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Impact of Successive Cyclones on Ecology and Economy of Coastal Odisha

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Abstract: *Odisha, located along the eastern coast of India, is one of the most cyclone-prone regions in the world due to its geographical position along the Bay of Bengal. In recent decades, the frequency and intensity of cyclones have increased, largely attributed to climate variability and change. Although significant improvements in early warning systems by the India Meteorological Department (IMD) and disaster response mechanisms by agencies such as the National Disaster Management Authority (NDMA) have substantially reduced mortality, the ecological and economic impacts remain severe. Coastal Odisha continues to experience extensive damage to agriculture, fisheries, infrastructure, and natural ecosystems, leading to long-term livelihood insecurity, particularly among rural and marginalised communities.*

This study examines the ecological and economic impacts of successive cyclones in coastal Odisha, evaluates existing disaster management and mitigation strategies, identifies key gaps in implementation, and proposes planning-oriented strategies for improving resilience. The study employs a mixed-method approach using both primary and secondary data, including field surveys, satellite imagery, and statistical analysis. Findings indicate that repeated cyclonic events have led to soil salinization, loss of biodiversity, degradation of coastal ecosystems, and significant economic losses in agriculture and fisheries sectors. The study emphasizes the need for integrated coastal zone management, community-based disaster preparedness, and ecosystem restoration strategies to reduce vulnerability.

Keywords: *Cyclone, Coastal Odisha, Ecology, Economy, Disaster Management, Climate Change, Vulnerability, Mitigation Strategies*

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Introduction

Odisha is a multi-hazard-prone state in eastern India with a coastline of approximately 550 km along the Bay of Bengal. The state comprises 30 districts, with nearly 83% of its population residing in rural areas and depending heavily on agriculture and allied sectors for livelihood. Due to its geographical exposure, Odisha is highly vulnerable to tropical cyclones, storm surges, flooding, and associated hazards.

Historically, Odisha has experienced some of the most devastating cyclones in India, including the 1999 Super Cyclone, Phailin (2013), Titli (2018), Fani (2019), cyclone Amphan (2020), Yaas (2021), Dana(2024). These events have caused widespread destruction of infrastructure, agricultural land, coastal ecosystems, and human settlements. Although the death toll has significantly decreased due

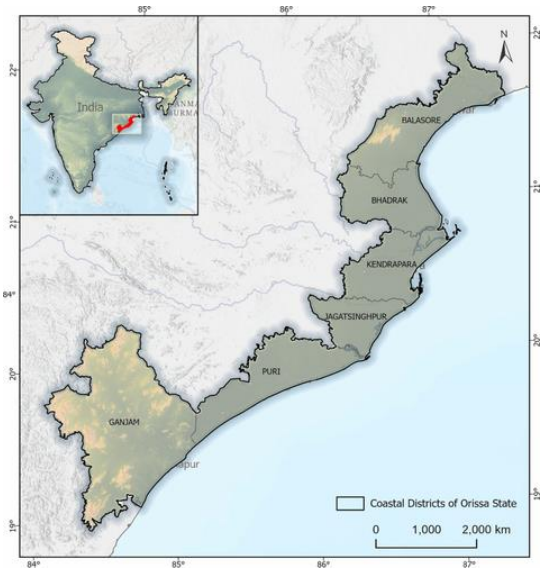
to improved forecasting and evacuation systems, economic and ecological losses have continued to rise.

Cyclones result in severe environmental consequences such as coastal erosion, mangrove degradation, saline water intrusion, and loss of biodiversity. Economically, they disrupt agriculture, fisheries, small-scale industries, and informal livelihoods, disproportionately affecting poor and vulnerable populations. The recurring nature of cyclones has further intensified long-term vulnerability in coastal districts, making sustainable disaster management a critical concern.

The present study focuses on assessing the impacts of successive cyclones on the ecology and economy of coastal Odisha, evaluating existing mitigation measures, identifying gaps in disaster management, and suggesting planning-based interventions for resilience building.

Materials and Methods

Study Area



Map 1: Study Area

The study focuses on the coastal districts of Odisha, particularly vulnerable regions such as Puri, Jagatsinghpur, Kendrapara, Bhadrak, Balasore, and Ganjam, which frequently experience cyclone landfall and associated impacts. These districts are particularly vulnerable because of their low-lying coastal geography and proximity to the Bay of Bengal.

