ASSESSMENT OF TOURISM DEVELOPMENT IN CALANGUTE: USING GEOSPATIAL TECHNIQUE

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DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, "ASSESSMENT OF TOURISM DEVELOPMENT IN CALANGUTE: USING GEOSPATIAL TECHNIQUE" is based on the results of investigations carried out by me in the Environmental Science at the School of Earth Ocean and Atmospheric Sciences, Goa University under the supervision of Dr. Nitin Sawant and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will not be responsible for the correctness of observations / experimental or other findings given the dissertation.

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COMPLETION CERTIFICATE

This is to certify that the dissertation report "ASSESSMENT OF TOURISM DEVELOPMENT IN CALANGUTE: USING GEOSPATIAL TECHNIQUE" is a bonafide work carried out by Ms. Shourya Shyamsundar Phadte under my supervision in partial fulfilment of the requirements for the award of the degree of Master of Science in the Discipline Environmental Science at the School of Earth Ocean and Atmospheric Sciences, Goa University.

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PREFACE

Tourism has long been recognized as a two-sided-coin, providing economic benefits while posing significant challenges to the environment and local communities, particularly in coastal areas. The genesis of this thesis "Assessment of Tourism Development in Calangute: Using Geospatial Techniques" lies in a profound interest in understanding the complex relationship between tourism growth and land use/land cover changes in Calangute over time using geospatial techniques. With its pristine beaches and vibrant tourism industry, Calangute provides a compelling case study to explore these dynamics. Calangute is a popular tourist destination in Goa, India. The preface of this thesis serves as a gateway to the exploration of tourism development in Calangute, offering insights into the motivations, methodologies, and objectives that support this research endeavor. It also extends gratitude to the individuals and institutions whose support and guidance have been instrumental in shaping this research. We aim to capture the spatial and temporal dynamics of tourism activities and their impact on the coastal environment through the holistic application of remote sensing, GIS, and spatial analysis. This approach allows us to identify patterns, trends, and hotspots of tourism development, which are important insights for sustainable management and planning. Utilizing the power of geospatial analysis, we can better understand the dynamics of tourism development, identify areas of concern, and formulate evidence-based strategies for sustainable tourism planning and conservation. As tourism grows in Calangute and other coastal destinations around the world, it is imperative that we adopt a proactive and sustainable approach to tourism management. I hope that this thesis will serve as a catalyst for informed decision-making, policy formulation, and collaborative action towards fostering a more sustainable future for tourism in Calangute and beyond. By working together, we can ensure that tourism development in coastal areas strikes a harmonious balance between economic prosperity, environmental preservation, and social well-being.

ACKNOWLEDGMENT

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ABBREVIATION USED

Entity	Abbreviation
Ministry of Environment and Forests	MoEF
Coastal Regulation Zone	CRZ
Environmental Impact Assessment	EIA
Low Tide Line	LTL
Land Use and Land Cover	LULC
Maximum Likelihood Classifier	MLC
Indian Space Research Organization	ISRO
Mobile- Satellite Service	MSS
Normalised Difference Vegetation Index	NDVI
National Institute of Oceanography	NIO
Non-Resident Indians	NRI
Operational Land Imager	OLI
Root Mean Square Error	RMSE
Thermal Infrared Sensor	TIRS
Thematic Mapper	TM
The Ocean Topography Experiment POSEIDON	TOPEX
United States Geological Survey	USGS
Aeronautical Reconnaissance Coverage Geographic Information System	ArcGIS
Linear Imagine Self Scanning Sensor	LISS
Digital Shoreline Analysis System	DSAS
End Point Rate	EPR

Earth Resource Data Analysis System	ERDAS
Enhance Thematic Mapper	ETM
False Color Composite	FCC
Geographical Information System	GIS
Global Positioning System	GPS
High Threshold Logic	HTL
High Tide Line	HTL
Indian Remote Sensing	IRS

ABSTRACT

The coastal region is rich in scenic beauty and precious natural resources. Coastal states like Goa presently depend heavily on their coastal zones. North Goa's coastline beaches are mostly under stress from infrastructure and development in order to boost tourism in the State. Tourism development in Calangute, a coastal village in Goa, India, has experienced significant growth in recent decades, leading to various environmental and socio-economic impacts. This study utilizes geospatial techniques to comprehensively assess the evolution of tourism in Calangute and its implications on the coastal environment. Through remote sensing, Geographic Information Systems (GIS), and spatial analysis, spatially explicit data on land use/land cover changes, coastal shoreline dynamics, and infrastructure development are analyzed. The study aims to identify patterns of tourism growth, understand land-use changes, assess coastal shoreline modifications, and propose sustainable coastal management strategies to mitigate negative impacts. By integrating geospatial data with field observations and socio-economic indicators, this research provides valuable insights for informed decision-making and sustainable tourism management in Calangute.

Chapter 1

CHAPTER 1: INTRODUCTION

1.1 Background

Tourism is a cultural, social, and economic event. It is the movement of people outside their normal environment for business or personal activities (Dina Fernandes, 2022). It is an important sector for the economic development of many countries, providing employment opportunities, foreign exchange earnings, and infrastructure development (Mihalic, 2002). However, uncontrolled/unplanned tourism development can hurt the environment, local communities, and cultural heritage. This is especially true in coastal areas, where the fragile natural environment is often threatened by the influx of tourists and associated infrastructure development.

In 1991, the land between the low tide line (LTL) and the high tide line, as well as the coastal areas including oceans, bays, creeks, rivers, and backwaters that are affected by tides up to 500 meters from the high tide line (HTL), were designated as coastal regulatory zones (CRZs) (Nayak, 2004). In accordance with the Environment Protection Act of 1986, the Ministry of Environment, Forests, and Climate Change has established the coastline regulation zones. Although the Union Environment Ministry creates the CRZ Rules, state governments, acting through their Coastal Zone Management Authorities, are responsible for ensuring its implementation. The Government of India established the Coastal Regulation Zone (CRZ) in 1991 to safeguard the coastal environment and coastal ecosystem (Panigrahi et al., 2012). According to MoEF's 2019 notification, enables construction along the coastline from 200m to 50m from the High Tide line (HTL) which will destroy the coastal ecology. The entire open beaches will turn into a concrete jungle (Fernandes et al., 2020).

Goa, a tiny state on the west coast of India is known for its beautiful beaches, rich cultural heritage as well as historical monuments (Pawaskar et al., 2012). It has a 105 km long coastline (Kunte et al., 2014). Goa is visited by a large number of international and domestic tourists each year (Pawaskar et al., 2012). Most of the tourism in Goa is concentrated in the coastal regions of Bardez, Salcete, Tiswadi, and Marmagao. Over 90 percent of domestic tourists and over 99 percent of international tourists frequent these areas (Sawkar et al., 1998). As a result, beach tourism is the most popular type of tourist that both policymakers and interested parties actively support. The first is domestic tourists, they look for a culture that's different from the rest of India because the Goans' image has a certain spirituality, a sense of freedom, and an "untraditional" style of dress. The second is the international tourists who visit Goa purely for the natural environment and beaches (Sawkar et al., 1998).

In Goa, Calangute is one of the most famous tourist destinations that attracts a large number of domestic and international tourists every year (Kamath et al., 1996). This has gradually increased the overall development of the Village. The purpose of this study is to assess the development of tourism in Calangute using geospatial techniques and to propose sustainable coastal management strategies to mitigate the negative impacts of tourism on the coastal environment.

The research focuses on the following key areas to understand the growth of tourism in Goa and specifically in the Calangute study area. Over the years, the number of tourists in Goa has grown significantly (Noronha et al., 2002), with Calangute being one of the major contributors. Understanding this growth provides insight into the factors driving tourism development in the region and the associated pressures on the natural and built environment.

