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REMOTE SENSING AND GIS-BASED COMPUTATIONAL ANALYSIS OF CLIMATE CHANGE IMPACTS IN THE COASTAL REGION OF THOOTHUKUDI DISTRICT, TAMIL NADU

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Abstract:

Climate change poses significant threats to coastal ecosystems, infrastructure, and livelihoods, particularly in vulnerable regions such as the coastal areas of Thoothukudi District, Tamil Nadu, India. This study presents a Remote Sensing and GIS-based computational analysis to assess the spatial and temporal impacts of climate change along the coastal region of Thoothukudi. Multi-temporal satellite imagery and geospatial datasets were utilized to examine key climate-induced parameters, including shoreline change, land use and land cover (LULC) dynamics, sea surface temperature variations, and coastal erosion patterns. Advanced image processing techniques and GIS-based spatial analysis were employed to extract, classify, and quantify changes over multiple time periods.

The computational framework integrates change detection algorithms, spatial overlay analysis, and statistical modeling to evaluate long-term environmental transformations and vulnerability hotspots. The results reveal significant alterations in coastal morphology, increased shoreline retreat in select zones, and notable shifts in land use patterns attributed to climate variability and anthropogenic activities. The study further demonstrates the effectiveness of geospatial technologies in providing accurate, scalable, and data-driven insights for coastal monitoring and climate impact assessment.

This research highlights the importance of integrating Remote Sensing, GIS, and computational analysis for evidence-based coastal management, climate adaptation planning, and sustainable development. The proposed approach can be extended to other coastal regions to support decision-making and early warning systems under changing climatic conditions.

Keywords: Remote Sensing; Geographic Information System (GIS); Climate Change; Coastal Vulnerability; Shoreline Change Analysis; Land Use and Land Cover (LULC); Thoothukudi District; Computational Analysis.

Introduction

Climate is defined as the interchange of energy and moisture between the atmosphere and earth. Temperature, Precipitation, and wind are the major climate variables, which continuously changing with a change in seasons. The climate is the average weather over a period of the time, ranging from months to thousands of years.

Climate change is mainly caused by anthropogenic emissions of greenhouse gases(McMichael et al., 2006), and its direct impacts include two aspects. Long-term variability is reflected by climate variations, such as the increasing land surface temperature. Short-term variability is characterized by the frequency of irregular weather events, such as floods, droughts, heat waves, and storms. Climate change has many, often adverse effects on human health (McMichael et al., 2006). Therefore, it is considered a significant health determinant, especially for those in vulnerable areas (Canbalonieri et al., 2014; Kolstad and Johansson, 2011). The World Health Organization (WHO) reported that 12.6 million deaths were due to climate change or climate change-driven forces (WHO, 2016), accounting for 23% of total deaths globally in 2012. Climate change directly impacts on land covers also. It is noticed in the study area also. In the Northern part of the study area, agriculture depends on rainfall. The impact of rainfall is experienced here. On the other hand, land use also plays a vital in the response of climate change. Increasing urbanization leads to high land surface temperature called Urban Heat Island. This also experienced in the study around the urbanization locations. The Coastal zone covered by chemical industries and harbor also leads a role in Air temperature and surface temperature.

The global ocean is already experiencing the significant impact of climate change and its accompanying effects. It includes air and water temperature warming, seasonal shifts in species, coral bleaching, sea-level rise, coastal inundation, coastal erosion, harmful algal blooms, hypoxic (or dead) zones, new marine diseases, loss of marine mammals, changes in levels of precipitation, and fishery declines besides extreme weather events (droughts, floods, storms), which affects the habitats and the species alike, which affect the health of marine species, nearshore, and deep-ocean ecosystems. To protect our valuable marine ecosystems, the study of climate change is an essential part nowadays. Research studies prove that erosion and deposition in the coastline are also due to the climatic parameters and the geo hazards. Rate of Erosion is higher when compared with the past. Such coastal hazards need to be

continually monitored for the prediction of the rate of erosion to forecast in the future. In turn, it will be useful for the preventive measures for the management aspects.

Objectives

- To analyses the climate parameters to understand the climate change scenario in the study area (Rainfall and Temperature),
- To assess the impacts of climate change on the environment in terms of vegetation index (NDVI), water index (NDWI), drought index (NDDI) in terrestrial region using Remote sensing and GIS techniques,
- To assess the impact of Climate Change on Land use and Land cover changes in Terrestrial region with special emphasis on land surface temperature,
- To determine the spatial and temporal distribution of ocean climate variables and their impacts, to determine the shoreline, change and its effects on coastal areas by CRZ studies, and bathymetry.

