International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Statistical Analysis and Predictive Modelling of North Circar Coastline: Unravelling the Future of Shoreline Dynamics

Perumala Susmitha[1, *], Dr. S. Narayana Reddy[2]

[1*] Perumala Susmitha, Research Scholar, Sri Venkateswara University College of Engineering, Department of ECE, Tirupati, Andhra Pradesh, India, 517502; Email: spsushmi032@gmail.com

[2] Professor, Sri Venkateswara University College of Engineering, Department of ECE, Tirupati, Andhra Pradesh, India

DOI: https://doi.org/10.55248/gengpi.5.0124.0263

ABSTRACT

The comprehensive research delves into the dynamic interactions between natural and human-induced factors in coastal regions, focusing on the vulnerable littoral area north of Andhra Pradesh, India. Utilizing remote sensing technology and Geographic Information Systems (GIS), the research analyses shoreline changes from 1988 to 2021, employing sophisticated methodologies such as Linear Regression Analysis (LRR) and Exponential Power Regression (EPR). The study identifies distinct erosion and accretion patterns, emphasizing the significant impact of physiographic features and anthropogenic influences on littoral dynamics.

The findings reveal notable disparities in erosion and accretion rates between the northern and southern portions of the study area, attributed to topographical variations and lithological composition. The central regions exhibit pronounced rates of shoreline alteration due to the combined effects of fluvial and marine impacts. The research employs predictive models to project future shoreline positions for 2030 and 2040, providing valuable insights for adaptation plans and policy guidelines.

This study underscores the critical importance of accurate coastal monitoring and analysis, demonstrating the efficacy of advanced technologies and statistical methodologies. The insights gained from this research have significant implications for coastal conservation and management strategies, offering fundamental knowledge for informed decision-making in vulnerable littoral regions worldwide.

Keywords: Coastal dynamics, littoral area, shoreline changes, remote sensing, Geographic Information Systems (GIS), erosion, accretion, Linear Regression Analysis (LRR), Exponential Power Regression (EPR), predictive modelling, physiographic features, anthropogenic influences, coastal conservation, adaptation strategies

1. INTRODUCTION

The interface between the land and marine ecosystems is dynamic, as it traverses the coastline. The coastal region experiences ongoing transformations as a result of diverse environmental stresses, which earns it the moniker of a dynamic or "living" coastal system. On a global scale, this geological phenomenon is widely recognised as one of the most active landforms on account of its rapid and dynamic characteristics. Coastal regions across the globe endure substantial pressures caused by a confluence of natural and human-induced elements. Although coastal regions comprise only 10% of the Earth's terrestrial surface, they provide shelter for an estimated 50% of the world's population (Bird, 2011). The increasing human population, the proliferation of unregulated urbanisation, and the expansion of industrial activities all pose imminent threats to the coastal habitats of the globe.

The littoral area is highly susceptible to a variety of natural events, including tidal inundation, wave dynamics, and rising sea levels, making it exceptionally vulnerable. The region's susceptibility is evident due to the combination of immediate and delayed events influenced by geomorphological, tectonic, hydraulic, and climatological factors. The observed phenomenon has the potential to yield both favorable and unfavorable outcomes. For instance, land erosion may deplete ecologically and economically valuable land, while land accretion can create additional usable land. Both these occurrences can be viewed positively (Ahmed, 2011). Changes in littoral boundaries have significant implications for the land, impacting economic, ecological, and societal dimensions directly due to this phenomenon.

Numerous factors play a role in influencing coastal erosion rates, including the warming of ocean waters and the gradual retreat of continental glaciers. The global variation in littoral dynamics rates is evident, underscoring the need for thorough and prolonged monitoring of coastal boundaries across multiple seasons and more frequent intervals, as highlighted by Camilleri et al. (2017). This data is essential for a comprehensive understanding of the ongoing complex coastal processes.

The transformation of littoral zones is a globally significant concern, with a particular focus on deltaic regions. Evaluating shorelines poses a considerable challenge due to their inherent dynamism characterized by constant oscillations and modifications. The littoral, serving as the dynamic boundary between terrestrial and aquatic environments, undergoes perpetual motion. This dynamism results from various factors, including storm surges, human interventions, changes in wind patterns, wave dynamics, tidal variations, and natural geomorphic processes.

These alterations occur over distinct durations, ranging from brief to protracted timespans. Hydrodynamic fluctuations, encompassing geomorphological changes like land fragmentation and the formation of barrier islands, as well as variations in sea level and river cycles, contribute to these phenomena. Topographical changes can also play a role, with immediate seismic activity or severe meteorological events potentially influencing these modifications. Besides alterations caused by natural forces such as wind, waves, currents, and tides, human activities can impact shorelines.

A variety of elemental forces, including tides, currents, waves, and wind, contribute to both accumulation and erosion, representing land movement in the same or opposite directions, respectively.Coastal erosion is a phenomenon that leads to the inundation of beach areas and the depletion of assets and structures located along the littoral, as stated by Srivastava et al. (2005). Coastal erosion presents a substantial international dilemma. Nandi (2013) argues that deltaic regions, including the Sundarbans, provide favourable conditions for the observation of this matter. The Ganges Delta and the Mekong Delta are two more geographical areas that demonstrate comparable attributes. Erosion is a continuous occurrence that gives rise to a multitude of detrimental outcomes, such as the exhaustion of natural and economic resources, consequently affecting the financial means of indigenous communities. One notable detrimental outcome is the reduction in habitats that provide support for biodiversity, which consequently leads to the depletion of biodiversity.