In addition, the study focuses on land use development trends and land cover changes in the study area from 1991 to 2021. Land cover alludes to the surface cover on ground, like infrastructure, forests, water, bare land etc. While land use tells us about for what purpose a particular land is being used for. It basically gives us an explanation of how people use land for socio-economic activities. LULC maps play a remarkable role in observing, designing and directing programs at local, national and global levels (Fernandes, 2022). This kind of data gives us a better picture about how to utilize land. Geospatial techniques, such as remote sensing and Geographic Information Systems (GIS), can be used to study land use and land cover patterns. These technologies allow for the collection, analysis, and visualization of spatial data (Pundt et al., 2000). Mapping and analyzing these changes help to understand the extent of environmental impacts and support sustainable planning and development strategies. It also provides insight into regional patterns of LULC changes associated with urbanization, agricultural expansion, vegetation and other tourism developments.

Accordingly, study of shoreline changes on the Calangute Beach of Goa between the years of 1991 to 2021, becomes essential to understand erosion, accretion and stable structure of the shore. The study focuses on changes in the coastal area to assess the effects of tourism on the coastal environment. Understanding these changes is crucial for the management of coastal areas and the implementation of measures to protect and preserve the coastal environment. This requires analysis of satellite images and geospatial data to identify shoreline changes, areas of erosion and coastal vulnerability.

Finally, the study proposes strategies for sustainable coastal management to mitigate the negative impact of tourism on the coastal environment. This includes measures to protect natural ecosystems, protect sensitive habitats, and promote responsible tourism. The proposed strategies are based on the understanding of tourism development, LULC changes and coastal changes in the study area. Therefore, the evaluation of tourism development in Calangute using geospatial techniques is crucial to understand the evolving dynamics of tourism and its impacts in a coastal environment. This study will contribute to informed decision-making and policy formulation for sustainable tourism development and coastal management in Calangute and environmental protection in coastal areas.

1.2 Aims and Objectives

Aim

This study aimed to utilize geospatial techniques to comprehensively assess the development of tourism in Calangute.

Objectives

Here the following objectives were undertaken for the study:

1. To assess the growth of Tourism in Goa and the study area.
2. To study development trends in Land Use Land cover change in the study region from 1991 to 2021.
3. To understand the Coastal Shoreline Changes between 1991 and 2021.
4. Propose sustainable coastal management strategies to mitigate the negative impacts of tourism on the coastal environment.

1.3 Research Questions/Hypotheses

The following are the research questions and hypotheses:

Research Questions:

1. What is the extent of tourism growth in Goa especially in the study area of Calangute?
2. How has land use and land cover (LULC) changed over time in the study region?
3. What are the patterns of coastal shoreline changes in Calangute?
4. What are the negative effects of tourism on the coastal environment in Calangute?
5. What sustainable coastal management strategies can be recommended to mitigate the negative impacts of tourism on Calangute's coastal environment?
6. How do geospatial techniques help to assess the development of tourism in Calangute and its impact on the environment?

Hypotheses

The extent of tourism development in Calangute, assessed using geospatial analysis, is significantly correlated with changes in land use and land cover over time.

1.4 Scope

The study will contribute to the existing knowledge on sustainable tourism development in coastal areas and provide valuable insights to decision-makers, researchers, and practitioners in the field. The results of the study help identify the main challenges and opportunities for sustainable tourism development in Calangute and provide recommendations for effective coastal management strategies.

Chapter 2

CHAPTER 2: LITERATURE REVIEW

The coastal modifications are rampant in Goa. The following literature reviews helped to put forth the research carried out in studying the changes at the global as well as regional levels. The modules used in the study by researchers helped to give a basic database and methodology for the present research work to carry out.

Nadaf, F. M. (2020) has covered studies on “Coastal Tourism and its Impact on the Goan Environment”. This paper focuses on understanding the growth of tourism in Goa and examines the impact of tourism on the coastal environment. The study was based on both primary and secondary facts which were gathered from field work and field observation. The secondary was collected from the tropical map, Geocoded falls color composite of IRS IC LISS III. GIS portals such as Google Earth, Wikimedia, and Bhutan Earth were also used for the studies. This paper provides an overview of the growth of tourism in Goa which is very rapid, unplanned, and haphazard. Hence this paper highlights the influence of the tourism industry on the coastal environment of Goa.

Ara et al., (2021) wanted to find out the Impact of Tourism on LULC and LST on a coastal Island in the Bay of Bengal. St. Martin’s Island is the most frequently visited tourist destination in Bangladesh, and it is widely famous for its coral ecosystem. The author’s focus was mainly on the coral reefs and surface temperature as the changes in surface temperature affected the local microclimate and coral reef. So, the authors selected some locations on St. Martin's Island and tried to quantify them based on the tourist pressure index (TPI). The next target was to explain the relationship between LULC change, TPI, and LST for the years 2005 to 2019. First, a supervised classification was employed with six land classes namely built-up, waterbody, vegetation, sandy, agriculture, and coral reef. It was found that LST and build-up showed an increasing trend, while vegetation was on a decreasing side. Concerning the relationship between TPI and LULC, it was seen that the changes in LULC were more repeated in areas where TPI was high. The increase in LST was escalated due to the frequent changes in LULC. In the last decade, it was seen that agricultural lands were reduced and a large number of hotels and resorts were constructed. A correlation analysis was also conducted regarding the 10 relationships between LST and TPI, and through this, it was observed that the commute in mean LST was higher in areas where the TPI score was higher. In simple words, the LST was high in places that were recognized as high tourist attractions.

Dey, J. et al., (2018) conducted a study on the Geospatial Assessment of Tourism Impact on the Land Environment of Dehradun Uttarakhand India. The authors assessed the impact of tourism for the following years 1972, 2000, and 2016 with the help of GIS techniques and remote sensing. The objective of this article was to analyze land use and land cover in Dehradun and to determine the impacts of tourism on natural slopes. For this, the authors used Landsat images from USGS Earth Explorer. The authors used ASTER-DEM to ascertain Dehradun's topography and object-based image classification to extract 14 land use and land cover from satellite photos. The LULCs have been defined as vegetation, constructed ecosystems, scrublands, forests, plantation agriculture, and water bodies; they also describe the climbs of the area as hard, medium, delicate, extreme, intense, and very steep. Results showed that the built-up area increased from 1972 to 2000, and at the same time water bodies, forest cover, vegetation, and agriculture showed a dwindle. The authors found that the built-up area has been increasing from a gentle slope to a very steep slope. The constructions taking place on the steep, very steep, and extreme slopes were inclined to landslides and other natural disasters.

Murali et. al., (2006) his research paper entitled "Change detection studies in coastal zone features of Goa, India by remote sensing". The data was collected from the National Institute of Oceanography, Dona Paula, Goa 403 004, India, and the Institution of Remote

Sensing, Dehradun, and also from handbooks. As the title determines the paper aimed to examine the change detection studies in Coastal zone features of Goa, India using Remote Sensing and Digital image classification techniques during 1990-2001. It was found that there are significant changes in Urban Land, barren land, vegetation, and mangrove covers. Thus, the Coastal zone of Goa has undergone extensive development in the last decades that is during 1990-2001 (Murali R, Vethamony P., 2006).

Alesheikh et al., (2007) carried out a study on "Coastline Change Detection Using Remote Sensing". Coast has a unique environment in which the atmosphere, hydrosphere, and lithosphere contact each other. The present methods for detecting changes on the coast are examined in this paper using satellite imagery. A new procedure has been developed based on the advantages and disadvantages of these methods. The proposed procedure was based on a combination of histogram threshold and band ratio techniques. The study area of this project was Urmia Lake; the 20th largest and the second hyper-saline lake in the world. The results have been checked with ground truth observations to evaluate the accuracy of the findings. The accuracy of the extracted coastline has been estimated at 1.3 pixels (pixel size=30 m). Based on this investigation, the area of the lake has been decreased by approximately 1040 square kilometers from August 1998 to August 2001. This result has been verified through TOPEX/Poseidon satellite information that indicates a height variation of three meters.