Review of literature:

MUTHUKUMARASAMY.R, MUKESH.M.V 2013 Coastal erosion along the Valinokkam and Thoothukudi coast has been quantified using Landsat ETM data from 1992 to 2012, showing varying rates of erosion and accretion across different periods. Erosion measured 369m (1992-2000), 573m (2000-2005), 172m (2005-2010), and 305m (2010-2012). Accretion was observed as 1258m (1992-2000), 120m (2000-2005), 531m (2005-2010), and 366m (2010-2012). Specific areas like Hare Island exhibit simultaneous erosion and accretion, with accretion dominating, indicating a pro-grading coastline. Wave patterns studied via 2012 Landsat imagery support these findings.

CHANDRASEKAR, N. MUJABAR, P.S. and RAJAMANICKAM, G.V. (2011) Heavy-mineral deposits along the south Tamil Nadu coast were mapped using multispectral satellite data and hyperspectral analysis with ENVI software. Endmembers were identified through spectral signature comparison with USGS spectral libraries and mapped using spectral angle mapper (SAM). Ground verification confirmed classification accuracy, highlighting the potential for eco-friendly mineral exploitation and the effectiveness of multispectral data in mineral mapping.

CHANG R., ZHU, R., BADGER, M., HASAGER, C.B., XING, X. And JIANG, Y. (2015) Offshore wind resources over the South China Sea were assessed by integrating

multiple satellite wind datasets (SAR, ASCAT) with WRF model simulations. Validation against in situ data showed good agreement, with improved accuracy when excluding offshore winds. Assimilation of satellite winds into WRF via WRFDA provided reliable wind resource statistics at 100 m height, enhancing offshore wind assessment.

CHATURVEDI, N. (2005) Chlorophyll variability in the Arabian Sea and Bay of Bengal (1997-2000) was studied using SeaWiFS data, with SST derived from NOAA AVHRR. Experimental investigation of heat transfer in an excited circular impinging jet revealed sensitivity to excitation frequency, showing enhancement or reduction near natural frequencies. Correlations between vortical structures and local heat transfer were analyzed through flow visualization and spectral methods.

Study Area:

Thoothukudi Coramandel coast is southern portions of Tamilnadu, located in the southern part of South India is taken up for the research work. It lies between 77°53'E to 78°26' E Longitude and 8°13' N to 9°10' N Latitude of Thoothukudi district in Tamil Nadu, India. This length of the coast is 200 km. The study area falls under Survey of India (SOI) toposheet numbers, 58 H 15, 58 K 4 & 8 and 58 L 1, 2, 3 & 5 respectively. Thoothukudi coast forms the southernmost tip of the Gulf of Mannar (GoM). Coral reefs islands (Van, Koswari, Kariya Shuli and Vilangu Shuli), mangroves, mudflats, dunes, and sandy beaches, seaweeds and seagrass beds are some of the sensitive ecosystems found here. In addition to the natural ecosystem noticed Thoothukudi coast also famous for several economic activities such as fisheries, salt pans, urban settlements, and industries. A major river that controls the drainage pattern in the study area is Tamirabarani; minor streams like Palaiyar, Nambiyar, and Hanuman Nadhi, and seasonal streams like Nilapparai and Puttanar channels are noticed in the study area.

Methodology:

The Materials and Methods used for the Climate change studies and coastal geohazards using Remote Sensing, Geographic Information System (GIS) and Global Positioning System are explained in this chapter. The procedure for Thematic Maps of the various parameters which have been analysed was prepared are explained here. The overall methodology adopted. The detailed methodology for each parameter is provided in the respective sections.

Result and Discussion:

This chapter dealt with the results and discussion to interpret the Climate change studies, and coastal geohazards assessment using Remote Sensing, Geographic Information System (GIS) and Global Positioning System. The study had carried out the Coastal Geohazards using DSAS and GIS software. The Coastal Regulation zone findings also enlighten in this chapter. The climate change study is described under two categories, i.e., Terrestrial parameters and Ocean parameters. Satellite data products and intensive field study had helped to assess the climatic parameters. All the results were taken to GIS, wherein all the thematic maps and further analysis were carried out. The results and discussion are detailed below.

