. The presence of pneumatophores (respiratory roots) and salt-excreting leaves are prominent morphological adaptations observed. These forests act as a natural barrier, protecting the inland areas from coastal erosion and storm surges.

5.3. Household Socio-Economic Profile

The survey data highlights a significant reliance on the mangrove ecosystem:

- Housing Patterns: Approximately 50% of the households live in *Kancha* (mud and thatch) houses, indicating a lower economic status and a high potential for utilizing forest materials for construction.
- Occupational Structure: Fishing is the mainstay of the economy, with 50% of the respondents directly involved in artisanal fishing within the creeks. The remaining population is engaged in labor or small-scale NTFP (Non-Timber Forest Products) collection.

5.4. Anthropogenic Dependency and Resource

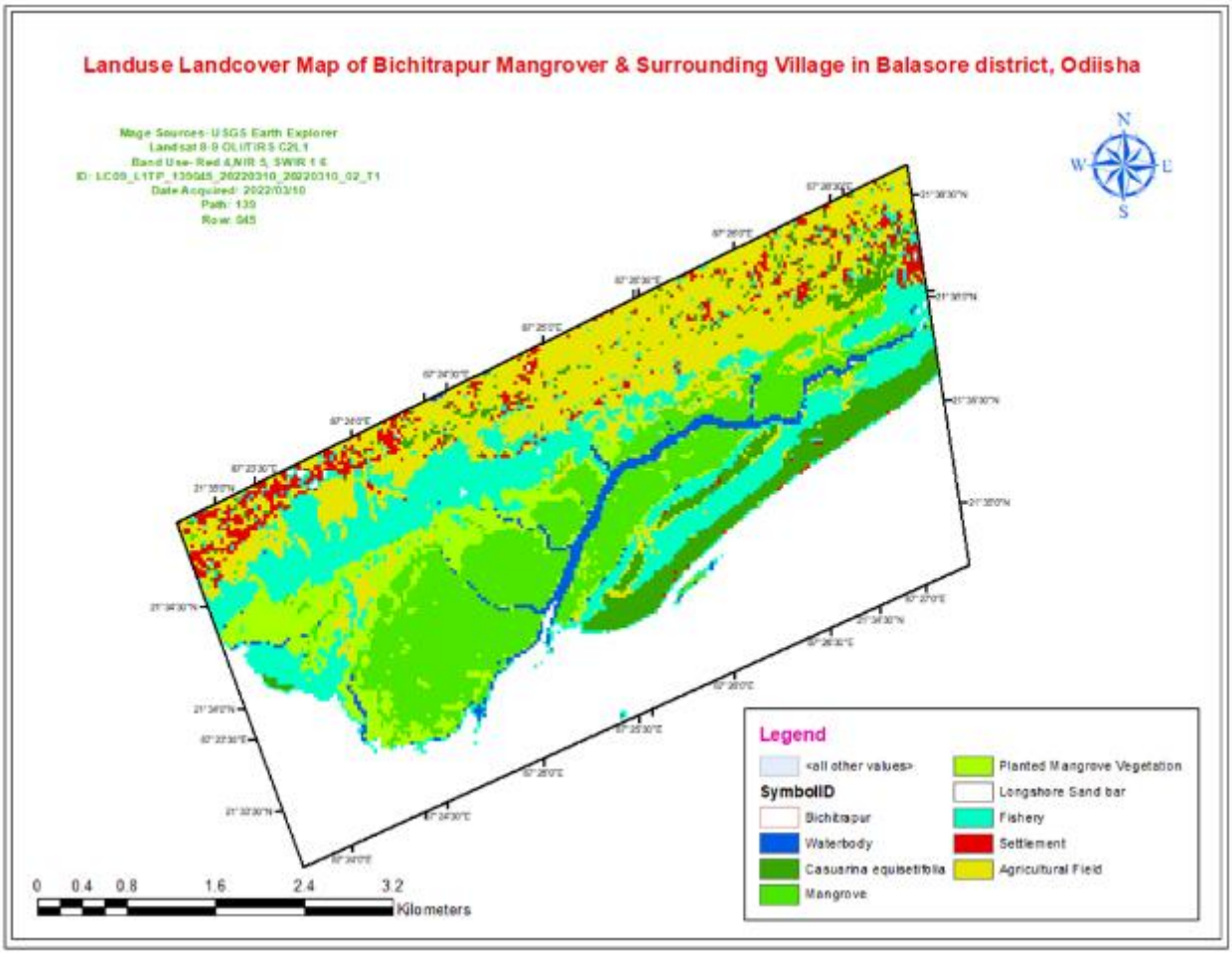
Utilization The local community exhibits a multi-dimensional dependency on the forest:

- Fuel and Food: A vast majority of the households depend on the mangrove for fuelwood and protein sources (fish, crabs, and mollusks).
- Economic Vulnerability: One of the most striking findings is that 100% of the respondents expressed dissatisfaction with their current economic stability and the existing resource management systems. This indicates a gap between the potential of the ecosystem (including tourism) and the actual benefits reaching the local community.