Kotha, M. et al., (2013) carried out their research entitled "Land-Cover Change in Goa-An Integrated RS-GIS Approach". The aim is to give a brief study on the Land-Cover Change in the entire state of Goa. Authors have used digital satellite data from 4 time periods: LANDSAT MSS Data-4 Bands- Jan 1973 LANDSAT MSS Data-7 Bands-Jan 1989. Indian Remote Sensing Satellite (IRS) 1C LISS 3- 4 Bands- Jan 1999 IRS-L4MX Data-4 Bands- Jan 2012 Satellite data has been used by authors to study the Land-Cover changes that occurred in the state of Goa from 1973 to 2012. Large parts of arable land have been converted to urban areas for the growing tourism industry. Mining in the last 2 decades has resulted in the depletion of vegetation cover and has converted parts of vegetation areas into barren land. According to TERI, vegetation cover has been reduced by more than 50% due to intensive mining of the land over a decade. Forests affected by mining have shown a good amount of increase in vegetation cover due to afforestation programs undertaken by mining and other development activities. The study highlights the gain in vegetation cover during the 1989-1999 period as compared to a loss of vegetation cover during the preceding period from 1973-1989. The above paper has mentioned FCC Images and classified images of Land-Cover classes of Goa for 4 time periods. From 1973 to 1989- 1999-2012, the water bodies have barely increased in number. Most tracts of vegetation cover have been cleared for urban development. Settlements have increased exponentially due to a steep rise in the population. Open lands have been reduced to a certain extent.

Tamassoki et al., (2014) have extended their research work on “Monitoring of shoreline changes using remote sensing (case study: coastal city of Bandar Abbas)”. Bandar Abbas City coastline changes have been tracked using the Max Likelihood Classification method (MLC) using imagery from the Landsat TM-5 sensor in 1984, 1998, and 2009. Monitoring showed that during the period from 1984 to 1998, the area of the coastline of Bandar Abbas increased by 804.09 hectares. The increase for the next eleven years was a little less than 140.81 hectares. The total length of the coastline dropped from 330 km to 271 km between 1984 and 2009, with a sharp downward trend. Results showed that in each period in which the area of coastline advanced, changes in the length of shoreline had been less prominent (E Tamassoki, H Amiri and Z Soleymani, 2014).

Misra et. al., (2015) examined the research on the “shoreline changes and Land-use/ land-cover along the South Gujarat coastline”. The dynamics of shoreline alteration are studied along South Gujarat's coastal regions using multitemporal remote sensing datasets. Significant environmental issues have been reported, mostly as a result of human activity, along the coastal zone in South Gujarat, India's three districts of Surat, Navsari, and Valsad. This study investigates decadal changes in shoreline change across time using satellite pictures from Landsat TM, ETM, and OLI. Significant variations in the form of shoreline erosion have been identified as a result of an analysis of shore changes within these areas. In addition, LULC maps for each region were produced for 2014 using group proportions as a pre-classification step, followed by a combination of supervised and unsupervised classification, called hybrid classification. For each dataset and the overall accuracy range between 90 and 95%, an accuracy assessment shall be carried out. The LULC study is carried out to identify the various classes in this region that are vulnerable to environmental degradation. The maps created for this study will aid in the creation of shoreline protection strategies as well as sustainable land use planning.

Sawkar et al., (1998) in their research paper entitled “Tourism and the Environment, Issues of Concern in the coastal zone of Goa”. The authors have extracted data on tourist arrivals (International as well as domestic tourists) from 1981 to 1995. This has helped the authors to observe the increase in the expenditure of tourists from 1981 to 1995 as well as the increase in the number of domestic and international tourists from 1981 to 1995. As reviewed in the above paper, the sudden disappearance of a species due to anthropogenic factors has caused stress in other species. Due to a steady decline in the number of mangroves in the coastal zone of Goa, the fish species and fish catch have been reduced. Deforestation of mangroves, land reclamation, and siltation have led to the loss of spawning grounds leading to a downfall of fish populations. There has been a loss of dunes due to construction activities along the coastal stretches of Goa. Anjuna and Baga-Calangute-Candolim stretches in North Goa; Betalbatim, Colva, Varca, Cavelossim, and Mobor in central Goa; Galgibaga in South Goa.

Yedage et al., (2015) has studied on "Change Detection Analysis using the Geospatial Technique – A Case Study of South Goa". This study focuses on the analysis of land use/cover changes taking place in the district of South Goa over 10-year periods and to understand the causes and effects of it. Remote sensing data Landsat 7 & 8 images were used in the years 2005 and 2015 from glovis.usgs.gov. GPS techniques were also been used and survey data was taken from the Town and Country planning office, Panjim. Further ArcGIS 10.1, ERDAS Imagine 9.2 and Microsoft Office 2007 software were used. Five different classes of land use were defined in the study area, i.e. buildable areas, vegetation, agriculture land, water bodies and barren lands. The paper suggests that there has been a significant increase in cultivable land in the middle and central areas and a tremendous decrease in natural vegetation areas. There has been an increase in built-up areas around major cities such as Margao and Vasco.

Nadaf, F. M. (2019) carried study on the "Geographical Analysis of The Coastal Landforms of Canacona Goa". Coastal areas are of great importance to humans because they have environmental, biological, societal and business values. Since the antiquity of man, oceans, and seas have served as a link between humans and lands. Sand and stony beaches, sea caves, estuaries, mangroves, bays, headlands, cliffs, hills, corals, ports, harbors, and coastal islands are the features that define the study titled Shoreline of Goa. Canacona taluka is the longest beach in all of them. The coast of Canacona was extremely fragile and ecologically vital, characterized by several coastal landforms caused by erosion and deposition. To carry out this study the author used both primary and secondary sources of data. Primary data was obtained from various sources like fieldwork and field observations. Secondary data was collected by topographic maps with different indexes with a scale of 1:50,000 and geo-coded FCC of IRS IC LISS III GIS portals such as Google Earth, Wikimedia, and Bhuvan Earth. Hence, this paper attempts to investigate the coastal landscape of Canacona and identify important coastal landforms.

Sobhani et al., (2021) studied the Habitat Integrity in Protected areas that were threatened by LULC changes and fragmentation, in a case study in Tehran Province, Iran. In this study, the period was from 1989 to 2019. This study aimed to inspect the landscape facet and study the change in those facets. To find the changes in LULC, Landsat images were downloaded from the USGS Earth Explorer. The GPS pointing technique was used to numerically correct the images. The Anderson scheme is an excellent system for presenting LULC details and classifications. Applying training samples for Land Use Land Cover classes, 600 samples were scrutinized from the collection, 300 samples were scrutinized for algorithms and 300 samples were assessed for classification. In the end, classification precision was scanned against ground truth data. In the study area, at 11.95% in 2019, compared to 10.43% in 1989, there seemed to be a very rapid growth of build-up. At the Tangeh Vashi Natural Monument, bare land showed an increasing trend with 81.42% in 2019 in contrast to 80.84% in 1989. In the Tangeh Vashi area, there was a number of tourist activities such as rock climbing, hiking and so on. These ventures have given rise to increased habitat fragmentation and the destruction of high-density pastures.

Similarly, Boori et al., (2015) analyzed LULC disturbance due to tourism in Jeseniky Mountain, Czech Republic. The authors performed a comparative study for 3 years, 1991, 2001, and 2013. They selected 3 tourist sites to analyze the tourism effect. The aim was to detect the aftermath of tourism on land covers such as pastures, agriculture, forests, and settlements. Landsat 5, Landsat 7, and Landsat 8 images were taken from NASA's archive of Landsat images. They were further processed in the ArcGIS software. In the beginning unsupervised classification was carried out and after field visitation supervised classification was obtained. The Digital Elevation Model (DEM) was applied to separate the high-elevation area from the low-elevation area. The results showcase that forest land and agriculture made up the largest percentage with 40% and 35% in 1991 and vice versa in the year 2013. Pastures showed a decreasing trend while forest and water bodies depicted an increasing trend. Authors have further said that the unfounded way of land use like transformation from farmland to woodland has led the way to land degradation. Finally, the authors have winded up saying that the land cover disruptions were not only related to tourism but also other factors like snow damage, wind, agriculture harvesting, population growth, and socio-economic activities.