Predicting future coastal locations with extreme precision is of the utmost importance for mitigating the detrimental effects of erosion. In the field of Geographic Information Systems (GIS), it is customary to implement predictive models that generate projections by leveraging historical data. The End Point Regression (LR) and End Point Rate (EPR) models are utilised in this investigation. The EPR model is a dependable methodology that generates linear projections through the utilisation of comprehensive historical data collected from coastal regions. The LR model, which employs long-term coastal data, is a linear approach to prediction. Both models are utilised in order to predict the future whereabouts of the littoral. Several factors influence the effectiveness of EPR and LR models, such as the precision of shoreline identification, the amount of time necessary to acquire shoreline data, and the number of data points utilised.

The methodologies utilised by policymakers and administrators in the field of coastal management enable the prediction of forthcoming shoreline dynamics. There has been a significant increase in the number of quantitative studies undertaken by academics regarding changes in coastal boundaries in recent times. There are a multitude of rationales for conducting these inquiries. The evaluations were conducted by incorporating data acquired via remote sensing methods and implementing GIS methodologies. The study mentioned above is carried out in various geographical areas, which gives it considerable significance in the field of coastal geomorphology (Camilleri et al., 2017)

The application of GIS and satellite-derived remote sensing data is of great importance in the realm of multi-temporal littoral mapping, given its pivotal function in coastal monitoring and assessment. The utilisation of semi-automated techniques for shoreline determination, the evaluation of relative changes in coastal units, the extraction of topographic and bathymetric data, and the projection of future shorelines have been made possible by technological advancements in these areas. There have been numerous contributors to the progress of geomorphological research.

Continuous monitoring of coastal ecosystems is crucial for understanding the processes underlying their changes and the dynamic characteristics of these environments, according to Nayak (2002). It is critical to guarantee the acquisition of accurate and dependable data. Effective implementation of policies and strategies for littoral zone management requires the application of suitable plans and strict adherence to regulations. A number of scholarly investigations, including those by Camilleri et al. (2017), Khamis et al. (2017), and Ramesh et al. (2017), have underscored the importance of incorporating spatial data concerning ecologically significant regions, coastal habitat conditions, land use, and land cover in order to guarantee the effective implementation of these initiatives.

Academics with a focus on littoral regions will face an extensive range of challenges in the twenty-first century. A multitude of factors, including anthropogenic activities and climate change, contribute to the emergence of these concerns. Multiple challenges are examined in the works of Thampanya et al. (2006) and Jha et al. (2012). These challenges encompass an array of issues such as the rise in sea levels, intensification of waves, heightened frequency and intensity of storms, unforeseeable variations in swells and depressions, sediment runoff, degradation of water quality, and intrusion of saltwater. The research has identified a number of concerns that have been expressed. Cooper and Zmud (1990), and Bodin et al. (2017) have all agreed that in order to effectively tackle these challenges, a thorough empirical understanding of their manifestations in coastal regions is essential.

Enhanced precision, accuracy, and cost-efficiency have resulted from the development of mapping technology in the domains of RS, GPS, and GIS. This revolution has been enabled by the development of geospatial technology. This claim is supported by evidence from prior research conducted by Shamsi (2005), Blankespoor et al. (2012), and Craglia et al. (2012).

Effective management of coastal ecosystems, according to Yang (2005), necessitates the thorough monitoring and analysis of numerous processes. In addition to a solid knowledge base, the effective completion of this undertaking requires the application of sophisticated technological tools for analysis. Although traditional field-based mapping methods continue to hold importance, their practical limitations present certain restrictions. Due to the aforementioned phenomenon, there is a growing trend among individuals to adopt remote sensing and mapping technologies owing to their dependable nature and cost-effectiveness. The research conducted by Wright (2009) and Yang (2009) provides evidence that it is possible to provide significant support in the decision-making processes concerning a range of coastal applications. Scientific investigations of the littoral environment have made substantial progress due to the innovations enabled by remote sensing and GIS technology. The importance of this issue becomes notably apparent when one takes into account the complex characteristics of coastal areas and the frequent changes that occur within them. A number of scholarly investigations, including those conducted by Chang and Lai (2014), Burgan and Aksoy (2018), Ehteram et al. (2018), and Nabipour et al. (2020), substantiate this assertion with empirical data.

The proliferation of human settlements along coastlines and the expansion of urban areas have presented coastal ecosystems worldwide with a multitude of challenges. The previously mentioned phenomenon has significantly increased the vulnerability of coastal ecosystems and worsened their degradation. As a result, the organisations tasked with the management and operation of these susceptible regions have an increased urgency to confront these obstacles. In their individual investigations, Small et al. (2000), Small and Nicholls (2003), and Ahmed (2011) have all examined a shared observation.

