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Climate Change and Mangrove Forest: Case Study of a Coastal District in Odisha, India

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***Abstract*— Mangroves are among the most delicate ecosystems on the planet and are increasingly threatened by climate change. Rising sea levels, ocean acidification, and shifting weather patterns pose significant risks to mangrove forests. This study emphasizes regional variations in climate change impacts and examines how these changes affect mangrove biodiversity, community structures, and geomorphological features. Secondary data from sources such as the Archaeological Department, Forest Department, and various published and unpublished materials were analyzed to assess the changing ecosystem of Dangamal village in Rajnagar block, Kendrapara district, Odisha.The study focuses on four critical climate threats: sea level rise, temperature increases, and changes in precipitation patterns. The findings highlight that mangrove conservation can simultaneously enhance environmental sustainability and promote social equity through adaptive strategies. Effective management of sediment elevation and ecological activities is essential for long-term protection. The research concludes with recommendations for policy-level interventions to safeguard this vital ecosystem.**

***Keywords*— Coastal Planning, Coastal protection, Mangrove, Socio-economic impacts, Sustainable adaptation.**

I. Introduction

Ecosystems play a crucial role in sustaining life on Earth by maintaining a well-defined hierarchy. Economic development thrives within these life-support systems. Mangrove ecosystems, shaped over centuries through natural evolution, hold significant ecological and social value. They are primarily harvested for fuel and serve as essential habitats for various species, including birds, animals, reptiles, and insects. Furthermore, mangroves act as natural shields against environmental disasters such as cyclones, storms, floods, and ocean currents. Their dense root systems and organic matter function like sponges, absorbing excess floodwater.

Despite their importance, mangrove forests worldwide are deteriorating at an alarming rate. This decline is attributed to unregulated human exploitation along coastal regions and accelerated climate change impacts, including rising sea levels, unpredictable weather patterns, and ocean acidification.

Urgent conservation efforts are essential to protect these vital ecosystems and their invaluable contributions to environmental stability.

II. Objectives

This research provides valuable insights into the functions and services of mangroves while exploring ecosystem dynamics and socio-economic patterns. It includes an extensive survey of local community perspectives on conservation efforts and existing alternatives within the Bhitarkanika Protected Area. The findings aim to support policymakers and protected area managers in making well-informed decisions for effective mangrove ecosystem management. The primary objectives of the study are as follows:

- Examine the ecological functions and productive uses of the Bhitarkanika mangrove ecosystem in Dangamal village, Rajnagar block, Kendrapara district.
- Evaluate the ecological benefits and utility contributions of the mangrove ecosystem.
- Analyze the significant changes in rural livelihoods due to shifts in the socio-ecological system triggered by climate change impacts on mangroves.
- Develop sustainable strategies to address issues associated with rising sea levels, increasing temperatures, and altered precipitation patterns affecting mangroves regionally.
- Propose strategic planning recommendations.

III. Methodology And Study Area

3.1 Methodology

This study investigates the effects of climate change on the mangrove ecosystem. The study is also citing the ecological amenities provided by this ecosystem. The notable changes in rural livelihood system of Dangamal area is also highlighted, which is a major concern for today. With the secondary data the climatic changes and its impact on the Mangrove system as well as the income scenario of the study area is presented in this paper.

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Basing upon the current scenario and the situation demand, the climate data has been taken into consideration for a period of 20 years for the study. That is from the year 2000 -2020. The climate data for the year 2000 has been taken as the reference year for the study. Based upon the data analysis over a period of 20 years, some inclusive and relevant facts and figures are coming out in pictorial format represented below. For this study statistical analysis has been using statistical tools of Ms Excel derived from the source Bhuvan panchayat portal, NRSC.

3.2 Study Area

The study area Dangamal village is a midmost size village positioned in Rajnagar Block of district Kendrapara, Orissa with total 339 families residing. As per Population Census 2011 the Dangamal village population consists of 1502 out of which 706 numbers represents males while 796 females.