Rimba et al., (2020) conducted a study on LULC change from 2000 to 2025 driven by tourism growth in Bali. The authors used the Land Change Model technique to identify and forecast the LULC change over a 25-year period, which will assist policymakers in enacting urbanization control measures. The authors of this study used Landsat 8 images and Landsat Thematic Mapper. Five categories were used to categorize the LULC maps: built-up, mangrove, open area, agriculture, and vegetation. This was done with the supervised classification and 100 survey points were assigned in this classification, the main focus was on built-up areas. To measure the exact accuracy of LULC the Kappa coefficient was employed. The study showed that build-up areas increased from 2000 to 2015 from 4,88.7 Ha to 25,589.8 Ha. It was visible that a majority of areas were converting from agriculture to build-up. To conclude, tourism activities drive major LULC changes and it thus creates social, physical, and environmental issues. Environmental problems such as water shortages, job conversion to the tourism sector, and poor garbage management. For the change analysis, it was predicted that build-up will continue to grow due to the increasing demand for housing and the development of tourism-related activities. And the major conversion will take place on farmlands and so it needs quick actions by the policy makers to control LULC change especially in the areas of agriculture.

Kausar, R. et al., (2016) studied about spatiotemporal LULC Analysis of Murree by using GIS - and remote sensing. The objectives of the research were as follows, to analyze the spatial and temporal land models of the region of Murree. Precisely the study would find about the spatial patterns of LULC, built-up area, and deforestation. The study utilized Landsat 4 and 7 images for the analysis from the USGS global visualization viewer. Then began the spatial analysis, images were first processed for reflectance, and next, different bands were combined to intensify the images for extraction regarding the necessary information. A supervised classification was used. All analyses were completed using the ARC-GIS software. The results showed that, in the study period itself, there was an increase from 57.37% of the built-up area to 69.1%. As well there is an increase in settlements to cater to the needs of population growth. But in 2005 the buildup showed a decreasing trend just because the area was hit by an earthquake. The following were the recommendations given by the authors. There is a high need for preplanned and proper strategies. The rapid increase in urbanization is affecting the local biodiversity and hence it needs to be protected.

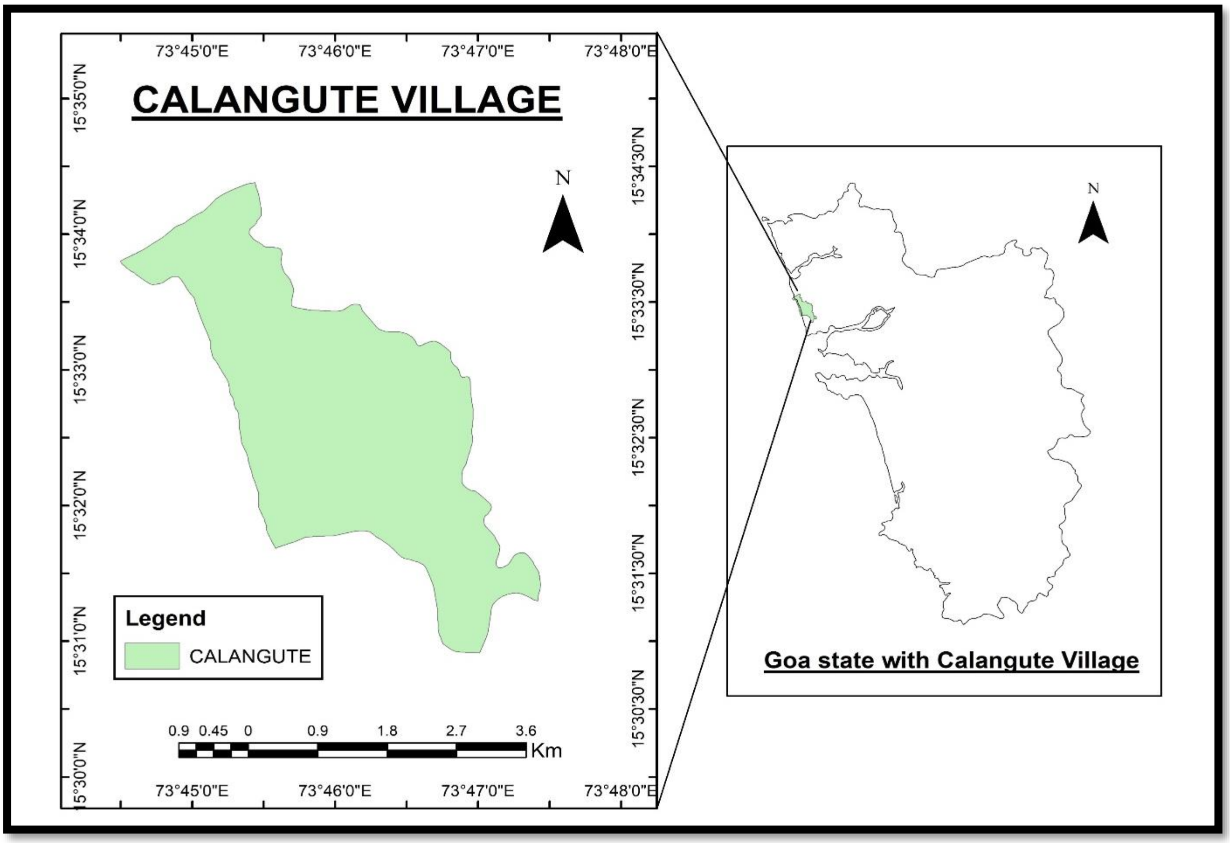
Indrawan et al., (2022) This paper gave information regarding LULC change in Badung Regency in Bali. The Bali Island being exploited due to the numerous tourism activities taking place the authors aimed to analyze LULC change from 2010 to 2020 and also to predict the changes in 2030. In this research Landsat and Sentinel images were used for the analysis. To recognize objects better the bands were exhibited in Red, Green and Blue format. The band combination used was, 321 for Landsat as well as the Sentinel images. The data was progressed using the ENVI and ArcMap software's. The results for 2010 to 2015, the major change was seen in the paddy fields which increased by 6,89.08 ha in contrast the forested areas decreased by 6,033.6 ha. The regions covering built up mangroves, mixed gardens and shrubs showed an increasing trend while Uplands were found to be depleting but water bodies did not change much. The results for 2015 to 2020 the major change was seen in built up areas which showed an increasing trend due to urbanization while forests, mangroves, uplands, shrubs and paddy fields showed a decreasing trend. But water bodies did not even change.

Chapter 3

CHAPTER 3: METHODOLOGY

3.1 Study Area (Calangute)

The state of Goa is located on the west coast of India and has a geographical area of 3702 square kilometers (Girap, 2006). It is located between latitudes N14°53'57" and N15°47'59" and longitudes E73°40'54" and E74°20'11" (Sonak, 2006). The State consists of 2 administrative districts i.e. North Goa and South Goa, which are further divided into 12 talukas viz. Pernem, Bardez, Bicholim, Sattari, Tiswadi, Ponda, Mormugao, Salcete, Sanguem, Dharbandora, Quepem, and Canacona (According to Goa State Biodiversity Board).



Map3.1: Location map of study area i.e. Calangute

(Source: Researcher)

Calangute is a village in the Bardez taluka district of North Goa and it is a tiny but world-famous tourist destination. It is located at a distance of 15 km from the state capital Panaji and having a population of 13,810 as per Census 2011, is one of the most densely developed tourism sites in North Goa attracting over 10 lakh tourists annually (Achrekar, 2021). Being closer to capital town, it is more accessible to visitors. Its geographical area is 7.01 square kilometers (Dina Fernandes, 2022).