On the East Coast Shoreline of India, numerous exhaustive investigations employing remote sensing methods and GIS have been undertaken. The patterns of geomorphological transformations, land use, land cover, coastal vegetation, and erosion mitigation strategies are investigated in this study. Researchers have utilised geospatial techniques to precisely delineate and analyse changes in coastal boundaries over a defined period of time. Profound developments have ensued in the field of littoral management as a consequence of this phenomenon.

Owing to its substantial population density, the littoral area of Andhra Pradesh is vulnerable to an extensive array of perils. A significant obstacle encountered in the region under consideration is the infiltration of saline onto agricultural land. The circumstance at hand has had a substantial detrimental impact on the agricultural community in the area. To optimise the effectiveness and efficiency of coastal management planning, it is critical to undertake an exhaustive investigation into the temporal dynamics of littoral changes and generate forecasts for forthcoming developments.

Coastal regions situated in deltaic zones worldwide undergo continuous and dynamic changes because of the interaction between natural and human factors, littoral changes are accompanied by an array of complications. These concerns may be classified into two discrete categories: those that stem from natural occurrences and those that are the result of human actions. To ensure efficient monitoring and management of these fluctuations, the utilisation of cutting-edge remote sensing equipment and predictive models is essential. The overarching goal of these initiatives is to ensure the protection of the inhabitants and properties located in the littoral zones.

2. STUDY AREA SELECTION

This study focuses on a coastal region located to the north of the Godavari River. Specifically, the districts of Kakinada and Visakhapatnam are directly adjacent to this coastal area. The total length of the coastline measures around 253 kilometres, excluding ports and artificially constructed sandbars. The research initially encompasses the entire coastal area and subsequently narrows down its analysis to the immediate shoreline environment. The coastal area north of the Godavari River is characterized by its diverse geography, encompassing sandy beaches, estuaries, and wetlands. The region serves as a vital ecological zone, hosting a variety of flora and fauna. The coastline stretches over a considerable distance, providing a unique habitat for marine life and a vital breeding ground for several species. Coastal erosion poses a significant threat to the region. Efforts are being made to implement coastal protection measures, including the construction of seawalls and groynes, to mitigate erosion and safeguard coastal communities. The picturesque beaches and scenic beauty of the coastal region attract tourists and contribute significantly to the local economy. Tourism-related activities, including hotels, restaurants, and recreational facilities, thrive in this area.

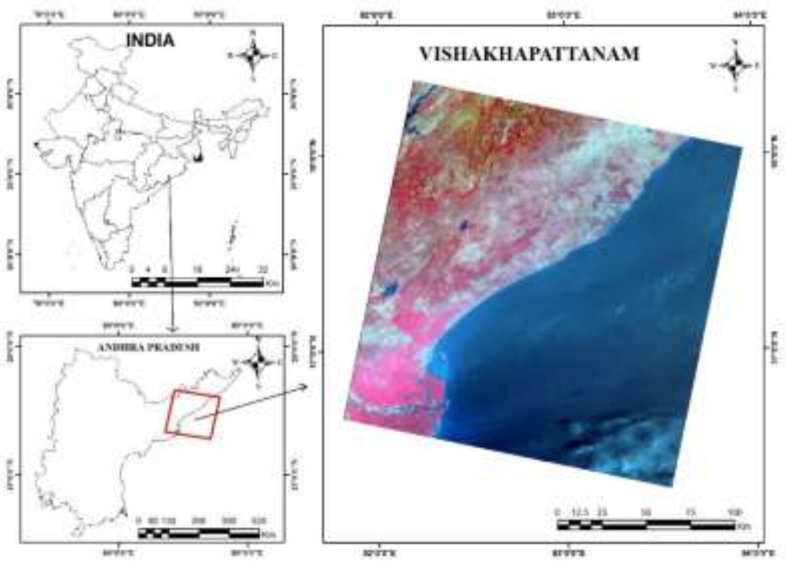

Figure 1: Study Area

3. DATA USED

Multi-temporal, multi-resolution satellite data obtained from the Landsat TM and OLI/TIRS instruments were utilised in this study. The datasets were gathered on days with negligible or no cloud cover between 1988 and 2021. The methodology of the study comprises comprehensive sub-sections that delineate the precise techniques employed to gather the data. Data was obtained from satellites LANDSAT 5 and LANDSAT 8.

The seven spectral bands comprising Landsat 4-5 TM images are as follows: bands 1-6 possess a resolution of 30 metres. Band 7 in thermal infrared was resampled from a distance of 120 metres. Images captured by Landsat 8 OLI/TIRS comprise eleven spectral bands. The resolution of bands 1-3 is 30 metres, while the resolution of bands 8 (panchromatic band) is 15 metres. The resolution of bands 10 and 11 (thermal infrared bands) is 100 metres.

The information was obtained using LANDSAT 4-5 TM Level-1 images, which were collected between 1988 and 2011, and LANDSAT 8 OLI/TIRS C1 Level-1 images, which were utilised from 2014 to 2021. In the study of littoral change, it is vital to select data with extreme care. By minimising the impact of seasonal climate changes, multi-date images guarantee the capture of significant variations in the Earth's surface. In order to accomplish this, the research predominantly gathered data in March of each year from 1988 to 2021, while accounting for the potential impact of seasonal variables. Moreover, in order to efficiently track evolving patterns, a monitoring interval spanning from three to four years was upheld.