Data Sources

The study uses both primary and secondary data sources:

1. Secondary Data: Reports and records from Odisha State Disaster Management Authority (OSDMA), National Disaster Management Authority (NDMA), India Meteorological Department (IMD), National Institute of Disaster Management (NIDM), district disaster management plans, academic journals, and published literature.
2. Primary Data: Household surveys, interviews, and field observations conducted in cyclone-affected coastal villages.
3. Remote Sensing Data: Satellite imagery used to assess land use change, coastal erosion, and vegetation loss.

Methodology

The research follows a three-stage approach:

1) **Pre-field Stage**

- Literature review on cyclone impacts and coastal vulnerability
- Study of physical, demographic, and economic characteristics of the region
- Identification of study sites.

2) **Field Stage**

- Household surveys using structured questionnaires
- Interaction with local communities, NGOs, and government officials
- Collection of geospatial and observational data
- Mapping of cyclone tracks and affected zones using GIS tools

3) **Post-field Stage**

- Interpretation and synthesis of findings

Results and Discussion

Odisha has one of the most cyclone-prone coastlines in India because it lies along the northern Bay of Bengal, where tropical cyclones frequently form and intensify. According to disaster-management studies, Odisha experienced nearly 100 cyclones between 1891 and 2018, more than any other eastern coastal state of India.

From north to south, the most cyclone-prone landfall zones are:

- Balasore Coast
- Bhadrak Coast
- Dhamra
- Paradip
- Kendrapara Coast
- Puri
- Gopalpur
- Berhampur region

Table 1 : Major Cyclones Affected the Odisha Coast

Year	Cyclone	Key Impact Areas
1864	Great Calcutta–Odisha Cyclone	Severe coastal devastation
1885	False Point Cyclone	Massive storm surge near Kendrapara coast
1942	Odisha Cyclone	Heavy loss of life and property
1971	Odisha Cyclone	Landfall near Paradip; over 10,000 deaths reported
1982	Paradip Cyclone	Significant coastal damage

1999	1999 Cyclone	One of India's deadliest cyclones; catastrophic storm surge and widespread destruction
2013	Cyclone Phailin	Landfall near Gopalpur; large-scale evacuation reduced casualties
2014	Cyclone Hudhud	Strong impacts in southern Odisha
2018	Cyclone Titli	Severe flooding and landslides in Gajapati district
2019	Cyclone Fani	Extremely Severe Cyclonic Storm; landfall near Puri with major damage
2020	Cyclone Amphan	Mainly affected northern coastal districts
2021	Cyclone Yaas	Severe storm surge in Balasore and Bhadrak
2024	Cyclone Dana	Major evacuation operation with limited casualties
2025	Cyclonic disturbances affecting Odisha coast	Heavy rainfall and coastal impacts from Bay of Bengal systems

Source : IMD(**India Meteorological Department)**, OSDMA (Odisha State Disaster Management Authority) post-disaster assessment reports.



Map:2 Wind & Cyclone zones of Odisha

District-wise Historical Impact Pattern

A. Very High Cyclone Risk Districts

The following districts repeatedly experience the highest winds and storm-surge impacts: Puri, Jagatsinghpur, Kendrapara, Bhadrak, Balasore, Ganjam.

These coastal districts receive:

- Extreme wind damage
- Storm surge flooding
- Large-scale tree and power-line failures
- Housing and agricultural losses

Studies of major cyclones over the last two decades show the southeast and northeast coastal districts are consistently the most affected.

B. Moderate Impact Districts

The moderately impacted districts are: Khordha, Jajpur, Mayurbhanj, Nayagarh, Cuttack

These districts are typically affected by:

- Strong winds
- Heavy rainfall
- Urban flooding
- Power disruptions

C. Rainfall-Dominated Impact Districts

During cyclone landfalls, inland districts often suffer more from rainfall than wind: Angul, Dhenkanal, Kandhamal, Keonjhar, Sundargarh.

Forecast Impact Framework (Used Operationally):

When a cyclone is forecast, districts are generally categorized as follows in the table no.3.

Table 2: Forecast impact maps

Impact Level	Wind	Rainfall	Likely Districts
Extreme	>120 km/h	>200 mm	Coastal districts near landfall
High	90–120 km/h	100–200 mm	Adjacent coastal districts
Moderate	60–90 km/h	50–100 mm	Central Odisha
Low	<60 km/h	<50 mm	Western Odisha

Source: IMD cyclone forecasts (track, maximum sustained wind speed, and rainfall forecasts) and Impact-Based Forecasting methodology.

