ADAPTING TO A RISING SEA: A CASE STUDY IN COASTAL MANAGEMENT UNDER CLIMATE CHANGE

UG DEPARTMENT OF EARTH SCIENCE

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Background

Coastal erosion continues to be a global problem, driven by persistent natural forces such as strong wave action, sea level rise, tides, currents, and severe weather events. Although the severity of erosion varies geographically, coastal communities and infrastructure along the Ghanaian eastern coast and beyond face heightened risk. In light of this rapid deterioration, the Atorkor-Dzita-Anyanui Sea Defense Project, the Keta Sea Defense project and a number of other similar projects were initiated to address the alarming erosion rate. Following the implementation of the projects, the average erosion rate was significantly reduced to approximately 2 meters per year[1]. While the Keta Sea Defense Project has proven successful in protecting specific areas, it has inadvertently exacerbated down-drift erosion along Kedzi and Hlorve (East of Keta), with the average erosion rate rising to as much as 8 meters per year in certain areas[2].

While erosion management techniques are deployed to mitigate the impacts of erosion, the efficacy of such measures under a changing climate necessitates rigorous evaluation. This study uses Digital Earth Africa Landsat 7 Imagery Services[3] and open-source shoreline change and coastline analysis tools[4],[5],[6] to investigate the impact of the Atorkor-Dzita-Anyanui and Keta Sea Defense Projects on shoreline change along the Dzita coast (Figure 1); southeastern of Ghana by quantifying the rate of shoreline change and exploring the relationship between shoreline retreat/accretion patterns, and climate change-induced sea-level rise over the past two decades in a bid to emphasize the importance of investing in coastal protection infrastructure, while also recognizing the need for long-term adaptation measures to address the escalating challenges posed by climate change.