4. METHODOLOGY

4.1 DELINEATION FROM SATELLITE IMAGES AND SHORELINE EXTRACTION ANALYSIS

After applying geometric correction and image enhancement techniques, the on-screen point mode digitization method was employed to outline the shorelines for each specific time period. The methodology involved the utilisation of a standard fake colour composite (FCC) consisting of blue, green, and near-infrared spectral bands to accurately demarcate the boundary between land and water. Previous studies have utilised Landsat satellite imagery to investigate changes occurring along the coastline, as demonstrated by Mahendra et al. (2011). The aforementioned investigations employed several methods of interpretation, including object-oriented classification and visual interpretation.

The aforementioned methodologies were utilised to assess alterations in the coastal region and produce predictions for future developments. The researchers extracted and analysed a dataset consisting of shorelines spanning the years 1988 to 2021. This analysis was conducted using the Digital Shoreline Change Analysis (DSAS v5.0) software. The examination of coastal change was conducted using this instrument, applying statistical approaches such as End Point Rate (EPR), Least-Squares Regression Rate (LRR), Net Shoreline Movement (NSM), and Shoreline Change Envelope (SCE), with a confidence level of 95% (Perumala Susmitha et al. (2022)).

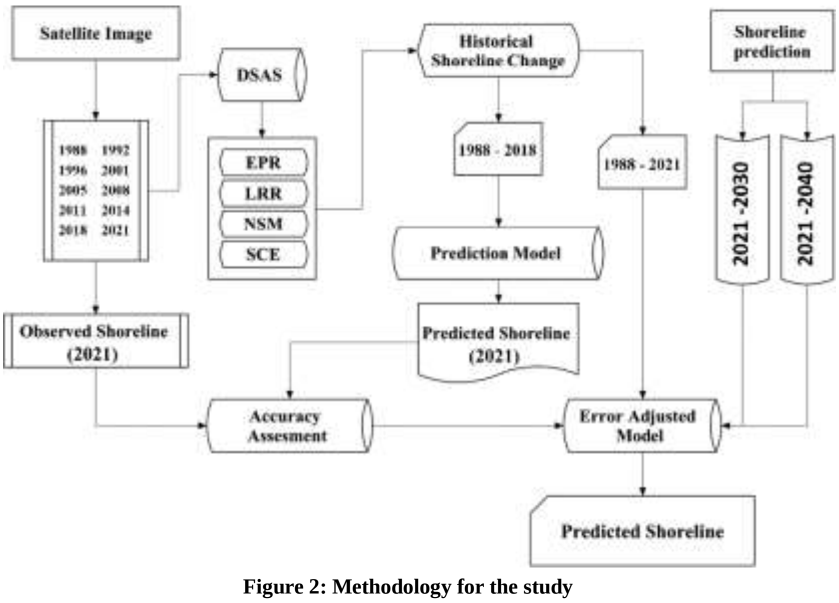

Figure 2: Methodology for the study

Empirical evaluations and future forecasts employed the use of EPR, a metric derived by dividing the distance of littoral movement by the time interval between the most current and earliest measurements. The calculation of the LRR, which represents the slope of the change statistic line, involved fitting a least-squares regression line to each littoral point along every transect. The linear regression method was employed to enable efficient computing while maintaining adherence to well accepted statistical principles. This involved utilising all available data, regardless of any swings in trend or correctness.

In order to accurately assess changes in the littoral zone, three key components were considered: the baseline, the shorelines, and the transect lines. The DSAS programme employed the baseline, which was positioned around 5,000 metres inland and ran parallel to the littoral, as the starting point for constructing all transects. To calculate shoreline change rates, transects were systematically produced at regular intervals of 100 metres along the baseline.

These transects intersected the shoreline at predetermined measurement places. The comparison between shorelines obtained from the model on a given date and the anticipated shoreline was conducted using the widely recognised Least-Squares Regression (LLR) approach, known for its high reliability.

The study involved the quantification of variations in shoreline positions obtained from DSAS data, followed by the analysis of shoreline alterations using a GIS to distinguish between accretion and erosion. The assessment of the results took into consideration various variables, such as tidal level, image resolution, digitization error, and image registration. These factors have the potential to impact the accuracy of shoreline positions and rates of change, specifically in relation to erosion (negative values) and accretion (positive values). Hence, the calculation of shoreline positional error (ϵ) for each transect involved the use of Equation (1):

$$\epsilon = \sqrt{\epsilon_{\text{seasonal}}^2 + \epsilon_{\text{tidal}}^2 + \epsilon_{\text{digitization}}^2 + \epsilon_{\text{rectification}}^2 + \epsilon_{\text{pixel}}^2} \quad (1)$$

In this equation, ϵseasonal represents seasonal error, ϵtidal is the tidal level error, ϵdigitization stands for digitization error, ϵrectification denotes rectification error, and ϵpixel signifies pixel error. This approach assumes that component errors follow a normal distribution (Dar & Dar, 2009). These total uncertainties were utilized as weights in shoreline change calculations.

