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MINI REVIEW

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Harnessing geography: How Odisha's natural and man-made features mitigate cyclone impacts

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ABSTRACT

Odisha, located on the eastern coast of India, frequently faces tropical cyclones from the Bay of Bengal, with notable events including the 1999 Super Cyclone, Cyclone Phailin (2013), and Cyclone Fani (2019). These cyclones have highlighted Odisha's vulnerability due to its geographic location, prompting significant advancements in disaster management strategies. This mini-review examines the geographical advantages and human interventions that mitigate cyclone impacts in Odisha. Natural features such as coastal geomorphology and mangrove forests, along with human-made systems including advanced meteorological tools, early warning systems, and resilient infrastructure, play crucial roles in reducing cyclone damage. The review includes a case study of Cyclone Fani, demonstrating the effectiveness of these strategies. Despite severe impacts, the combined efforts of natural and human-made interventions significantly mitigated damage and casualties. The study concludes that enhancing mangrove conservation, upgrading early warning systems, and investing in resilient infrastructure is vital for future cyclone preparedness. Continuous adaptation to climatic changes and innovative disaster risk management strategies are essential to maintain Odisha's resilience against severe cyclonic events. Future research should focus on integrating advanced technologies with traditional knowledge to develop comprehensive and sustainable disaster management frameworks.

KEYWORDS

Cyclone mitigation; Disaster management; Coastal geomorphology; Resilient infrastructure

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Introduction

Odisha, a state on the eastern coast of India, is frequently affected by tropical cyclones originating in the Bay of Bengal. Notable cyclones include the devastating 1999 Super Cyclone, Cyclone Phailin in 2013, and Cyclone Fani in 2019. These cyclones have varied in intensity and impact but consistently highlight the region's vulnerability due to its geographic location. The 1999 Super Cyclone was particularly catastrophic, leading to widespread destruction and loss of life, which prompted significant advancements in disaster management and mitigation strategies [1].

Understanding the geographical advantages that aid in cyclone mitigation is crucial for developing effective disaster management strategies. Both natural features, such as coastal geomorphology and mangrove forests, and human interventions, including early warning systems and resilient infrastructure, play pivotal roles in reducing the impact of cyclones. This mini-review aims to explore these geographical advantages in detail, examining how they have been leveraged in Odisha to protect lives and property during cyclonic events [2].

Natural Geographical Features

Coastal geomorphology

Odisha's coastline stretches over 480 kilometers and is characterized by diverse geomorphological features, including sandy beaches, dunes, and estuaries. These natural formations serve as the first line of defense against cyclonic impacts. The coastline's sandy beaches and dunes help dissipate wave energy, while estuaries act as natural buffers that absorb and reduce the force of storm surges. The unique structure of the coastline, with its varied topography, plays a crucial role in mitigating the impact of cyclones by reducing their intensity before they reach inland areas [3].

Natural barriers along Odisha's coast, such as sand dunes and beaches, act as shock absorbers for cyclonic waves. These formations help reduce the height and energy of storm surges, preventing severe flooding and erosion in coastal and adjacent inland regions. For instance, during Cyclone Fani, areas with well-preserved sand dunes experienced less severe flooding compared to regions where natural barriers had been degraded. This demonstrates the importance of maintaining and restoring these natural features to enhance coastal resilience [2].

Mangrove forests

Odisha is home to significant mangrove forests, particularly in the Bhitarkanika National Park, which is one of India's largest mangrove ecosystems. These forests cover extensive areas along the coast and estuarine regions, providing critical ecological and protective functions. The dense mangrove cover in Bhitarkanika, as well as smaller patches in other coastal areas, plays a vital role in mitigating the impacts of cyclones by acting as natural buffers that absorb the energy of storm surges and reduce wind speeds [4].

Mangrove forests are highly effective in protecting coastal regions from cyclonic impacts. Their complex root systems stabilize the soil and prevent erosion, while their dense canopies reduce wind speed and wave energy. Studies have shown that areas with healthy mangrove forests suffer significantly less

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damage during cyclones compared to areas without such vegetation. For example, during Cyclone Phailin, regions with dense mangrove cover experienced lower levels of flooding and infrastructure damage, underscoring the protective value of these ecosystems [5].