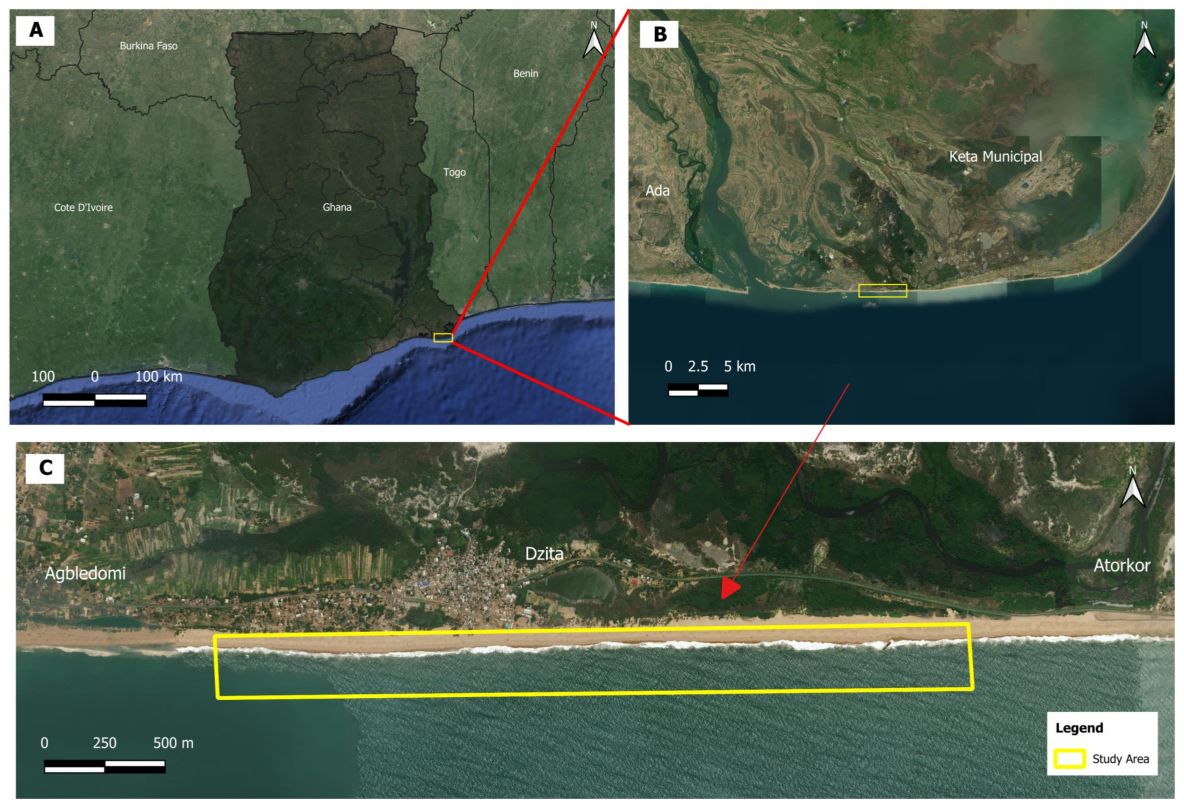

Fig 1. Location of study area; Dzita Coast

Results & Discussion

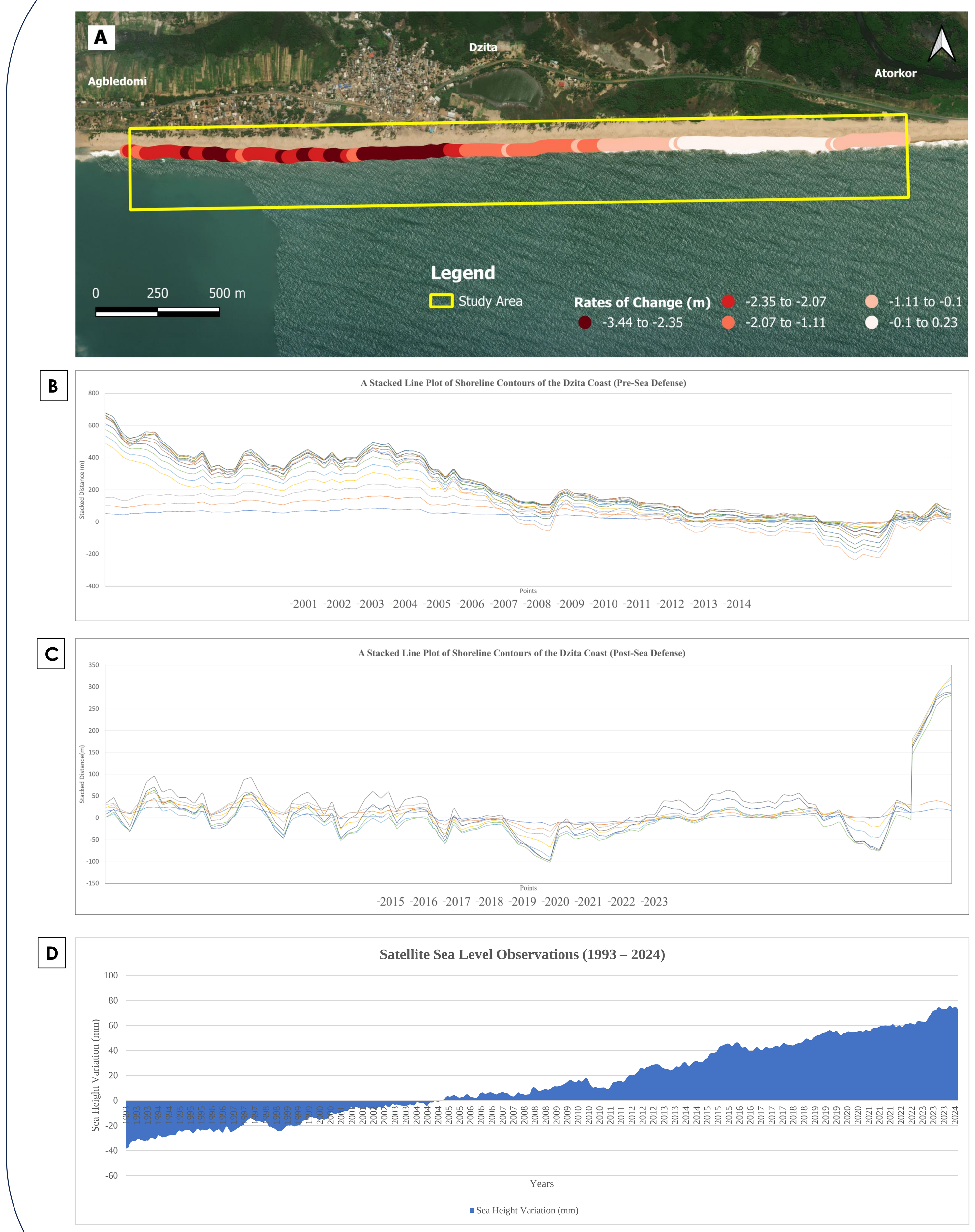

Fig 3. A- Shoreline Change Visualization (Interactive online, see QR code), B & C- Shoreline Contour Visualization pre- and post-sea defense respectively, D – Line Plot showing Global Mean Sea Level (1993-2023**)**

Shoreline Change

A comparative analysis of shoreline patterns during the pre-sea defense (2001-2014, figure 3B) and post-sea defense (2015-2023, figure 3C) periods reveals significant shifts in coastal dynamics. Prior to the seawall construction, the coastline experienced substantial erosion, evidenced by the pronounced retreat of the shoreline. However, following the implementation of the sea defenses, shoreline retreat slowed considerably, and in some areas, even accretion was observed. This suggests that the seawalls have been effective in mitigating erosion in certain locations.

Global Mean Sea Level Data

Data sourced from NASA[7] indicates a steady rise in global mean sea levels since 1993 (figure 3D), reaching average heights of ~101.9(±4.00)mm. This increase, primarily driven by the melting of land-based ice and the expansion of seawater, has contributed to coastal erosion factors such as intensified wave energy, amplified storm surges, and altered coastal currents.

Statistical Correlation

Spearman's Rank Correlation tests revealed a weak correlation between global mean sea level data and shoreline change data, suggesting a complex relationship influenced by multiple factors. While sea level rise is a significant contributor to coastal erosion, other variables (which also can be affected by sea level rise and climate change at large), such as tidal action, sediment supply, human activities, and river damming, also play crucial roles. This interplay of factors likely explains the observed quasi-linear relationship between sea level rise and shoreline change, where the impact of sea level rise is not strictly linear but is modulated by additional variables. Although the correlation analysis does not yield a strong linear relationship, the data indicates a potential influence of sea level rise on coastal erosion. However, it's essential to acknowledge the synergistic effects of sea level rise with other factors, such as those mentioned above, in driving shoreline change.

Limitations