These values were annualized to estimate the error (ϵ) for shoreline change rate at any given transect, as expressed in Equation (2):

$$\epsilon = \sqrt{\frac{\epsilon_{t1}^2 + \epsilon_{t2}^2 + \ldots + \epsilon_{tn}^2}{T}} \quad (2)$$

In this equation, $t1$, $t2$, and tn represent the total shoreline position error for different years, and T represents the 43-year period of analysis. The maximum annualized uncertainty, using the best estimate for this study, was determined to be ±0.53 meters per year.

5. FUTURE SHORELINE PREDICTION

The inclusion of historical processes is of utmost importance in order to enhance the precision of projected coastline locations, thus providing significant perspectives on forthcoming shoreline positions (Mukhopadhyay et al., 2012). The technique of extrapolating a constant rate of change is often used in research settings for the purpose of shoreline prediction (Eliot & Clarke, 1989). Various statistical and conventional methodologies are employed to predict future littoral positions, including erosion and accretion rates (Mukhopadhyay et al., 2012). The current study employed the statistical methodologies of End Point Rate (EPR) and Least-Squares Regression Rate (LRR) to predict the anticipated position of the shoreline in the year 2021. Among the different methodologies that were evaluated, the LRR statistical instrument was determined to be the most pragmatic and reliable in terms of predicting future shorelines. Consequently, it was utilised in the study.

The future shoreline position was predicted using the shoreline movement rate (slope), the time interval between observed and predicted shorelines, and the model intercept, expressed in Equation (3):

$$\text{Predicted Shoreline Position} = y_2 + s \times (x_t - x_2) \quad (3)$$

Here, $y2$ represents the recent shoreline position, s is the slope, xt corresponds to the future shoreline date, and $x2$ denotes the recent shoreline date. To calibrate the prediction model, two shoreline positions were required: the earliest ($y1$) and the recent ($y2$). For the EPR model, the prediction was based on two shoreline positions, while the LRR model necessitated a minimum of three shoreline positions. The model was employed to estimate future shorelines for short-term changes (2030) and long-term changes (2040).

Remote sensing and geostatistical models offer valuable information on coastal spatial dynamics (Rowley et al., 2007). However, discrepancies between model outputs and observed data can occur. Therefore, model outputs need validation against observed information. Root Mean Square Error (RMSE), indicating the absolute fit of the model to the data, and $r2$, a relative measure of fit, were considered for validation. Lower RMSE values suggest a better fit, while higher values indicate errors. Both $r2$ and RMSE were used to validate observed and model-predicted shoreline change rates for the year 2021, following Equation (4):

$$\text{RMSE} = \sum_{i-1}^{n} \left(\left((xm_i - xa_i)^2 + (ym_i - ya_i)^2 \right) \right)$$

Here, xm_i and ym_i are the model-generated positions, and xa_i and ya_i represent actual x and y positions of shoreline sample points from the baseline. The positional shifts in each sample point were calculated by comparing actual and estimated shorelines for 2021, and the future shoreline prediction was tested by applying the estimated error at each sample point.

6. RESULT AND DISCUSSION

Regional based Results (Perumala Susmitha et al. (2022))

The study area has been divided into six distinct sectors to facilitate detailed statistical analysis.

a) **Northernmost Part:** In this region, EPR indicates moderate erosion with moderate to very high accretions. LRR follows a similar trend as EPR, but NSM shows maximum very high erosion and very high accretion.

b) **Adjacent to Northernmost Part:** EPR suggests moderate erosion, some moderate accretion, and a few high to very high accretions. The region's opening exhibits very high erosion due to its dynamic nature. LRR mirrors the EPR trend, while NSM indicates mostly very high erosion and very high accretion, with a few areas showing moderate erosion to high accretion.

c) **Central Part:** EPR displays mostly high and moderate erosion, some moderate accretion, and very high accretion near the river opening due to its dynamic nature. LRR and NSM patterns align with EPR, with areas showing very high erosion and some exhibiting moderate erosion to high accretion. The river opening in this area demonstrates very high accretion.

d) **Adjacent to Central Part:** EPR indicates mostly high and moderate erosion with few areas of moderate accretion. The opening near the river displays moderate accretion due to its dynamic nature. LRR shows a similar trend as EPR, while NSM highlights mostly very high erosion, some very high accretion, and areas with both high erosion and very high accretion near the river opening.

e) **Upper Part:** EPR reveals mostly moderate to very high accretion, transitioning to high to moderate erosion. The river opening demonstrates very high accretion due to its dynamic nature. LRR and NSM trends align with EPR, with areas showing very high accretion and very high erosion, particularly near the river opening, indicating significant accretion.

f) **Southernmost Part:** In this region, EPR, LRR, and NSM all indicate similar outcomes, with predominant very high accretion and adjacent very high erosion. This area is characterized by marshy land, making it highly dynamic in nature.