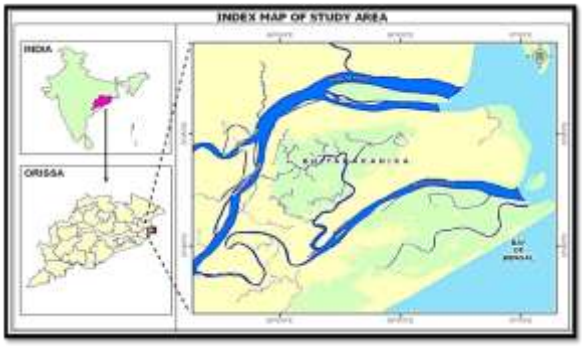

Figure 1: Index Map of the Study Area (Bhitarkanika, Odisha, India)

Source: Compiled by the author (2024) using NRSC Bhuvan GIS and Survey of India base layers.

3.3 Location

The village Dangamal covers 8.37 km² areas. Total geographical area is 195 Hectares.

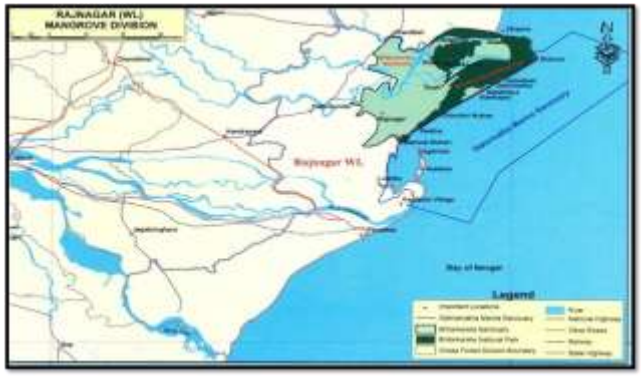

Figure 2: Rajnagar Mangrove Division Map

Source: Bhuvan Panchayat Portal, National Remote Sensing Centre (NRSC), Government of India.

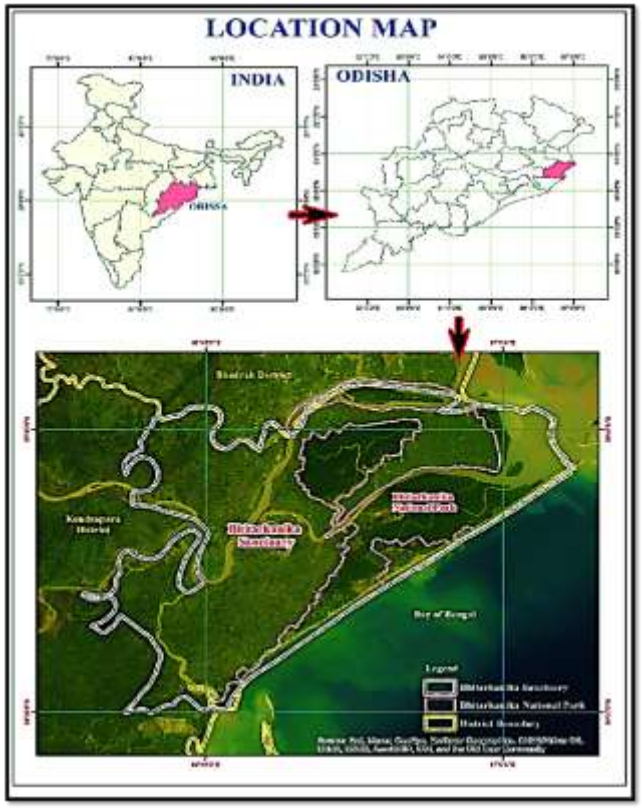

Figure 3: Bhitarkanika Location Map

Source: Bhuvan Panchayat Portal, NRSC.

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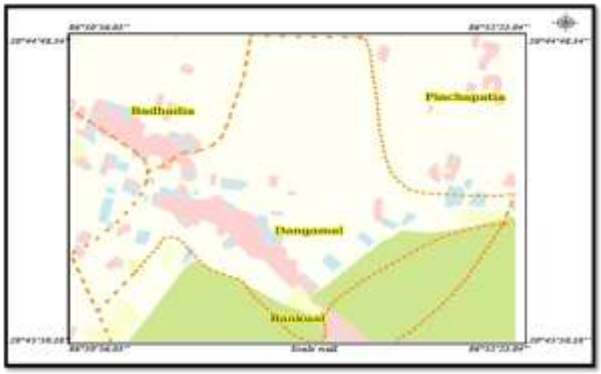

Figure 4: Satellite Map with Administrative Boundary

Source: Bhuvan Panchayat Portal, NRSC (Processed using GIS tools).