Figure 3.1: Calangute Beach

Calangute is known as the queen of beaches (Tantrigam, 1999). Among all the beaches, Calangute is the largest and exceedingly popular among North Goa. With respect to Calangute, the beach is visited by the domestic travellers as well as the international travellers (Kadam et al., 2018). Most tourists arrive during Christmas and New Year, and traffic is heavy at these times. A famous destination is the church of St. Alex, where you can see the beauty of decorative altars and architectural style inside the church. The reason behind the popularity of this beach is its location between the Candolim beach and Baga beach. Over the years, it has developed into a mecca of tourist and bag packers (Fernandes, 2020). Water sports are the major attraction of Calangute beach. Also, beach parties and beach clubbing are very famous. However, the large influx of tourists to this world class tourist beach destination, in turn, has created several negative impacts on the region (Achrekar,2021). Coastal tourism in Goa has placed heavy pressure on the coastal land and beaches, environment, water, energy and sanitation facilities (Dessai, 2023).

3.1.1 Physiography of the study area

Physical Environment

The Calangute beach has a long stretch of sand without any debris (example: seashells, pebbles, cobbles).

Figure 3.2: Beach Stretch

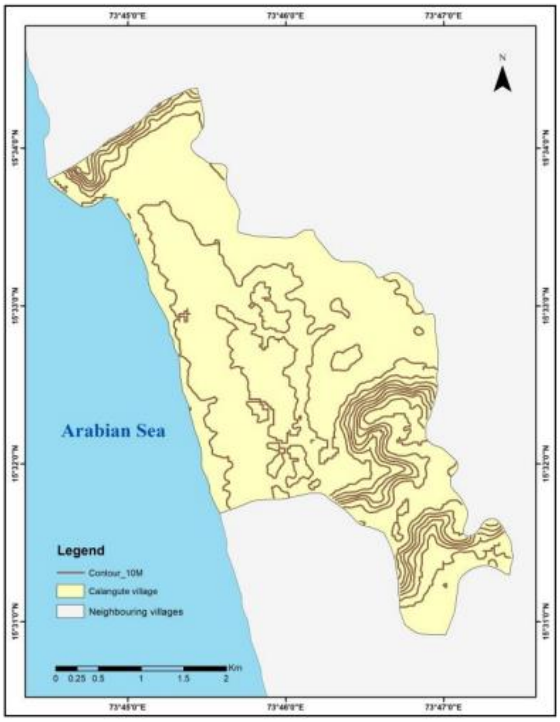
This beach stretches 5km long. The shore gradient is a bit angular (gentle slope). There is less vegetation around Calangute beach (Achrekar, 2021).

Figure 3.3: a)

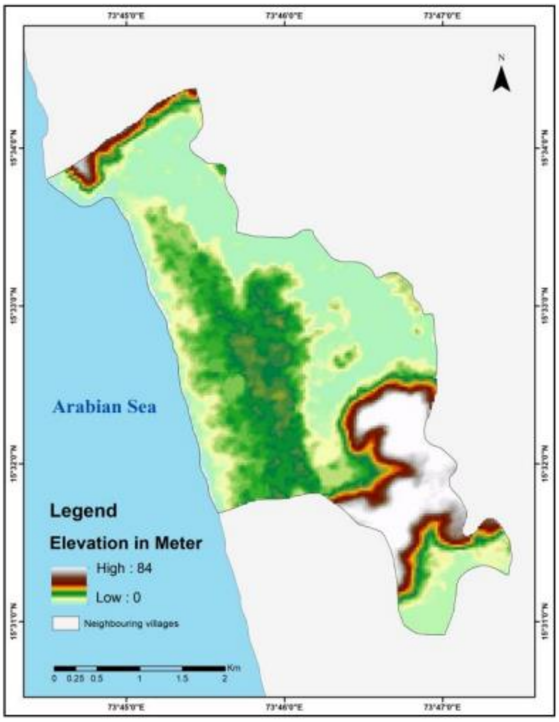
Beach shacks are a unique sight on all major beaches, and are of a purely temporary nature (Mascarenhas, 1999). Calangute beach shacks are very close to the sea.

Figure 3.3: b)

Figure 3.3: a) and b)- Calangute Beach Shacks

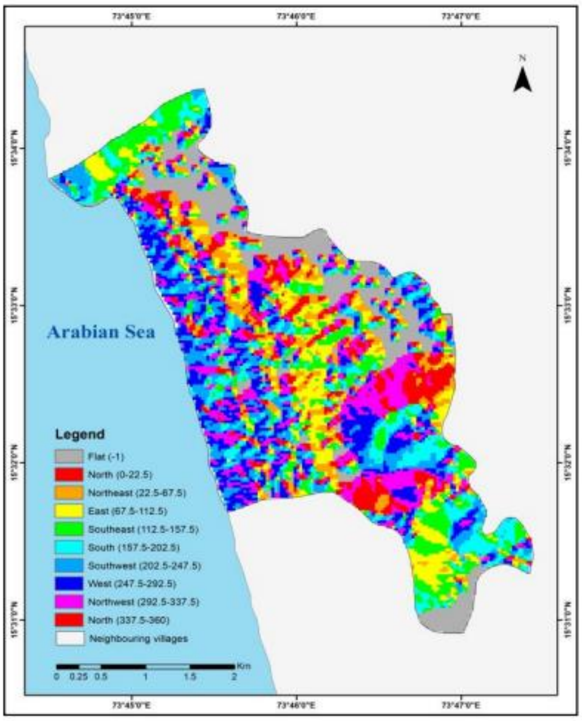


Map3.2: Contour map of Calangute



Map 3.3: Elevation map of Calangute

(Source: Researcher)



Map 3.4: Aspect map of Calangute

(Source: Researcher)

The contour map (3.2) of Calangute shows the elevation levels of the area, indicating hills, valleys, and flat terrain. It provides a visual representation of the topography, allowing viewers to understand the land's shape and steepness. Contour lines closer together indicate steeper slopes, while lines spaced further apart represent flatter areas.

An elevation map (3.3) of Calangute illustrates the varying heights of the land surface throughout the region. It shows high and low-elevation areas, helping to identify hills, valleys, and flat terrain. This map provides a straightforward visual representation of the vertical relief or altitude differences across Calangute's landscape.

An aspect map (3.4) of Calangute indicates the direction in which slopes face across the region, whether they face north, south, east, or west. It helps to understand sunlight exposure, drainage patterns, and their impact on the landscape's characteristics, influencing factors like soil moisture and vegetation distribution.

Drainage

The village bounded with Chapora in the North and river Baga in the south. Both are perennial rivers and the study area is between the mouths of both the rivers. The records obtained from the village Panchayat states that the study area has a salinity of 39 percent. It is due to this high percentage of salinity the coastal village faces the problem of fresh water. In the summer season the well water turns salty due to high salinity problem faced by the village. Hence fresh water is used for domestic purpose is supplied by the government. A total number of 10 street taps have been installed out of which only 6 street taps are operational in both the villages.

The villages are also endowed with five fresh water streams of which 3 are perennial in nature. The stream water is used for agriculture. The Panchayat records reveal that there are 50 open wells for the use of the villages where fresh water is available. Some household have their own wells which satisfies the daily water needs. Overall 75 percent of a total household has a tap connection.

Climate

Likewise, in other parts of Goa, Calangute have cool winters and hot summers. The Village lie to the west of Goa and the climate is influence by Arabian Sea. The climate is moderate. There is no particular season as it is close to Arabian Sea. Minimum temperature varies from 21˚ C to 30˚C. The area is under the influence of south west monsoon winds and hence receives showers from June to October. While in winters, the village experiences cool to chill weather at night and fairly pleasant to warm weather condition during the day. Summers are hot and humid.

Precipitation

During this period, Calangute receives abundant rainfall that nourishes the vegetation and replenishes the water sources. Rainfall received is about 300 to 350 cm per year. During the dry season, from October to May, it rains significantly less and the weather is sunny and dry. Generally, the village receives abundant rainfall during the monsoon months, which maintains its lush greenery and creates a refreshing atmosphere for tourists enjoying the coastal paradise.