6.1 QUANTITY RESULTS

The present study encompassed a comprehensive analysis of littoral change throughout the whole 253-kilometer coastline of Andhra Pradesh, conducted over the period from 1988 to 2021. The investigation revealed notable changes in the geographical positions of coastlines over this time period. The study determined that the mean annual rate of shoreline change between the years 1988 and 2021 was 1.13 metres (LRR = 0.25ca m/y), leading to a total net shoreline movement (NSM) of 189.44 metres. At the southern estuary, where the coastal area experienced a significant retreat at a pace of -128.6 metres per year (Littoral Retreat pace = 98.92 m/y), the erosion was particularly pronounced. In contrast, it can be observed that the northern region exhibited the highest level of accretion, with an annual accumulation of 102.78 metres (LRR = 81.36). It is noteworthy to emphasise that erosion and accretion were shown to be prominent phenomena occurring at the mouths of rivers, indicating that significant changes in coastline were driven by both marine and fluvial processes.

In addition, the study found that the average erosion rate was -5.05 metres per year (with a Local Relative Rate of -4.98), whereas the average accretion rate was 4.59 metres per year (with a Local Relative Rate of 4.25). The observed results indicate that the coastal region undergoes erratic variations, with erosion being the prevailing pattern. The research area exhibited notable decreases in erosion or accretion rates in both its southern and northern parts. The findings of this study were later utilised to predict the future positions of shorelines in the years 2030 and 2040.

6.2 FUTURE SHORELINE PREDICTION RESULTS

This study conducted a thorough analysis of alterations to the shoreline, focusing specifically on the timeframes of 2030 and 2040, in order to have a deeper understanding of both short-term and long-term changes. Coastal regions worldwide are increasingly vulnerable to the occurrence of intense climatic events, such as storm surges, cyclones, and tsunamis (Basheer Ahammed & Pandey, 2019b). While these events were not included in the upcoming predictions for coastal areas, they offer valuable insights for the formulation of adaption plans and policy guidelines.