Human-made Geographical Interventions

Early warning systems

Implementation of advanced meteorological tools and data sharing

Odisha has invested heavily in advanced meteorological tools to enhance its cyclone prediction and monitoring capabilities. The deployment of Doppler radars, satellite-based observation systems, and automated weather stations has significantly improved the accuracy and timeliness of cyclone forecasts. These technologies enable real-time data collection and analysis, facilitating effective early warning dissemination. Collaboration with national and international meteorological agencies ensures comprehensive data sharing and coordinated responses, further enhancing the state's preparedness for cyclonic events [6].

Community awareness and preparedness initiatives

In addition to technological advancements, Odisha has prioritized community awareness and preparedness initiatives. The state government conducts regular public information campaigns, drills, and training programs to educate residents about cyclone preparedness. Community-based disaster management committees have been established to ensure localized response efforts. These initiatives have been instrumental in enhancing public awareness and readiness, enabling timely evacuations and reducing casualties during cyclonic events. Successful examples of community-based disaster management include the mass evacuations conducted prior to Cyclone Phailin, which significantly minimized the loss of life [7].

Resilient infrastructure

Cyclone shelters and their strategic placement

The construction of cyclone shelters across Odisha's coastal region has been a critical intervention in reducing cyclone-related casualties. These shelters are strategically located to ensure accessibility for vulnerable populations, particularly in low-lying and high-risk areas. Designed to withstand high winds and flooding, these shelters provide safe havens for residents during cyclonic events. Data from past cyclones, such as Cyclone Fani, demonstrate the effectiveness of these shelters in protecting lives. The strategic placement and robust construction of cyclone shelters have played a vital role in enhancing community resilience [8].

Improvements in housing and public infrastructure

Odisha has also made significant advancements in housing and public infrastructure to better withstand cyclonic impacts. Building codes have been updated to ensure that new constructions are resilient to high winds and flooding. Public infrastructure, including roads, bridges, and drainage systems, has been reinforced and upgraded to improve their durability and functionality during cyclonic events. These improvements have contributed to a reduction in structural damage and economic losses during cyclones. For example, the implementation of flood-resistant housing designs has minimized the extent of damage to residential areas during recent cyclones [8].

Case Study: Cyclone Fani

Cyclone Fani originated in the Bay of Bengal in late April 2019 and quickly intensified into an Extremely Severe Cyclonic Storm. It followed a north-northeast trajectory, making landfall near Puri, Odisha, on May 3, 2019. The cyclone's path included key dates and times when it intensified and made landfall, causing significant concern due to its projected impact. Moving at high speed, Fani traversed through Odisha, West Bengal, and Bangladesh before dissipating [9].

Intensity and classification

Cyclone Fani was classified as an Extremely Severe Cyclonic Storm (ESCS) with wind speeds exceeding 200 km/h. It brought intense rainfall and high storm surges, making it one of the most powerful cyclones to hit Odisha in recent years. Meteorological data indicated peak wind speeds of around 215 km/h and substantial rainfall amounts, contributing to widespread flooding and damage. Fani's intensity was comparable to other significant cyclones in the region, such as the 1999 Super Cyclone and Cyclone Phailin, but its impact was mitigated by improved preparedness measures [10].

Damage and impact

Cyclone Fani caused extensive damage to infrastructure, agriculture, and the economy. The most affected areas included the Puri district, where the cyclone made landfall, leading to severe damage to buildings, roads, and electrical infrastructure. The human toll was significant, with numerous casualties, injuries, and large-scale displacement of populations. Public services, including electricity, water supply, and transportation, were severely disrupted. Despite the extensive damage, the impact was less catastrophic than previous cyclones due to effective mitigation measures [11].

Analysis of geographical features and human interventions

Role of coastal geomorphology

Odisha's coastal geomorphology, including natural formations like sand dunes, beaches, and estuaries, played a crucial role in mitigating the impact of Cyclone Fani. These natural barriers absorbed and dissipated the energy of storm surges, reducing the height and intensity of waves reaching inland areas. Specific regions with well-preserved sand dunes and beaches experienced less severe flooding and erosion, demonstrating the importance of maintaining these natural defenses. For example, the Chilika Lake region, protected by sand dunes, suffered less flooding compared to other areas [12].