6. Discussion

The Interplay The interplay between geomorphology and human dependency is evident. The geomorphic stability of the beach ridges directly affects the extent of mangrove cover, which in turn dictates the availability of resources for the villagers. However, the high degree of dependency, if not managed through sustainable tourism and alternative livelihoods, may lead to the degradation of these sensitive estuarine landforms. The recent surge in tourism in Bichitrapur offers a potential pathway for economic diversification, provided it is managed under an eco-tourism framework.

6.1. Landuse and Landcover (LULC)



6.2. Vegetation Identification

Name of the Plant		Characteristics	Figure
Local Name	**Scientific Name**		
Beubeta Mangrove	Beubeta Excoecaria	Plant division angiosperms2. Maximum height 15 m. 3.Plant shape irregular. 4. Plant growth from tree shrubs.	
Geria	Suaeda Meritima	1.Its grow to about 35 cm in salt marshes. 2. height is 7 – 10 cm. 3. Known by the common names henbaeeous secpwed and annual seablite. 4. It is the yellow – green shrubs with fleshy, succulent leaves and green flowrs.	

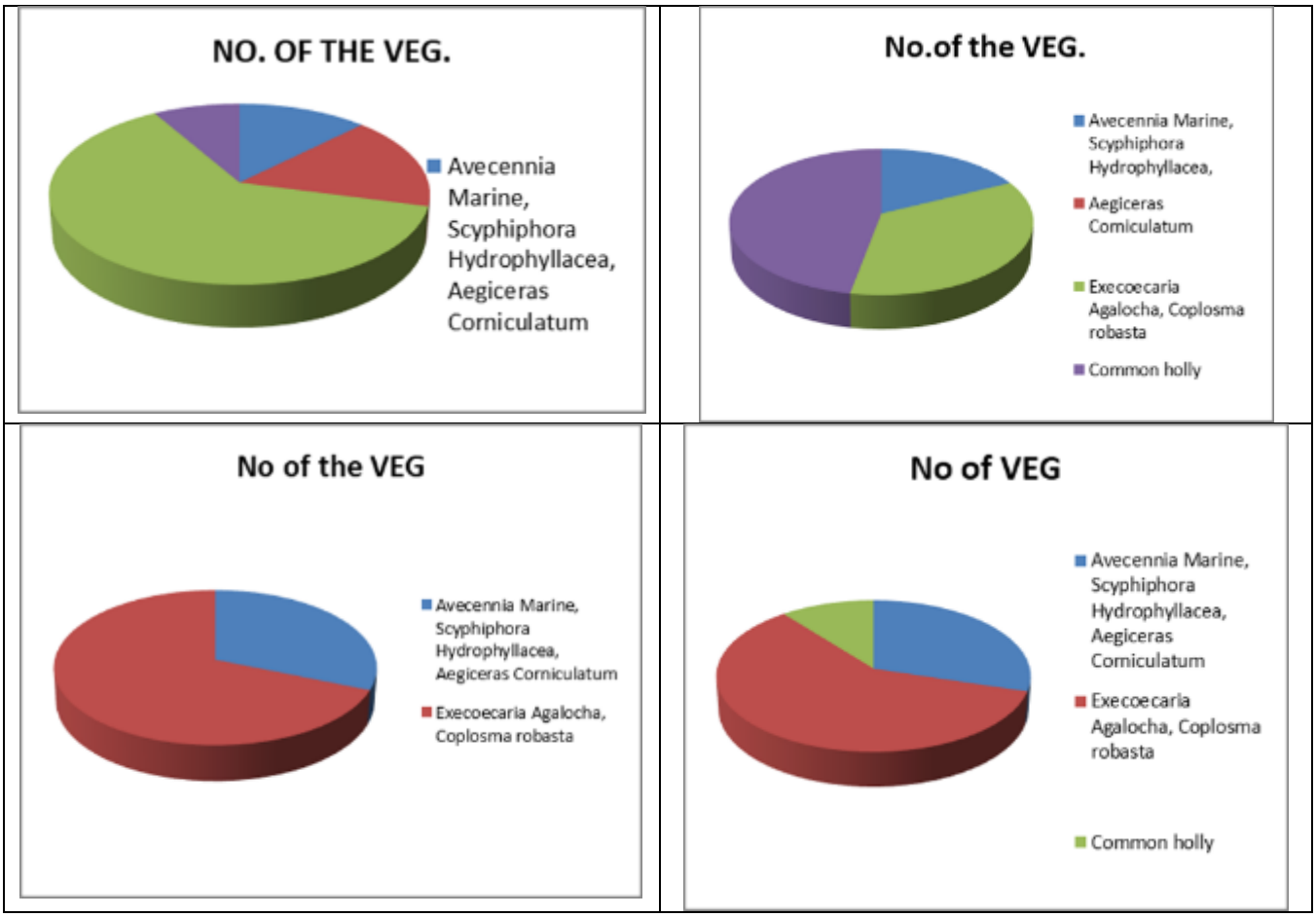
Horgocha Plant	Common Holy	1.Holies have alternative simple leaves. 2. The leaves of many species have wavey margins tripped with spines. 3. The height is 90 -100cm. 4.The male and female flowers are usually borne on separate plants.	
Graymang	Avicennia Merina	1.It has smooth height grey bark made up of thin, stiff brittle flakes. 2. The leaves are thik. 3.Height 5- 8 cm long. 4. Upper sun face is bright ,glossy and green.	
Black Mangrove	Aegiceras Cornicultum	1.Small evengreen trees. 2.Height is 6 cm leave. 3.Flower fragnant white. 4.Fruit capsule in brunches, yellow, cresent shaped with painted apex.	
Buttabutta mangrove	Excoecaria Agallocha	1.Plant division is angiosperms. 2. Lifespan is perinmial. 3.Mode of nutrition autotropic. 4. Maximum height is 15 m.	
Spurred Mangrove	Ceriops.	1.Ceriops tagal is a shubs or small tree with compact crown. 2.It usually grow up to 6m. 3.Bark fleekeing,high grey,smooth with buttress roots and thin breathing roots. 4. Branches are large,thick7 almost fleshy &bmarked with scars.	
Red mangroves	Rizophora Stylosa	1.plant division is angiosperms. 2.Life span is perennial. 3.maximum height is 20m. 4.Mode of nutrient auto tropic. 5.Stilt roots measuring up to 3m.	