Figure 5: Dangamal Bhitarkanika satellite image

Source: Bhuvan Panchayat Portal, NRSC

3.4 Geology

The soils of this region are classified in two parts, designating 'Khadar' and 'Bhangar' (GSI, 1974). The current soils contain, silt, sand, and clay with variegated boulders along with pebbles. The river flow gets influenced twice daily by high and low tides at approximately six hourly intervals.

3.5 Climate

This area has a tropical monsoon climate. The highest temperatures typically occur in April and May, while the lowest temperatures are observed during the winter month of January. The relative humidity throughout the year scales from 70% to 84%. The wind speed is over 20 km from March to June. The amount of rainfall shows around 1642.34 cm per annum. June and October month counts the maximum rainfall. The pervasiveness of tropical cyclones is the significant weather phenomenon.

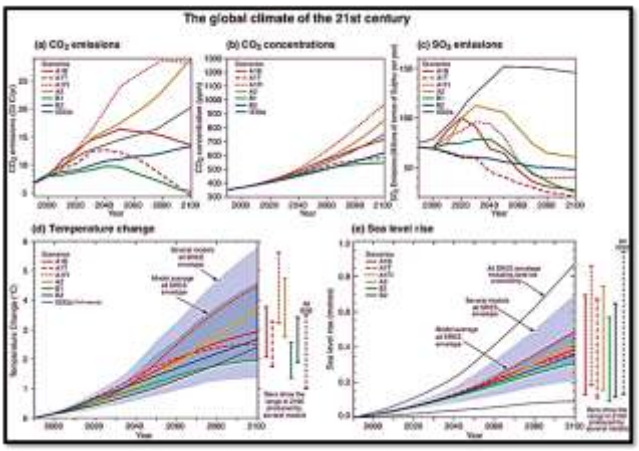

Figure 6: 21st century: CO2 emission (a) CO2 emissions (b) SO2 concentration (c) SO2 emissions (d) Temperature Change (e) Sea level Rise

Source: Climate datasets retrieved from Bhuvan Panchayat Portal, NRSC (2000–2020).

3.6 Demographic Profile

Dangamal 2011 Census Details

The primary language spoken in Dangamal is Oriya. The village has a total population of 1,502 residing in 339 households. Females make up 53% of the population. The overall literacy rate stands at 60.8%, with female literacy recorded at 28.2%.

Table I:
Census Data with various Census Parameters, Population

Census Parameter	Data
Total Population	1,502
Number of Households	339
Female Population	796
Male Population	706
Literacy Rate (%)	60.8% (913 individuals)
Female Literacy Rate	28.2% (424 individuals)
Scheduled Tribe Population	25.4% (381 individuals)
Scheduled Caste Population	6.8% (102 individuals)
Working Population (%)	51.1%
Child Population (0-6 years)	254

Source: Census of India 2011; demographic parameters extracted through Bhuvan Panchayat Portal

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IV. Background Of The Problem

Mangroves represent a distinct and diverse group of salt-tolerant, predominantly arboreal flowering plants that thrive in tropical and subtropical regions (Ellison & Stoddart, 1991). The potential impact of climate change on mangrove ecosystems has garnered significant attention.

Sea-Level Rise: Rising sea levels have a direct influence on the elevation of mangrove habitats. One of the most pressing challenges is whether the rate at which mangrove sediment elevation changes can keep pace with the accelerating sea-level rise.

Precipitation/Rainfall. Increased evaporation and decreased rainfall will increase salinity, resulting a remarkable reduction in mangrove area.

Temperature: Species composition change (extinction); Changing phonological patterns is expected due to increased surface temperature (e.g., timing of flowering and fruiting).