Forecast impact maps usually combine:

- IMD wind forecasts
- Rainfall forecasts
- Storm surge models
- Exposure (population, housing, crops, infrastructure)

Impacts of Successive Cyclones on the Ecology and Economy of Coastal Odisha

The repeated occurrence of these cyclones has had significant ecological and economic consequences. Understanding their cumulative impacts is essential for sustainable coastal development and disaster resilience.

A. Ecological Impacts

Successive cyclones have significantly degraded the coastal ecosystem of Odisha. Major impacts include:

1. Damage to Coastal Ecosystems

- Strong winds, storm surges, and flooding destroy coastal vegetation, sand dunes, and wetlands.
- Sensitive ecosystems such as Bhitarkanika National Park and mangrove forests suffer extensive damage.
- Loss of natural barriers increases vulnerability to future storms.

2. Salinization of Soil and Water

- Seawater intrusion during storm surges increases soil salinity.
- Agricultural lands become less fertile, reducing crop productivity.
- Freshwater ponds and groundwater sources are contaminated with saltwater.

3. Loss of Biodiversity

- Cyclones destroy habitats of birds, reptiles, fish, and other wildlife.
- Nesting sites of endangered species such as the Olive Ridley sea turtle are often affected.
- Disturbance of ecological balance can reduce species populations.

4. Coastal Erosion

- Repeated cyclonic events accelerate shoreline erosion.
- Beaches and coastal settlements lose land, threatening both ecosystems and human habitation.

5. Waterlogging and Pollution

- Flooding causes prolonged waterlogging in low-lying areas.
- Debris, sewage, and chemicals contaminate rivers, ponds, and coastal waters, affecting aquatic life.

B. Economic Impacts

The economic consequences of cyclones are severe and long-lasting:

1. Agricultural Losses

- Standing crops such as paddy, vegetables, and pulses are damaged by high winds and flooding.
- Soil salinity reduces agricultural productivity for several seasons.
- Farmers incur substantial financial losses.

2. Fisheries and Livelihoods

- Fishing boats, nets, and coastal infrastructure are damaged.
- Fishers lose income due to restrictions on fishing and reduced fish catches.

- Aquaculture farms suffer heavy losses from inundation and salinity.

3. Infrastructure Damage

- Cyclones damage roads, bridges, power lines, schools, hospitals, and communication networks.
- Large public expenditures are required for reconstruction and rehabilitation.

4. Impact on Tourism

- Coastal tourist destinations such as Puri Beach and nearby attractions experience damage.
- Tourist arrivals decline temporarily, affecting local businesses and employment.

5. Increased Government Expenditure

- Significant funds are spent on disaster relief, evacuation, rehabilitation, and rebuilding infrastructure.
- Resources that could be used for development are diverted to disaster management.

6. Poverty and Migration

- Recurrent disasters reduce household savings and assets.
- Loss of livelihoods forces some families to migrate in search of employment.
- Vulnerable communities face greater economic insecurity.

C. **Social Vulnerability**

Despite compensation and relief measures, recovery remains slow and inadequate for most affected households.

a) Poor and marginal communities are disproportionately affected.

b) Migration from coastal villages to urban areas has increased due to livelihood insecurity.

c) Health risks, including waterborne and vector-borne diseases, have increased post-disaster.

d) Women, children, and elderly populations are the most vulnerable groups.

Table 3: Sector-Level Impact Assessment

Sector	Exposure	Expected Impact
Coastal communities	Very High	Evacuations, housing damage, service disruption
Agriculture	High	Crop losses from flooding and salinity intrusion
Fisheries	Very High	Vessel damage, fishing bans, income losses
Ports & shipping	High	Delays, closures, cargo disruptions
Power infrastructure	Moderate–High	Grid outages and transmission damage
Transportation	High	Road, rail, and airport disruptions from flooding
Insurance & disaster relief	High	Elevated claims and emergency expenditures

Source: IPCC, WMO, UNDRR, World Bank, IMD, and NDMA literature on tropical cyclone impacts.

Table 4: Timing Risk Window

Period	Relative Risk
June–July	Moderate
August–September	Moderate
October–November	Very High (historical peak for damaging Bay of Bengal cyclones)
December	Moderate

Source: IMD – Historical Perspective on Tropical Cyclones

The strongest concern for eastern India—including Odisha—is typically the post-monsoon period (October–November) when sea-surface temperatures remain high and atmospheric conditions often become favourable for intense Bay of Bengal cyclones. Historically, this period produces many of the basin's most destructive storms.