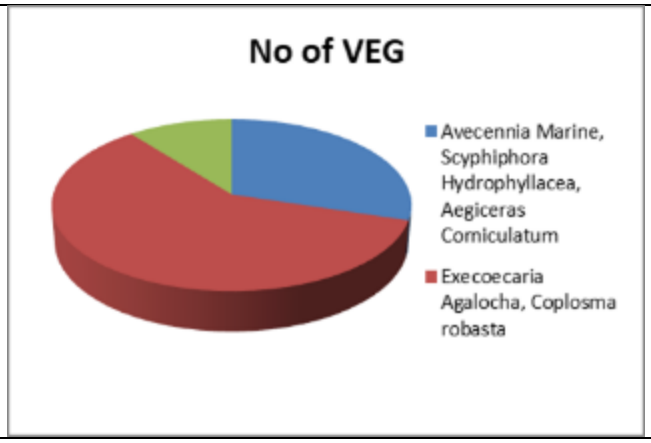
Portulaca Oleracea	Common Purslane	1.Succulent Leaves. 2.Small yellow petaled flowers. 3.The fleshy stems are from 10 – 30cm long. 4. The pale yellow flowers,3-10 mm broad.	

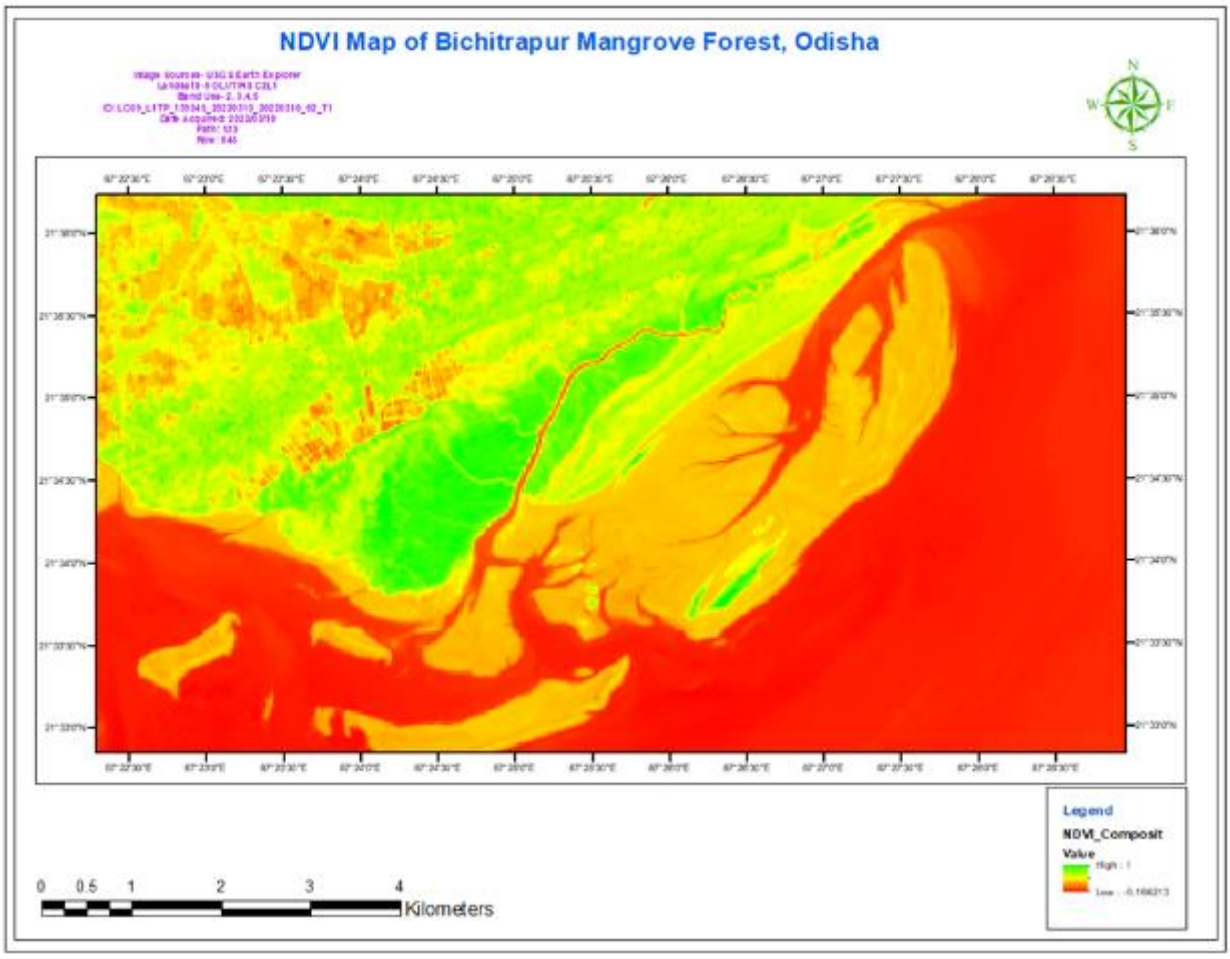
6.3. Vegetation density of Bichitrapur

GRID NAME	AREA(m)	F	% OF VEG.	C.C.	VEG. RICHNESS	HIGHEST HEIGHT (m)	LOWEST HEIGHT (m)	V.C.C.	NAME OF THE VEG.	NO. OF THE VEG.
A	*30.5/18*	*48*	*40%*	*2.5*	*Common holly- 30*	*6.5*	*0.5*	*yes*	*Avecennia Marine, Scyphiphora Hydrophyllacea, Aegiceras Corniculatum*	*6*
									Execoecaria Agalocha, Coplosma robasta	*8*
									Common holly	*30*
									Common Purslane, Suaeda Meritima	*4*
B	*25/25*	*85*	*60%*	*3*	*Common holly- 40*	*6.5*	*0.5*	*yes*	*Avecennia Marine, Scyphiphora Hydrophyllacea, Aegiceras Corniculatum*	*15*
									Execoecaria Agalocha, Coplosma robasta	*30*
									Common holly	*40*
C	*30/30*	*90*	*50%*	*2*	*Execoecaria Agalocha, Coplosma robasta- 55*	*6.5*	*2*	*yes*	*Avecennia Marine, Scyphiphora Hydrophyllacea, Aegiceras Corniculatum*	*25*
									Execoecaria Agalocha, Coplosma robasta	*55*
									Common holly	*10*
D	*7.5/20*	*47*	*55%*	*2.5*	*Execoecaria Agalocha- 28*	*6*	*1.5*	*yes*	*Avecennia Marine, Scyphiphora Hydrophyllacea, Aegiceras Corniculatum*	*14*

									Execoecaria Agalocha, Coplosma robasta	*28*
									Common holly	*5*
E	*15/15*	*39*	*40%*	*3*	*Execoecaria Agalocha- 29*	*6.5*	*.02*	*yes*	*Avecennia Marine, Scyphiphora Hydrophyllacea, Aegiceras Corniculatum*	*8*
									Execoecaria Agalocha, Coplosma robasta	*29*
									Common holly	*2*







6.4. Vegetation Climax Character

- Mangrove wetland vegetation are characterized by such qualities as a humid climate , saline environment, waterlogged soil or muddy soil.
- Their capable of tolerating salinity ranging from 2- 90 %.
- They contain a complex salt filtration system and a complex root system to cope with saltwater immersion and wave action.
- Mangroves are almost exclusively tropical,but occurs in the subtropics. They do not tolerate frost, but can cope with air temperature down to 5 degree c.
- Their occurance is most closely related to seawater temperature and grow best in water that is 50% freshwater and 50% seawater l.