V. Data Analysis And Result

With reference to comprehensive impact of climate change on mangrove domain are as follows:

Sea-level rise

The reduction in mangrove area about 10–20% could be possible due to relative sea-level rise. "Rising sea-level will put an immense impact on mangroves. These include net lowering in sediment elevation, which provides finite area for landward migration.

Figure 7:(a) Probability of inundation to one-meter (b) Inundation with mean sea level rise, Bhitarkanika, Orissa along the Bhitarkanika coast, Orissa

Source: Computed from NRSC (Bhuvan Panchayat) time-series data, 2000–2020.

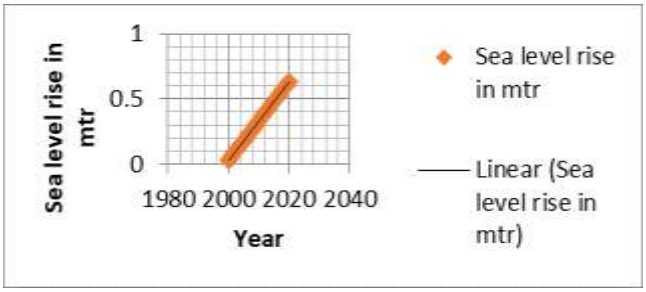

Figure.8: Year wise Sea level rise in Dangamal Bhitarkanika region.

Source: NRSC Bhuvan Panchayat portal climatic dataset (2000–2020)

The above graph representing the Year wise rise in sea level Dangamal Bhitarkanika region. This is showing the gradual increase in sea level from the year 2000 to 2020. The sea level rise of the mangrove forest can actuate erosion, increased salinity and weakening of root structures. If these trends continue, it is anticipated that future sea-level rises will inevitably pose a serious threat to the Bhitarkanika Conservation Area.

The above result presents that some forests are flooding faster than they can adapt with increasing sea-level rise. Eventually many coastal mangrove trees will be killed by flood caused by sea-level rise. These are being highlighted in this paper. Eventually it is bringing a great change in socio economic life of the local people.

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Temperature:

The unswerving effects of surged CO2 and rise in temperature condition levels are plausible to expand mangrove productivity. Concisely, a sole spatial smirch of warming is elucidated as the foremost pragmatic equilateral function of the model-averaged-temperature. The following graph shows the 10 years' time series of Dangamal regions in Rajnagar (Fig.8). The fingerprint was assessed, producing a time series of dot products year by year (2000-2020) the graph (Fig .8). It shows the increase in temperature which ultimately affects the density of the sea-level. This evaluation is based on the linear trend of the dot product time series, which is alluded to as the "trend" below. This perspective concerned with the regional averaged temperature which is rising gradually. It is a warming signal not only for the study area but also the state.

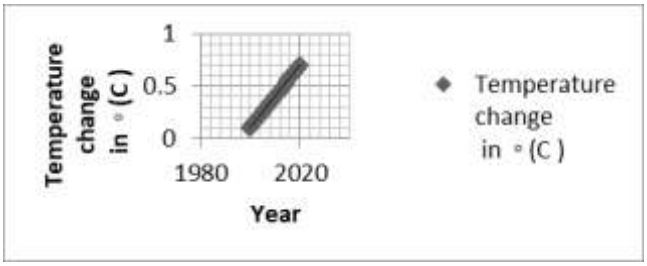

Figure.9 Year wise Temperature change in Dangamal Bhitarkanika region.

Source: Author (2024), NRSC Bhuvan climate data.

Effect on the Occupation of Local People

Workers profile of Dangamal Village

Table II:
Dangamal Working Population ---Census 2011

Category	Total	Male	Female
Total Workforce	767	403	364
Primary Workers	116	107	9
Cultivators (Primary Workers)	16	16	0
Agricultural Laborers	60	56	4
Household Industry Workers	3	3	0
Other Primary Workers	37	32	5
Marginal Workforce	651	296	355
Non-Working Population	735	303	432

Source: Census of India 2011; workforce classification accessed via Bhuvan Panchayat Portal.