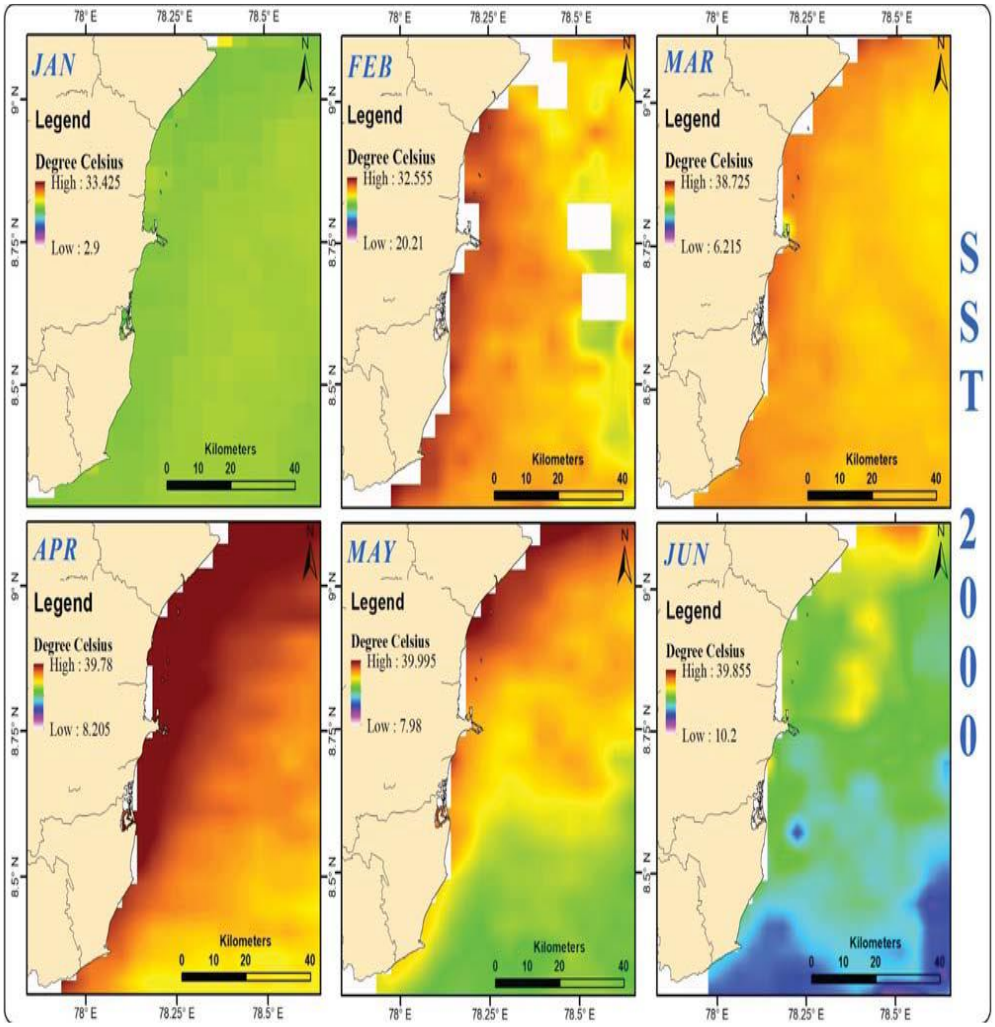

Figure 1: Sea Surface Temperature Changes

Conclusion

The climate change scenario in the study area was analyzed using terrestrial and oceanic climatic parameters over 1990–2019. Rainfall trends indicate generally lower annual rainfall than the state average, except for a peak in 2008. The NE Monsoon season recorded relatively high rainfall, with a decadal increase from the first to the third decade. Spatially, southern locations like Thoothukudi and Thiruchendur received significant rainfall, while northern locations such as Surangudi and Vaippar experienced lower rainfall. Overall, rainfall was scanty to deficit across the decades.

Standard Precipitation Index (SPI) showed extreme drought in several stations between 1990 and 2004, improving to near-normal or moderate wet conditions after 2004, with high rainfall in 2008. NDVI and NDWI analyses revealed severe to extreme drought conditions during 1997–2019, influenced by rainfall variability and land surface temperature changes. The combined NDDI confirmed persistent severe to extreme drought over this period.

Land surface temperature (LST) ranged from 32°C–35°C (1997–2009), dropped to 21°C–24°C in 2015, then rose to 28°C–33°C in 2019. The overall trend shows temperature increases with some fluctuations. Urban Heat Island (UHI) studies showed green islands dominating in 1997, expanding violent heat islands in 2005 and 2009, a resurgence of green islands in 2015, and renewed heat island expansion in 2019, linked to climatic changes.

Land use and land cover (LULC) changes from 1997 to 2019 reflect both climate and anthropogenic impacts. Fallow land and cropland decreased, while barren land, saltpans, and residential areas expanded. Vegetated sand and shrublands diminished, converted into barren land and urban areas. These shifts demonstrate urbanization and climate change effects, including reduced rainfall and rising temperatures, contributing to drought conditions.

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