Role of mangrove forests

Mangrove forests provided significant protection during Cyclone Fani, particularly in areas like Bhitarkanika and other mangrove-dense regions. The dense root systems and canopies of mangroves reduced the force of storm surges and wind speeds before they reached inland settlements. Studies have quantified the reduction in wave height and energy due to mangroves, highlighting their effectiveness in protecting coastal regions. During Cyclone Fani, regions with healthy mangrove forests experienced lower levels of damage, underscoring the critical role of these ecosystems in cyclone mitigation [13].

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Effectiveness of early warning systems

The early warning protocols activated in anticipation of Cyclone Fani were highly effective. Accurate forecasts, timely alerts, and widespread dissemination of information enabled mass evacuations and preparedness measures. Local and national meteorological agencies coordinated to ensure the public received timely and accurate warnings, significantly reducing the number of casualties. The success of these early warning systems during Cyclone Fani demonstrates the importance of continued investment in meteorological technologies and communication strategies [14].

Impact of resilient infrastructure

Resilient infrastructure, including cyclone shelters, reinforced housing, and improved public infrastructure, played a crucial role in reducing the damage and casualties during Cyclone Fani. Areas with robust cyclone shelters and flood-resistant buildings suffered less damage and had lower casualty rates. The effectiveness of these infrastructures highlights the importance of continued investment in resilient construction practices and the strategic placement of cyclone shelters to enhance community protection during cyclonic events [8].

A comparative study with previous cyclones and lessons learned

Comparison with the 1999 Odisha super cyclone

Cyclone Fani and the 1999 Super Cyclone differed in intensity and impact, with the latter being more catastrophic. However, the response to Cyclone Fani benefited from the lessons learned since 1999, including improved early warning systems, better community preparedness, and enhanced infrastructure resilience. These advancements resulted in a more effective response during Fani, reducing casualties and damage compared to the 1999 event. The evolution of disaster management practices since the 1999 Super Cyclone has significantly enhanced Odisha's ability to cope with severe cyclones [15].

Comparison with cyclone Phailin

Cyclone Fani and Cyclone Phailin had similar meteorological characteristics and impacts. However, the continuity of improvements made post-Phailin, particularly in community preparedness and infrastructure resilience, contributed to a more effective response during Fani. The successful evacuation and sheltering of vulnerable populations during both cyclones underscore the effectiveness of these measures. Additional lessons learned from Phailin, such as the importance of timely evacuations, were applied during Fani, further enhancing preparedness and response [14].

Lessons learned and recommendations for future preparedness

Key lessons learned from Cyclone Fani include the effectiveness of natural and human interventions in mitigating cyclone impacts. Recommendations for further improvements include enhancing mangrove conservation, investing in more resilient infrastructure, and expanding early warning systems. Continuous adaptation to evolving climatic conditions and sustainable disaster risk management strategies are essential for improving future cyclone preparedness and resilience. Emphasizing the integration of natural defenses and technological advancements will be crucial for effective disaster management [16].

Conclusions

Odisha's geographical features, including its coastal geomorphology and mangrove forests, combined with human interventions such as early warning systems and resilient infrastructure, play a vital role in mitigating cyclone impacts. The effectiveness of these natural and man-made strategies was evident during Cyclone Fani, where the damage and casualties were significantly reduced compared to previous cyclones. This highlights the importance of leveraging geographical advantages in disaster management.

Future improvements should focus on expanding mangrove plantations, upgrading early warning systems, and enhancing community preparedness. Continued investment in resilient infrastructure and sustainable coastal management practices will be crucial for mitigating the impacts of future cyclones. Emphasizing the importance of continuous adaptation and innovation in disaster risk reduction strategies will ensure that Odisha remains resilient in the face of increasingly severe cyclonic events.

Disclosure Statement

The author declares no potential conflicts of interest.

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