Vegetation

The village of Calangute in North Goa, India has diverse coastal vegetation. Mangrove forests thrive on its sandy beaches and estuaries, providing essential habitats for a variety of plant and animal species while stabilizing shorelines and filtering pollutants. The coastal landscape is decorated with coconut palms, iconic symbols of tropical beaches that provide shade and natural beauty. Other tropical vegetation includes acacia trees, mango trees, banana plants, and various palm trees and flowering plants. Despite urbanization and the development of tourism, there is still abundant tropical vegetation that contributes to the ecological wealth of the region. Calangute Village's horticultural gardens and parks offer residents and visitors the opportunity to enjoy green spaces adorned with ornamental plants and landscaped gardens, promoting a connection with nature in an urban environment.

3.1.2 Administrative setup of the study area

Table 3.1: Village Administrative details of study area i.e. Calangute

Village Administrative Aspects/ Villages	**Calangute**
Total Area (Sq.km.)	11.72
Total Population	13,810
Neighbouring villages	Anjuna, Arpora, Nagoa, Saligao, Marra, Nerul and Candolim

(Source: Record as per Census 2011)

3.1.3 Socio-Economic background of the study area

Socio-economic background of the related study helps in to study how economic activity affects and is shaped by social processes. It examines how societies and regions advance, remain stationary, or decline as a result of their local, regional, or global economies. Thus, the following sums help in to understand the same.

Demographics

The population of Calangute: The Calangute census town has a population of 13,810 of which 7,199 are males, while 6,611 are females as per a report released by Census India 2011 (Achrekar et al., 2021). The population of children aged 0-6 is 1,271 which is 9.20 percent of the total population of Calangute. In Calangute census town, the female sex ratio is 918 against the state average of 973. Furthermore, compared to the state average of 942 in Goa, Calangute's child-sex ratio is approximately 1,017. The literacy rate of Calangute is 88.16 percent lower than the state average of 88.70 percent. Around 91.05 percent of men in Calangute are literate while female literacy rate is 84.97 percent. The census town of Calangute has a total of more than 3305 houses that provide basic amenities like water and sanitation. It also has the power to build roads within the census town and tax property within its jurisdiction. alangute Census Town's population is currently projected to be 19,400 in 2024. Further, the schedule census of 2021 for Calangute city was postponed due to covid, so the 2021 data are not available. According to the reports, the census will be conducted in 2024.

Table 3.2: Calangute City/Town Future Population 2021-2031

Calangute City	Population
2011	13,810
2021	17,900
2022	18,400
2023	18,900
2024	19,400
2025	19,900
2026	20,400
2027	21,000
2028	21,600
2029	22,200
2030	22,800
2031	23,400

(source: Calangute Town Population Census 2011 – 2024)

Transport

Road transport is the most common and convenient mode of transport in Calangute. The village is well connected to the major cities of Goa via the road network. Visitors can reach Calangute by hiring taxis, rickshaws, or self-drive rental cars from nearby cities such as Panaji (the capital of Goa) Margao, and Vasco da Gama. Calangute village has a well-developed transport infrastructure including road, air, and rail connectivity, making it easily accessible to visitors from all over India and the world. Whether traveling by road, air, or rail, tourists have several options to reach Calangute and explore its beautiful beaches, attractions, and cultural heritage.

Occupation

Apart from tourism, agriculture also contributes to the occupation of Calangute village, although to a lesser extent. Some residents engage in small-scale farming and grow crops such as rice, coconut and vegetables in the surrounding countryside. In addition, fishing is another traditional activity in Calangute, and local fishermen fish along the coast.

Figure 3.4: Fising Boats

However, due to the growth of tourism and associated development, the fishing industry has become relatively less dominant compared to tourism-related activities. In recent years, entrepreneurship and companies serving the needs of small businesses have grown both for tourists and residents. It includes services such as transportation, welfare, entertainment, and retail that contribute to the diverse economic landscape of Calangute Village. Overall, tourism is the main economic sector of Calangute Village that contributes to economic growth, job opportunities, and socio-cultural development within the urban districts.

Figure 3.5: Local Fisherman

3.1.4 Tourism

Calangute is also known as golden beach. It is also the busiest and commercialized of all beaches in Goa. Travelers and backpackers from all over the world are drawn to Calangute Beach because of its immense popularity, and the beach is always packed with visitors.

Figure 3.6: Essential amenities on Beach

This beach is largest in north Goa and visited by thousands of domestic and international tourists (Kadam et al., 2018). The beach is full of huts and many clubs open on the beach. Many performances are organized on the beach, such as rock, pop-beat shows, outdoor dances and parties.

Calangute has all the amenities of the modern world, including banks, post offices, exchange offices for currencies, and medical centers. The beach, accommodation facilities, water sport activities make Calangute one of the best places in Goa. From June to September, visitors avoid visiting the place due to rough seas and tides that make swimming dangerous, but locals believe that Calangute is at its best during the monsoon months. Most of the tourists buy antiques, junk jewellery, sake boxes, beach appropriate clothes on Calangute beach.

Table 3.3: Domestic and foreign tourist arrivals across Goa from 2012 to 2021

Years	Domestic Tourist	Foreign Tourist
2012	2.34	0.45
2013	2.63	0.49
2014	3.54	0.51
2015	4.76	0.54
2016	5.65	0.68
2017	6.9	0.89
2018	7.08	0.93
2019	7.12	0.93
2020	3.26	0.3
2021	3.31	0.02

(Source: Department of Tourism)

Domestic and Foreign Tourist Arrivals across Goa from 2012 to 2021

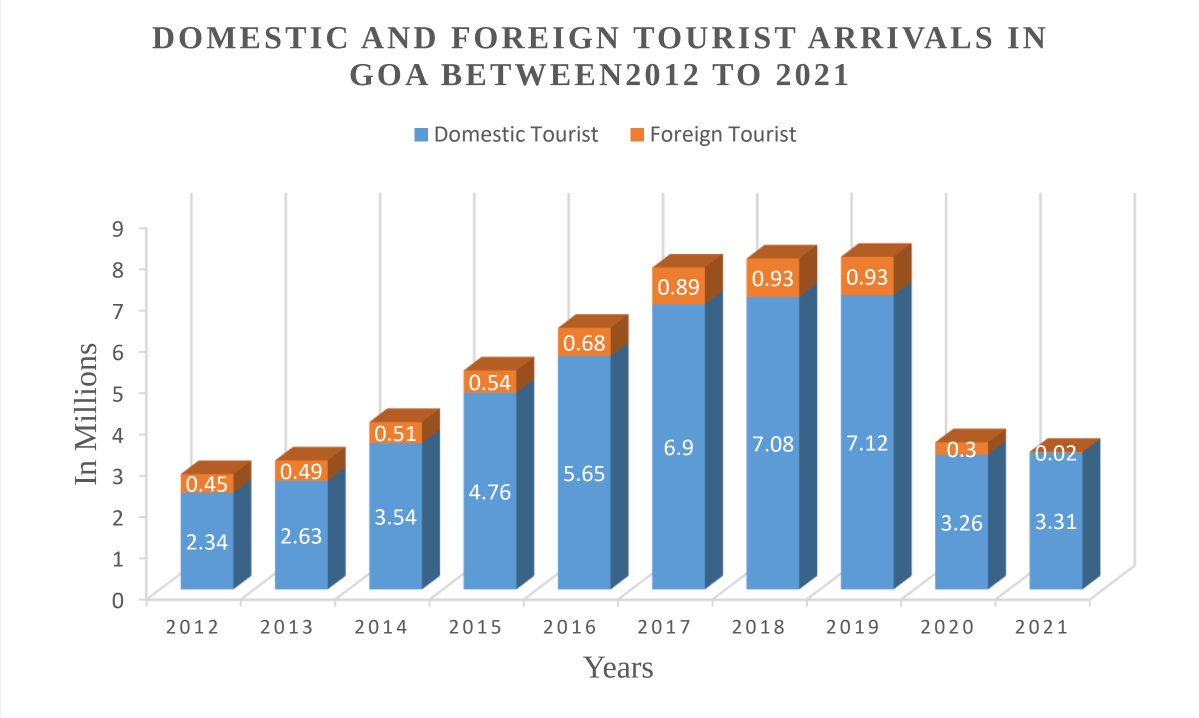


Figure 3.7: Domestic and foreign tourist arrivals across Goa

(Source: Department of Tourism)

The above graph shows the data of the Arrival of Tourists: both domestic and foreign tourists. The tourists have visited Goa in millions. As seen from the above table 3.3 and figure 3.7, the number of tourists visiting Goa from 2012 to 2020 has increased year by year. Most of the tourists visiting Goa are Domestic tourists (about 85%), whereas about 15% of tourists are foreign tourists. The numbers of tourist arrivals have gradually increased from 2012 to 2019 for 7 years, whereas there was a sharp decline in the number of tourist arrivals in 2020 due to the COVID-19 pandemic (based on data that the Department of Tourism has provided).