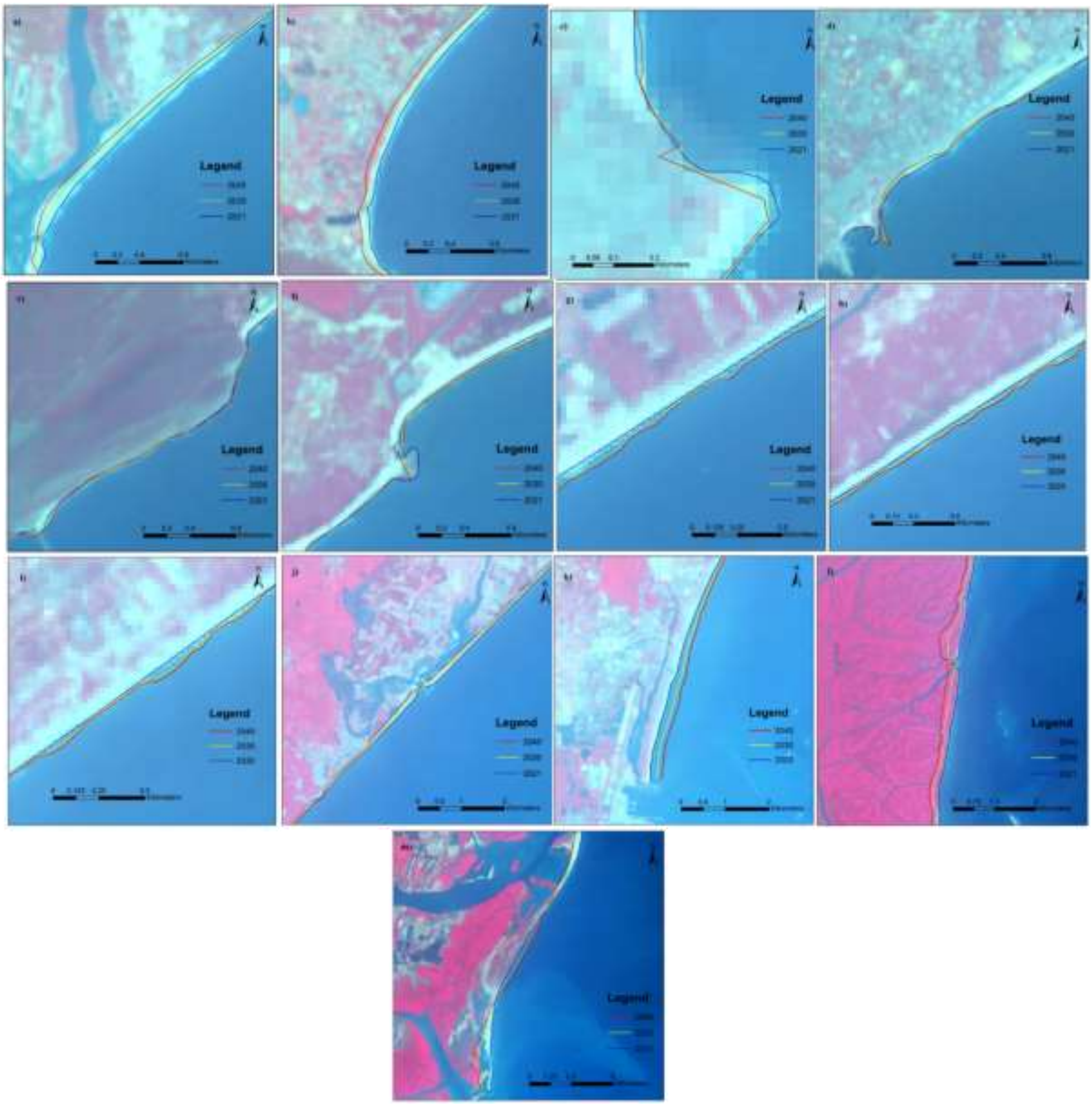

Figure 3. Positional Shift of the predicted Shoreline

The study conducted a quantitative analysis to determine the mean shift in the littoral zone, revealing a negative displacement of -3.43 metres for the period spanning from 2021 to 2030. This investigation employed the LRR model as the primary analytical framework. The estimated rate of increase from 2021 to 2040 is expected to dramatically rise to -12.02 metres. It is worth mentioning that a substantial accumulation is expected to take place along the western coastline, leading to a displacement of 940.42 metres towards the sea. In contrast, it is anticipated that erosion will manifest within the aforementioned region, exhibiting a displacement of 3296 metres during the temporal span from 2021 to 2030. Based on long-term studies, it is projected that there will be a substantial landward shift of -5104.6 m and a littoral shift of 1458 m in the neighbourhood from 2021 to 2040.

7. CONCLUSION

This study emphasises the importance of remote sensing technology and GIS methodologies in the prediction and analysis of dynamic coasts. The Digital Littoral Analysis System has been identified as the most effective tool for monitoring and analysing littoral motions. Statistical methodologies, such as Linear Regression Analysis (LRR) and Exponential Power Regression (EPR), are the most direct and effective approaches for examining historical rates of littoral change within this particular system. The present study employed Landsat data with a spatial resolution of 30 metres, which is commonly adopted for regional-level investigations due to its satisfactory degree of detail.

The research findings indicate that there are notable disparities in erosion and accretion rates between the northern and southern portions of the study area. The rates of erosion and accretion shown a relative decrease along the beaches in the northern region. The observed disparity can be attributed to the distinctive physiographic features of northern Andhra Pradesh, which encompass its elevated topography and the robust lithological composition of the Eastern Ghats, which provide shielding to the northern coastline. In contrast, the coastal plains constitute a significant portion of the southern coast. However, the absence of river tributaries in this region contributes to a deceleration in the rate of shoreline alteration.

The centre portions of the study area exhibit the most notable rates of erosion and accretion as a result of the combined effects of fluvial and marine impacts. The coastal regions under consideration exhibit distinct characteristics such as intricate stone formations, sand bars, spits, and deltaic terrains, which inherently make them susceptible to erosion. Subsequent inquiries could potentially explore the integration of advanced technologies, such as Differential Global Positioning System (DGPS) and geotagging applications, in conjunction with high-resolution satellite imagery, to enhance the accuracy of delineating littoral positions.

The design of shorelines is significantly influenced by a variety of natural and anthropogenic forces. The factors encompassed in this category consist of littoral drift, nearshore bathymetry, tidal influence, oceanic waves, and the implementation of engineered structures like breakwaters and seawalls. Coastal engineers, administrators, and authorities involved in coastal zone management must recognise and consider these factors as a matter of utmost importance. The findings derived from this study yield crucial fundamental information that greatly impacts the advancement of effective strategies for coastal conservation and management.

8. REFERENCES

[1] Ahmed A. 2011 Some of the major environmental problems relating to land use changes in the coastal areas of Bangladesh. Journal of Geography and Regional Planning 4, 1–8.

[2] Bird E. 2011 Coastal Geomorphology: An Introduction, 2nd edn. John Wiley & Sons Ltd, Chichester, UK.

[3] Blankespoor B., Dasgupta S. & Laplante B. 2012 Sea-level Rise and Coastal Wetlands: Impacts and Costs. The World Bank, Washington DC, USA.

[4] Bodin Ö., Sandström A. & Crona B. 2017 Collaborative networks for effective ecosystem-based management: a set of working hypotheses. Policy Studies Journal 45, 289–314. https://doi.org/10.1111/psj.12146.

[5] Burgan H. I. & Aksoy H. 2018 Annual flow duration curve model for ungauged basins. Hydrology Research 49, 1684–1695.

[6] Camilleri S., De Giglio M., Stecchi F. & Pérez-Hurtado A. 2017 Land use and land cover change analysis in predominantly man-made coastal wetlands: towards a methodological framework. Wetlands Ecology and Management 25, 23–43. https://doi.org/10.1007/s11273-016-9500-4.

[7] Chang F.-J. & Lai H.-C. 2014 Adaptive neuro-fuzzy inference system for the prediction of monthly shoreline changes in northeastern Taiwan. Ocean Engineering 84, 145–156.

[8] Craglia M., de Bie K., Jackson D., Pesarisi M., Remetey-Fulopp G., Wang C., Annoni A., Bian L., Campbell F., Ehlers M., van Genderen J., Goodchild M., Guo H., Lewis A., Simpson R., Skidmore A. & Woodgate P. 2012 Digital earth 2020: towards the vision for the next decade. International Journal of Digital Earth 5, 4–21. https://doi.org/10.1080/17538947.2011.638500.