For planning purposes, I would rate the current season's risk profile as:

Table 5: Rating of Risk Profile

Impact Category	Rating
Humanitarian risk	High
Infrastructure risk	High
Agricultural risk	Moderate–High
Maritime risk	High
Economic disruption	Moderate–High
Confidence level	Moderate (season still developing)

Source: Primary Investigation & Interpretation

For Odisha specifically, the principal risks remain coastal flooding, storm surge, and heavy rainfall flooding, especially from any Bay of Bengal systems that form during the late monsoon and post-monsoon phases.

Evaluation of Disaster Management

While Odisha has made significant progress in cyclone preparedness through early warning systems and evacuation planning, several gaps remain:

a) Insufficient long-term rehabilitation measures

b) Weak implementation of coastal zone regulations

c) Limited livelihood restoration programs

d) Inadequate ecosystem-based disaster risk reduction strategies

Evaluation of Existing Mitigation Measures

Institutional Measures

- Strengthening of the Odisha State Disaster Management Authority.
- Improved disaster preparedness and emergency response systems.
- Community-based disaster management initiatives.

Structural Measures

- Construction of cyclone shelters.
- Embankments and coastal protection structures.
- Strengthening of critical infrastructure.

Early Warning Systems

- Advanced forecasting and warning dissemination.
- Timely evacuation programs.
- Effective coordination among government agencies.

Achievements

- Significant reduction in cyclone-related fatalities compared to 1999.
- Improved evacuation efficiency.
- Enhanced public awareness and preparedness.

Gaps in Disaster Management

Ecological Gaps

- Limited focus on ecosystem-based disaster risk reduction.
- Inadequate mangrove restoration efforts.
- Insufficient monitoring of long-term environmental impacts.

Economic Gaps

- Slow livelihood recovery after disasters.
- Inadequate compensation mechanisms.
- Limited insurance coverage for farmers and fishers.

Planning and Governance Gaps

- Weak integration of disaster risk reduction into land-use planning.
- Encroachment in hazard-prone coastal zones.
- Lack of coordination between environmental and development planning.

Social Gaps

- Vulnerability of women, children, elderly, and marginalized communities.
- Unequal access to relief and recovery resources.
- Limited community participation in planning processes.

Planning-Based Interventions for Resilience Building

a) Ecosystem-Based Approaches

- Large-scale mangrove restoration and conservation.
- Protection of wetlands and coastal buffers.
- Promotion of nature-based solutions for coastal defense.

b) Resilient Land Use Planning

- Hazard-sensitive zoning regulations.
- Restriction of development in high-risk coastal areas.
- Integration of disaster risk assessments into development plans.

c) Climate-Resilient Livelihoods

- Diversification of income sources.
- Promotion of climate-resilient agriculture.
- Sustainable fisheries and aquaculture practices.

d) Infrastructure Resilience

- Cyclone-resistant housing and public buildings.
- Climate-resilient transportation and utility networks.
- Strengthening of coastal protection infrastructure.

e) Community-Based Resilience

- Capacity building and disaster preparedness training.
- Strengthening local governance institutions.
- Inclusion of vulnerable groups in decision-making processes.

f) Technology and Data Management

- GIS-based hazard mapping.
- Real-time monitoring systems.
- Use of remote sensing for damage assessment and planning.

Conclusion

Successive cyclones in coastal Odisha have caused severe, repeated damage to the environment and the economy. These extreme weather events have led to ecological degradation, such as the destruction of coastal habitats, loss of biodiversity, soil salinisation, and reduced agricultural productivity. Coastal farming and fishing communities have been especially affected, as recurring storms damage crops, livestock, and fishing infrastructure, leading to long-term livelihood insecurity. In addition, public infrastructure, including roads, housing, embankments, and communication systems, often suffers significant damage, resulting in substantial economic losses and slowing regional development.

Despite these impacts, Odisha has made notable progress in reducing cyclone-related deaths through improved disaster preparedness. Early warning systems, timely evacuations, and the widespread construction of cyclone shelters have greatly enhanced community safety. These measures have shifted the focus from emergency survival to long-term resilience and recovery.

Adaptation strategies such as mangrove restoration along the coast have strengthened natural protection against storm surges, while community-based disaster management programs have improved awareness and response capacity at the local level. However, sustainable recovery requires a comprehensive approach that combines ecological restoration with socio-economic resilience. Key priorities include strengthening coastal infrastructure, improving healthcare and evacuation networks, expanding early warning systems, and integrating land-use planning with climate adaptation strategies.

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