Domestic and Foreign Tourist Arrivals across Calangute

In 2021, The COVID-19 pandemic has severely affected tourism worldwide, resulting in a significant decrease in tourist arrivals to destinations like Calangute. Both domestic and foreign tourists decreased compared to previous years due to travel restrictions, closures, and health.

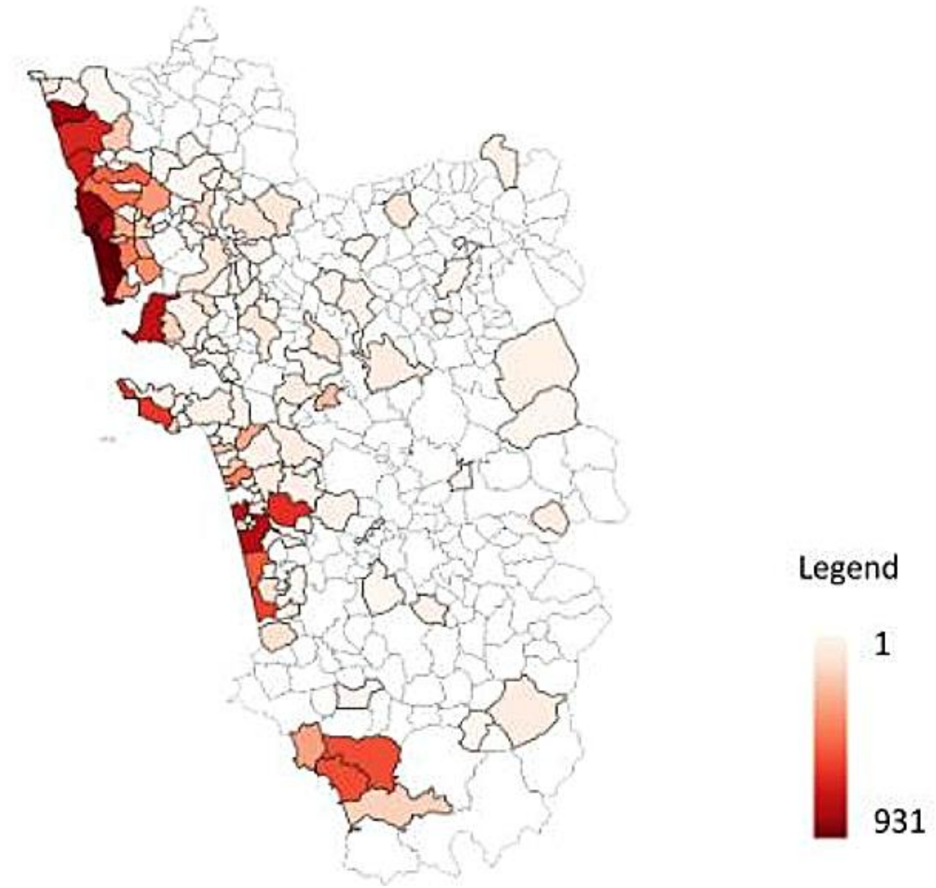
With the vaccination measures and the gradual easing of travel restrictions, tourism started to recover in 2022 (Times of India). Domestic tourism has recovered faster than international tourism as more people choose domestic tourism. By 2023, Calangute tourism had grown further as vaccination rates have increased and confidence in travel has been restored. Domestic tourists continue to grow as people look to beach destinations like Calangute for vacations and leisure trips. Foreign tourists also show signs of improvement but still are at pre-pandemic levels, due to ongoing concerns and restrictions in some source markets.

Tourism to Calangute in 2024 may see continued growth as the impact of the pandemic recedes further and travel returns to normal. Both domestic and foreign tourist arrivals may have increased compared to last year, which was due to factors such as stagnant demand, increased vaccination, and desire to travel. experience.

Overall, while tourist arrivals to Calangute declined in 2021 due to the pandemic, the following years have seen a gradual recovery and growth as travel restrictions eased and travel confidence was restored.

Hotels and Guest Houses in Goa

Data were taken from the Department of Tourism about hotels and guest houses. The following map 3.5 shows the hotels and guesthouses in the villages, darker red indicates that there are more hotels and guesthouses in that village, it was found that Calangute village had the most hotels and guesthouses, which was 931. Lighter red means less number of hotels and guesthouses.



Map 3.5: Map of Hotels and Guest Houses

(Source: Department of Tourism)

It was found that Calangute in the Taluka of Bardez, North Goa had the highest number of Hotels and Guest houses which were 931.

Figure 3.8: Hotels in Calangute

Adventure

Calangute beach in Goa is the hub for all things adventurous. Everyone can enjoy virtually any water sport here on the beach. There is professional staff that helps the beginners. A good time to enjoy them is only between the months of October and May when the weather is favourable.

Figure 3.9: Adventure Activities

The time duration of a sport varies from anywhere between a few minutes to an hour and so does its pricing. Calangute water sports are not only safe but also budget friendly. The safety of the tourists is a priority here and it is ensured by using some of the most modern equipment for water sports. The prices are fair and competitive. The water sports start around 10 in the morning and continue till 5 in the evening, considering the safety of people (according to the trip advisor).

Jet Ski Ride

Figure 3.9: a)

If speed fascinates, try the Jet Ski Ride experience at Calangute Beach that crash through the waves at speed. The machines are easy to use, so even if someone is a beginner, they don't have to worry about safety. They can choose either a ski trip with accompanying staff or drive their own. The whole thing takes about one minute.

Figure 3.9: b)

Figure 3.9: c)

Figure 3.9: Adventure activities -a) Jet Ski Ride, b) Banana Boat Ride, c) Speed Boat Ride

Banana Boat Ride

Banana Boat Ride is a water sports experience that is more fun than adventure. If want to have fun with family and kids, this is the best sport. It is a banana-shaped rubber boat that can accommodate 4-6 people. It is pulled by a speedboat, which also sometimes overturns the banana boat during the ride. The duration of playing sports is usually 10 minutes.

Speed Boat Ride

Water sports are incomplete without mentioning speed boating. Anyone who loves speed and adventure will fall in love with this water sport almost immediately. Nothing compares to the feeling you get when you accelerate into the open sea at over 50 mph, quickly leaving the beach and its hustle and bustle behind and heading for the calm of the sea. The duration of the activity is 5 minutes and can be booked for at least 6 people.

Bumper Ride

Very similar to the banana ride, the bumper ride is equally exciting and perfect for the adventure seeker. You are placed in a large inflatable tube attached to a speedboat and pulled out into the open sea to crash into huge waves. Although it may not be fun for everyone, you will be on an adventure, every time you drop your tube into the waves, great fun. The operation takes about 3 minutes and up to 2 people can fit in one tube.