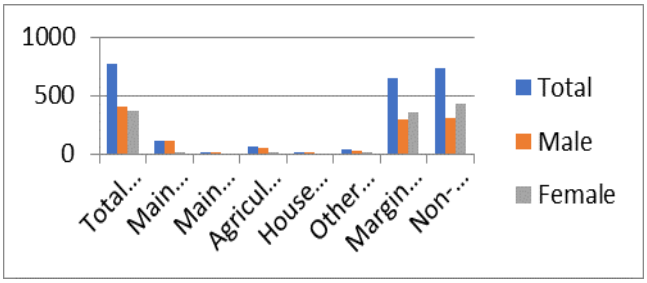

Figure.10-Dangamal Working Population ---Census 2011

Source: Census of India 2011; NRSC Bhuvan Panchayat Portal Visualization.

Compound climate change effects will drastically impact on mangrove ecosystems. Due to high tides the local people who are in the tertiary sector such as boat riders, ticket collectors are being affected as there will be risk in involving the tourist during the specific time period. This is the mini Amazon of India where people come across the world, which enhances the tourism industries and creates ample employment opportunities. Frequent cyclones affect the quality of the soil due to salinity, which results in the livelihood of the farmers.

Frequent cyclones affect the quality of the soil due to salinity, which results in the livelihood of the farmers and tourism industries. The above fig clearly shows the involvement of people in other sectors than farming.

VI. Discussion

The findings of this study highlight the profound and accelerating impacts of climate change on the Bhitarkanika mangrove ecosystem, particularly in and around Dangamal village. The analysis of 20 years of climatic and environmental data (2000–2020) demonstrates that sea-level rise, increasing temperatures, and altered precipitation regimes are exerting cumulative pressure on mangrove stability, species composition, and ecosystem services.

The steady rise in sea level in the study area indicates an increased likelihood of prolonged inundation, root weakening, and salinity intrusion. These trends align with global observations reported by Field (1995) and Gilman et al. (2008), who suggest that sediment elevation in many mangrove regions is insufficient to match the pace of sea-level rise. The Bhitarkanika ecosystem appears similarly vulnerable, as indicated by the observed 10–20% potential reduction in mangrove area. Such ecological shifts pose long-term risks to biodiversity and habitat structure.

Temperature trends show a clear upward trajectory, consistent with regional warming signals reported in Odisha. Higher temperatures influence phenological responses, productivity, and carbon assimilation in mangroves, supporting the findings of Ellison & Stoddart (1991) and Singh (2010). Warmer conditions may initially enhance growth, but prolonged heat stress can destabilize species balance and reduce resilience to storm surges and salinity fluctuations.

Socio-economic data reveal that climate-driven ecological stressors directly affect rural livelihoods. Agriculture, fisheries, and tourism—three major livelihood sectors—are especially vulnerable. Increased salinity, erosion, and cyclone frequency reduce agricultural productivity, degrade soil quality, and undermine the tourism economy, which depends heavily on safe waterways and predictable weather conditions. The study's results corroborate earlier work by Bahinipati & Sahu (2015) showing that mangrove degradation increases local vulnerability to cyclones and economic stress.

The discussion underscores that mangrove conservation is not merely an environmental imperative but also a socio-economic necessity. Integrated management—combining ecological monitoring, controlled land-use practices, community participation, and adaptive infrastructure—offers the most effective pathway to safeguarding both ecosystems and livelihoods. The results also emphasize the need for long-term climate-adaptive policy frameworks involving local stakeholders and state agencies to sustain the integrity of the Bhitarkanika mangrove landscape.

VII. Conclusion

Rapid climate fluctuations pose a serious threat to the entire mangrove ecosystem. Considering these challenges, it becomes essential to adopt a holistic and integrated management strategy. Safeguarding mangroves can help mitigate risks such as coastal flooding, soil erosion, saline water intrusion, and severe storm surges, ultimately benefiting the socio-economic well-being of the local communities. Effective conservation efforts should include sustainable coastal land-use planning, which involves setting limits on logging and other extractive activities. Engaging local communities plays a crucial role in protecting these valuable ecosystems and curbing illegal encroachments and deforestation. Enforcing stringent forest regulations is imperative to prevent indiscriminate exploitation. Additionally, constructing more canals can alleviate waterlogging, reducing the likelihood of coastal flooding.

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