- They do share the unique capability of growing within reach of the tides in salty soils .

6.5. Ghost tree - cause and significance :-

Ghost forest are areas of dead trees in former forest typically in coastal region where rising sea levels or tectonic shifts have altered the height of ladmass.

The breathing roots of mangrove are trapped by overwash sand fan lobes.

Half of the tree trunks and intertidal Swamp floors are deposited by encroachment sand in the storm.

Mangroves. are killed by transgressive sand sheet.

Techtonic activity: -

Where, in a convergent plate boundary, there has been orogenic uplift, followed by the earquake creating ghost forest.
Tusunamis :

Large earthquake can also cause tusunamis. It is possible to determine that ghost were created by earthquake.

Global warming: -

As a result of global warming direct effect of temperature & indirect effects of larvae feeding in the phloem tissue of tree, creating ghost forest.

Significance:: -

- Ghost tree are striking of sea level driven and land conversion. So we understand the aggression of sea.
- It protect from various coastal erosion, wave , flood etc.
- Ghost tree provides fuel on nearest living people's.

6.6. Various Types of Vegetation

6.7. Sediment Facies Assessment

We have studies the three layer of sediment in this field area. We have asses the three layer and fine that three layer are parallel orientation and no cross bed found. In this soil layer three laminated layer organic blackish layer present in between two layer.

Soil profile of the study area : -

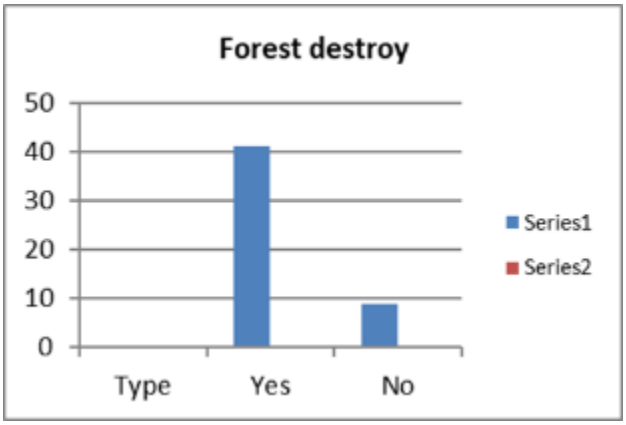
In study area 5 type of soil profile are observed.

Sedimentological Character of the Study area

- Medium sand and ash color seen in the layer of A3.
- Clay, fine sand and reddish brown color seen in the layer of A4 and A6.
- Fine sand, silt, brownish black are observed in the layer A7.