[9] Dar I. A. & Dar M. A. 2009 Prediction of shoreline recession using geospatial technology: a case study of Chennai Coast, Tamil Nadu, India. Journal of Coastal Research 25, 1276–1286.

[10] Ehteram M., Mousavi S. F., Karami H., Farzin S., Singh V. P., Chau K. & El-Shafie A. 2018 Reservoir operation based on evolutionary algorithms and multi-criteria decision-making under climate change and uncertainty. Journal of Hydroinformatics 20, 332–355.

[11] Eliot I. & Clarke D. 1989 Temporal and spatial bias in the estimation of shoreline rate-of-change statistics from beach survey information. Coastal Management 17, 129–156. https://doi.org/10.1080/08920758909362081.

[12] Jha A. K., Bloch R. & Lamond J. 2012 Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank, Washington DC, USA.

[13] Khamis Z. A., Kalliola R. & Käyhkö N. 2017 Geographical characterization of the Zanzibar coastal zone and its management perspectives. Ocean and Coastal Management 149, 116–134. https://doi.org/10.1016/j.ocecoaman.2017.10.003.

[14] Mahendra R. S., Mohanty P. C., Bisoyi H., Srinivasa Kumar T. & Nayak S. 2011 Assessment and management of coastal multi-hazard vulnerability along the Cuddalore–Villupuram, east coast of India using geospatial techniques. Ocean & Coastal Management 54, 302–311. https://doi.org/10.1016/j.ocecoaman.2010.12.008.

[15] Mukhopadhyay A., Mukherjee S., Mukherjee S. & Ghosh S. 2012 Automatic shoreline detection and future prediction: a case study on Puri Coast, Bay of Bengal, India. European Journal of Remote Sensing 45, 201–213.

[16] Nabipour N., Mosavi A., Hajnal E., Nadai L., Shamshirband S. & Chau K.-W. 2020 Modeling climate change impact on wind power resources using adaptive neuro-fuzzy inference system. Engineering Applications of Computational Fluid Mechanics 14, 491–506.

[17] Nandi S (2013) Assessment of shoreline changes and its future prediction using geospatial techniques in deltaic Sundarban, West Bengal, M.Tech. thesis, BIT, Mesra, Ranchi, India

[18] Nayak S. 2002 Use of satellite data in coastal mapping. Indian Cartographer 22, 147–157.

[19] Ramesh R., Purvaja R., Krishnan P., Lakshmi A. 2017 Conservation of coastal wetlands: An appraisal of the policy and legal framework in South Asian nations. In: Wetland Science (Anjan Kumar Prusty B., Chandra R. & Azeez P. A., eds.). Springer Nature, Switzerland, pp. 515–544.

[20] Randolph B. Cooper and Robert W. Zmud 1990 Information Technology Implementation Research: A Technological Diffusion Approach Vol. 36, No. 2 https://doi.org/10.1287/mnsc.36.2.123

[21] Rowley R. J., Kostelnick J. C., Braaten D., Li X. & Meisel J. 2007 Risk of rising sea level to population and land area. Eos, Transactions American Geophysical Union 88, 105–107.

[22] Shamsi U. M. 2005 GIS Applications for Water, Wastewater, and Stormwater Systems. CRC Press, Boca Raton, FL, USA.

[23] Small C. & Nicholls R. J. 2003 A global analysis of human settlement in coastal zones. Journal of Coastal Research 19, 584–599.

[24] Small C., Gornitz V. & Cohen J. E. 2000 Coastal hazards and the global distribution of human population. Environmental Geosciences 7, 3–12.

[25] Srivastava A, Niu X, Di K, Li R (2005) Shoreline modeling and erosion prediction, ASPRS 2005 Annual Conference Geospatial GoesGlobal: From Your Neighborhood to the Whole Planet March 7 - 11, 2005, Baltimore, Maryland

[26] Thampanya U., Vermaat J. E., Sinsakul S. & Panapitukkul N. 2006 Coastal erosion and mangrove progradation of Southern Thailand. Estuarine, Coastal and Shelf Science 68, 75–85.

[27] Wright D. J. 2009 Spatial data infrastructures for coastal environments. In: Yang X. (ed.). Remote Sensing and Geospatial Technologies for Coastal Ecosystem Assessment and Management. Springer-Verlag, Berlin, Heidelberg, Germany, pp. 91–112.

[28] Yang X. 2005 Remote sensing and GIS applications for estuarine ecosystem analysis: an overview. International Journal of Remote Sensing 26, 5347–5356. https://doi.org/10.1080/01431160500219406.

[29] Yang X. 2009 Remote Sensing and Geospatial Technologies for Coastal Ecosystem Assessment and Management. Springer-Verlag, Berlin, Heidelberg, Germany.

[30] Perumala Susmitha., Dr.S. Narayana Reddy 2023 GEOSPATIAL TECHNIQUES ON IMPACT OF SHORELINE CHANGE AND LAND USE PATTERN CRITICAL ANALYSIS, AT IN AND AROUND SOUTH WEST COAST, Semiconductor Optoelectronics, Vol. 41 No. 04 (April 2022), 742-760 https://bdtgd.cn/.