This study utilized Landsat 7 imagery, which while providing wide coverage for the 2001-2023 period, might have limitations in terms of spatial resolution and atmospheric effects. Additionally, using global sea levels might not capture local variations in sea level rise. Furthermore, the study's focus on a specific region and time period limits its generalizability to other coastal areas or timeframes.

Methodology

Annual Shoreline Extraction & Analysis

Image Acquisition + Tide Height Modelling

MNDWI Differentiation + Annual Composites

Extraction of Shorelines + Calculating Rates of Change

Statistical Correlation Tests

Visualization of Shoreline Change + Global Mean Sea Level (GSML)

Fig 2. Methodology Workflow

Scan QR Code for access to GitHub Repo with detailed step-by-step guidelines for Annual Shoreline Extraction analysis and other related data!

NB: Annual Shoreline Extraction & Analysis workflow is an adaptation of Bishop-Taylor et al. (2021b)

Conclusion

The findings of this study underscore the critical need for data-driven, adaptive coastal management strategies. By quantifying the impact of the sea defense projects and highlighting the complex interplay between shoreline change and sea level rise, this research lays the foundation for providing valuable insights for policymakers and coastal communities in understanding the drivers of coastal erosion for assessing the economic implications on tourism, fisheries, and infrastructure. The study's findings emphasize the importance of investing in coastal protection infrastructure while recognizing the need for long-term adaptation measures to address the escalating challenges posed by climate change.

Recommendations

Future research could benefit from incorporating a wider range of data, including satellite imagery covering larger areas, local sea level data, and advanced quasi-linear statistical models. This comprehensive approach could even possibly enable an accurate prediction of shoreline changes and provide a deeper understanding of the complex interactions between sea level rise, coastal processes, and human activities. By incorporating these recommendations, policymakers could make informed decisions and develop effective strategies to protect coastal communities and mitigate the economic consequences of coastal erosion in the face of climate change.

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