Soil Chemical properties

6.8. Household data Manipulation


Forest destroy
50
40
30
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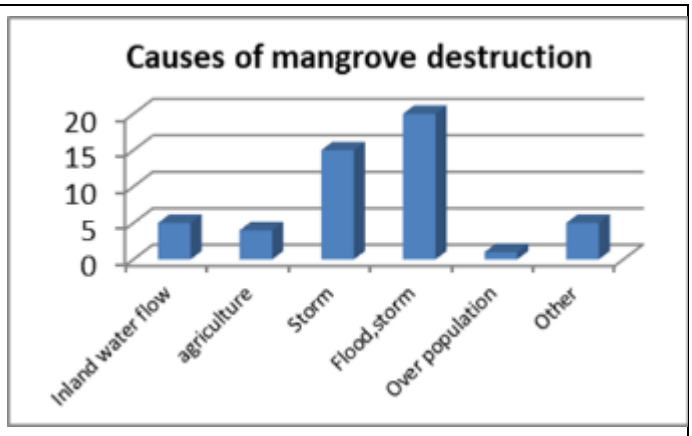
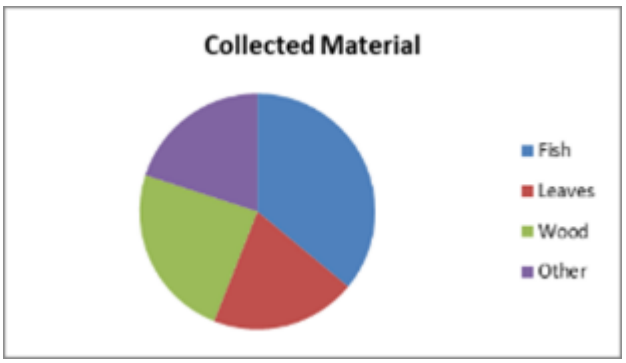
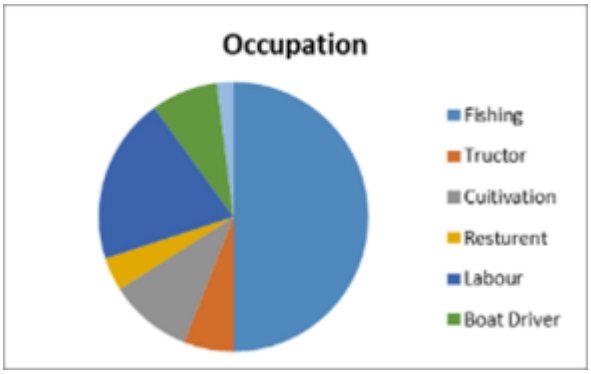
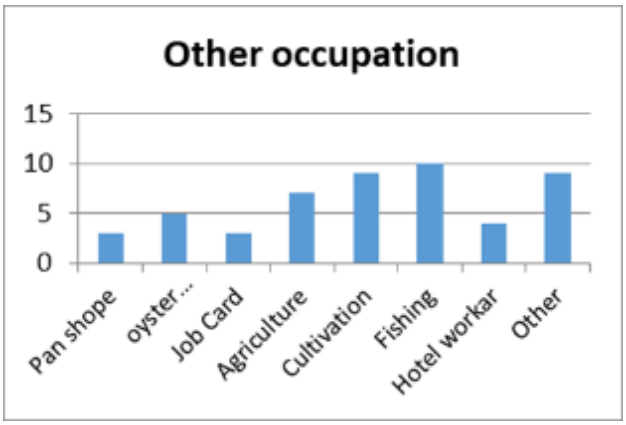
10
0
Type
Yes
No
Series1
Series2


Causes of mangrove destruction
20
15
10
5
0
Inland water flow
agriculture
Storm
Flood,storm
Over population
Other


Collected Material
Fish
Leaves
Wood
Other


Occupation
Fishing
Tructor
Cultivation
Resturent
Labour
Boat Driver


Other occupation
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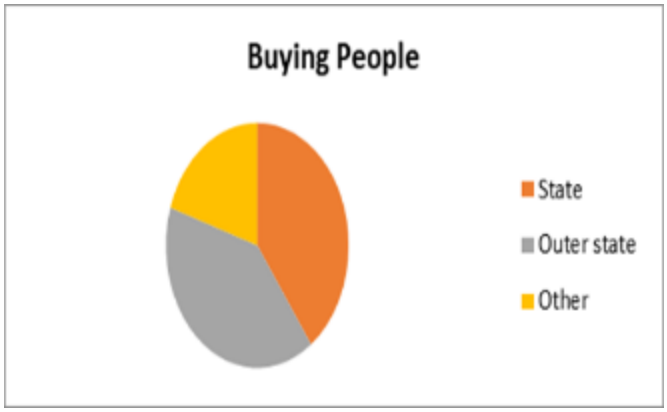
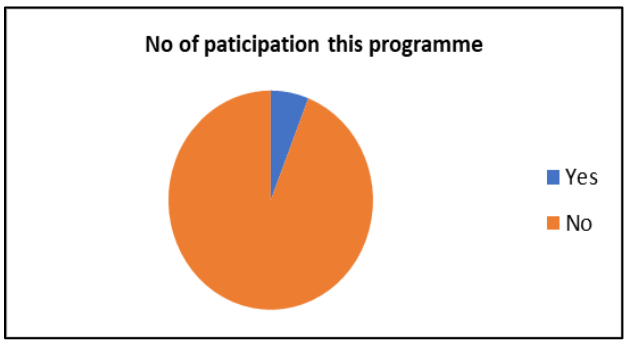
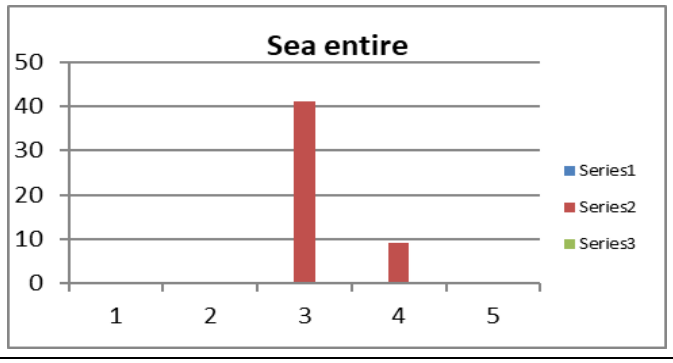

Buying People
State
Outer state
Other


No of paticipation this programme
Yes
No


Sea entire
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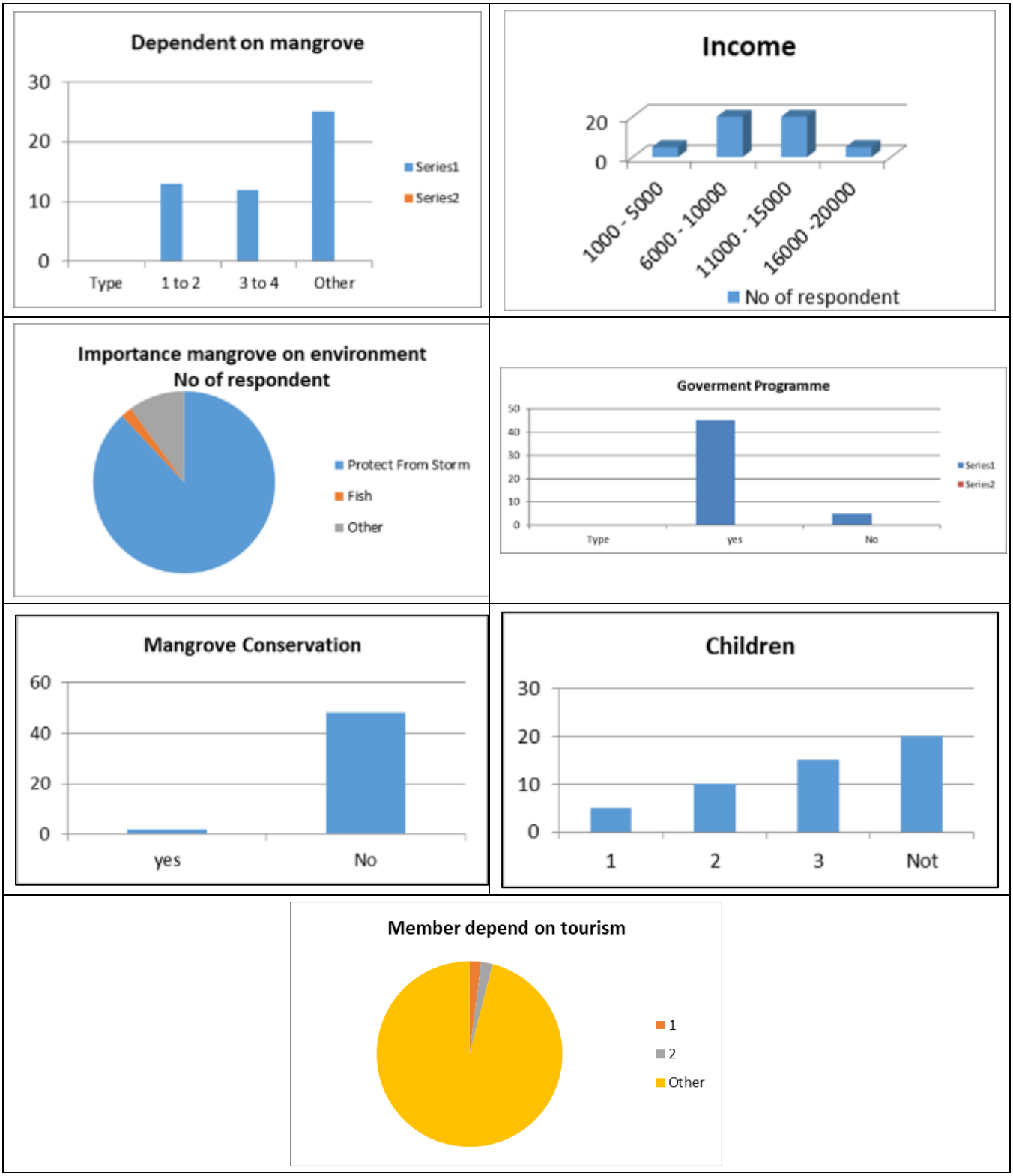
30
20
10
0
1
2
3
4
5
Series1
Series2
Series3



7. Major Findings

The research on the Bichitrapur mangrove ecosystem and its socio-economic interface has yielded the following key observations:

7.1. Geomorphological Stability and Landforms:

The study area is characterized by distinct landforms such as chenier ridges, beach ridges, and extensive mudflats. These geomorphic units are crucial for the natural colonization and expansion of mangroves.

The Subarnarekha estuary plays a vital role in sediment deposition, which has led to a noticeable increase in the mangrove cover in this part of the Balasore district.

7.2. Ecological Dominance:

The forest exhibits a specialized biodiversity, with *Avicennia marina* and *Excoecaria agallocha* being the climax species. These species are well-adapted to the semi-diurnal tidal cycles and varying salinity levels of the estuary.

The ecosystem acts as a significant "bio-shield," protecting the coastal villages of Bhograi block from the direct impact of cyclonic surges and coastal erosion.

7.3. Socio-Economic Dependency:

Livelihood: Fishing is the primary occupation, with 50% of the households directly dependent on the estuarine creeks for their daily income.

Resource Extraction: There is a heavy reliance on the mangrove forest for Non-Timber Forest Products (NTFP), specifically for fuelwood, traditional medicine, and protein sources (crabs and mollusks).

Housing: A high percentage of the population (50%) resides in *Kancha* (temporary) houses, which reflects both the economic vulnerability of the region and the local use of forest-derived materials for construction.

7.4. Management and Sustainability Gaps:

Economic Dissatisfaction: A critical finding of the survey is that 100% of the respondents reported a lack of satisfaction with their current economic status and the existing resource management framework.

Tourism Potential: While Bichitrapur is emerging as a significant ecotourism and research spot, the local communities feel a disconnect between the revenue generated from tourism and their personal socio-economic upliftment.

Awareness: Although the villagers are aware of the forest's importance, the lack of alternative livelihood options forces a continued high-pressure dependency on the mangrove's natural resources.

8. Conclusion

The study on the "Interplay between Estuarine Geomorphology and Anthropogenic Dependency in the Bichitrapur Mangrove Forest" underscores the critical link between the physical evolution of coastal landforms and the socio-economic survival of fringe communities. The geomorphological setup of the Subarnarekha estuary, characterized by its unique chenier ridges and tidal mudflats, provides an indispensable ecological niche for mangrove species like *Avicennia marina*. These landforms not only support a rich biodiversity but also act as a primary life-support system for the local population. The findings reveal a profound dependency of the local households on mangrove resources, with fishing and NTFP collection being the pillars of the local economy. However, the high level of economic dissatisfaction (100% of respondents) and the prevalence of inadequate housing conditions highlight a significant gap in the current developmental framework. While the geomorphic stability of the region allows for mangrove expansion, the intense anthropogenic pressure, driven by poverty and a lack of alternative livelihoods, poses a potential threat to this sensitive ecosystem. To ensure the long-term sustainability of the Bichitrapur mangrove forest, the study suggests a shift towards a community-based conservation model. Integrating the local community into the emerging ecotourism sector could provide the necessary economic diversification to reduce direct forest dependency. Furthermore, coastal management policies should prioritize the protection of the Subarnarekha estuarine dynamics to maintain the natural geomorphic processes that sustain these mangroves. Ultimately, the synergy between geomorphic preservation and socio-economic upliftment is essential for the resilience of both the environment and the people of Bichitrapur.

9. Suggestions and Management Strategies

Based on the findings of the study, the following strategies are proposed for the sustainable management of the Bichitrapur mangrove ecosystem and the upliftment of the dependent communities:

9.1. *Promotion of Community-Based Ecotourism (CBET)*: Since Bichitrapur is an emerging tourist spot, the management should transition from general tourism to a community-led model.

Suggestion: Local youth can be trained as nature guides and boat operators. This will create a direct link between conservation and income, reducing the 100% economic dissatisfaction currently observed.

Benefit: It provides an alternative to timber collection and over-fishing.

9.2. *Habitat Restoration and Geomorphic Monitoring*: The stability of the Subarnarekha estuary is vital for mangrove health.

Suggestion: Regular monitoring of shoreline changes and sedimentation rates using Remote Sensing and GIS is necessary.

Action: Afforestation programs should prioritize climax species like *Avicennia marina* in the newly formed mudflats to stabilize the landforms.

9.3. *Diversification of Livelihoods*: To reduce the heavy anthropogenic pressure on forest resources (fuelwood and fishing):

Suggestion: Introduction of scientific "Aquasilviculture" (integrating fish farming with mangrove protection).

Action: Promoting Self-Help Groups (SHGs) for value-added mangrove products (e.g., honey collection) and sustainable poultry or cattle rearing to decrease the dependency on *Kancha* house materials.

9.4. *Infrastructure and Disaster Resilience:* Given that 50% of the population resides in *Kancha* houses:

Suggestion: The government should facilitate the conversion of vulnerable houses into disaster-resilient permanent structures under rural housing schemes.

Action: Construction of multi-purpose cyclone shelters near the forest fringes to ensure safety during estuarine surges.

9.5. Strengthening Institutional Frameworks:

Suggestion: Establishing a "Joint Mangrove Management" (JMM) committee involving the Odisha Forest Department and local village heads.

Benefit: This will bridge the gap between policy-making and the actual needs of the villagers, ensuring transparent resource distribution.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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