Windsurfing

Windsurfing in Goa is one of the most exciting experiences. Hanging in the sky in the wind and pulling the boat away quickly is a complete adventure in itself. The training usually takes one minute and can simply choose between windsurfing or water windsurfing. All the water sports mentioned above are very common and popular among the public as well. In addition to the ones discussed, there is a whole list of them that are available elsewhere. From diving, and surfing to windsurfing, kayaking and scuba diving.

Safety measures on beach

Figure 3.10: Safety board

Figure 3.11: Surf Rescue Teams

Figure 3.12: Lifeguards

Calangute Beach has implemented various safety measures, including surf rescue teams, lifeguard patrols and security boards in order to ensure the protection of its visitors.

Surf Rescue Teams

Surf rescue teams are specially trained individuals equipped to deal with emergencies in the water. These teams usually consist of experienced lifeguards, swimmers and first responders who have the necessary skills and knowledge to perform lifesaving tasks, provide first aid and deal with various coastal emergencies. Surf rescue teams are deployed at Calangute Beach during tourist seasons and weekends, ensuring that there is always a quick response in case of an emergency. These groups are responsible for patrolling the beach, monitoring water conditions and assisting swimmers and the beach in distress.

Lifeguards

An integral component of any beach safety strategy is lifeguards. They are in charge of maintaining a careful eye on the beach and its patrons, making sure that everyone abides by safety regulations, and offering prompt aid in the event of an emergency. Calangute Beach lifeguards go through extensive training programs covering a range of beach safety topics, such as crowd control, CPR, first aid, and water rescue skills. Lifeguards are positioned at specific locations along the beach during their shifts, which enables them to keep a watchful eye on the ocean and its users. They are also in charge of upholding safety regulations, such as those that forbid swimming in designated no-swimming areas or during hazardous times.

Safety Boards

Any beach safety plan must include safety boards, sometimes referred to as safety signs or beach safety signs. These signs, which are positioned thoughtfully along the shore, give beachgoers vital information about potential risks, safety precautions, and emergency protocols.

The safety boards at Calangute Beach address a variety of subjects, such as:

- Water safety advice, including recognizing shifting weather patterns, avoiding swimming alone, and remaining in approved places.
- Knowledge about potentially harmful sea organisms, like jellyfish and stonefish, and how to prevent or handle contacts with them.
- Information regarding the amenities available at the beach, such as the locations of first aid stations, bathrooms, and lifeguard stations.
- Using safety equipment, such as rescue tubes and safety vests, should be explained.
- Provide emergency contact details, such as lifeguard, police, and medical service numbers in the area.

Therefore, the safety measures put in place at Calangute Beach, including surf rescue teams, lifeguards, safety committees, and cooperation with local authorities and tourism representatives, play an important role in ensuring that visitors can enjoy the natural beauty and vibrant atmosphere of the beach without compromising their safety. By continuously evaluating and improving these measures, Calangute Beach remains committed to providing a safe and enjoyable environment for all its visitors.

3.2 Introduction to Methodology

Geospatial techniques, such as remote sensing and Geographic Information Systems (GIS) are used for the analysis.

Remote sensing is a technique to acquire the physical properties of a particular area without physically being present over there (Dina Fernandes, 2022). It permits the users to visualize, capture and analyze features and objects on the earth's surface. Remote sensing uses various sensors like satellites, drones, airplanes and so on to capture images.

For earth observations, image resolutions also have to be considered, there are 3 types of resolutions. Spatial resolution, Spectral resolution and Temporal resolution. Spatial Resolution depends on the pixel size (Atkinson et al., 1997). The smaller the pixel size the more details will be provided and hence it will have a very high spatial resolution. Spectral Resolution gives us the spectral details in each band. High spectral resolution will have narrow bands compared to low spectral resolution which will have broader bands. Temporal Resolution refers to the time taken for a satellite to completely cover a full orbit.

<u>There are 2 types of Remote Sensing.</u>

Active sensors and Passive sensors. Active sensors are the ones that dispense their own source of energy from the satellite onto the surface to capture the image. While passive sensors are the ones which use energy from the sun to capture the image. Remote sensing can be used for numerous tasks like tracking clouds to predict the weather conditions, analyzing the growth of a particular area in terms of changes in buildup, vegetation etc. Remote sensing can also be used for disaster management, warnings before a disaster, ensuring safety during the disaster and also getting back to normal conditions after the disaster (Dina Fernandes, 2022).

GIS software's are used to collect, manipulate, create, analyze and interpret. A geographic information system (GIS) is a computer system for capturing, storing, querying, analyzing, and displaying geospatial data (Chang, 2016). GIS helps users understand patterns, relationships, and geographic context. Geographic information systems are now used for land use planning, ecosystems modelling, landscape assessment and planning, transportation and infrastructure planning, market analysis, visual impact analysis, facilities management, real estate analysis and many other applications (Escobar et al., 2008).

The methods in this study are described as follows:

For the present research, the study is based on both primary as well as secondary data. The primary data is gathered from various sources like GPS survey via mobile app named; GPS Essentials, field work and field observations. (GPS) Global Positioning System is a United States owned utility that provides users with positioning, navigation, and timing (NTP) services (Enge, 1994). There are three segments to this system: the space segment, the control segment, and the user segment. The United States Space Force is developing, maintaining and operating space and control segments (Luba et al., 2005).

After investigating the study area and cross referencing with the available literatures and other supplementary data, the study was executed.

3.3 Preliminary analysis

- Visiting the study area
- Noting down the locations with the help of a GPS tracker
- Gathering information of the tourism from the locals.
- Photographs were taken for better study and analysis of the area.

The non -spatial data was gathered from the census data and reports from the internet. The data with regards to village population, literacy, density of population has derived from the village panchayat and census data websites.

GPS survey was done to fix the location of the settlements, commercial areas and location points were then transferred on to the satellite images by giving the same coordinates systems through GPS essentials. This helped to carry out on-screen digitization to deal with Spatio-Temporal changes over a period of time in a study area.

3.4 Preparation of maps

LANDSAT data was downloaded from United States Geological Survey (USGS) Earth Explorer (https://earthexplorer.usgs.gov/) pertaining to LANDSAT TM (Thematic Mapper), LANDSAT ETM+ (Enhanced Thematic Mapper Plus) and LANDSAT OLI/TIRS (Operational Land Imager/ Thermal Infrared Sensor) for the year 1991, 2001, 2011 and 2021 respectively.

Data Collection

Table 3.4: Remote sensing data used in the research

Sr. No.	Satellite	Sensor	Resolution	Data Source	References
1.	LANDSAT 5	TM	30m	USGS Earth Explorer	https://earthexplorer.usgs.gov
2.	LANDSAT 7	ETM+	30m	USGS Earth Explorer	https://earthexplorer.usgs.gov
3.	LANDSAT 8	OLI_TIRS	30m	USGS Earth Explorer	https://earthexplorer.usgs.gov

After downloading Landsat images, it was pre-processed for atmospheric correction to remove cloud cover or any atmospheric noise. Analysis like atmospheric correction and line scan errors were performed for the respective bands of Landsat in QGIS 3.12.3. The process of eliminating atmospheric effects from the reflectance values of photos captured by satellite or aerial sensors is known as atmospheric correction. So herein, the data processor tries to remove clouds, haze etc from the image.

Downloading & Installing QGIS

QGIS is an open-source Geographic information system software application which provides Functionality and plugins to view, store and analyze geospatial data.

Downloading QGIS

- Open web browser, go to home of QGIS.com. Click "Download Now". From download page choose the required version of QGIS and download based on the platform.
- Installing QGIS on a PC is the next step after downloading it.
- Double click the installation file that has been downloaded, read the license agreement and proceed.

Further, Band composite was performed for downloaded datasets to convert the bands into False Color Composite. False color images are multispectral images created using bands other than visible red, green and blue as the red, green and blue components of the picture display. False color composite allows us to visualize wavelengths that the human eye cannot see (i.e. near-infrared). With the help of village shapefile of the study region, FCC of Calangute were extracted by performing "extract by mask" operation in ArcMap 10.5 from USGS Earth Explorer.

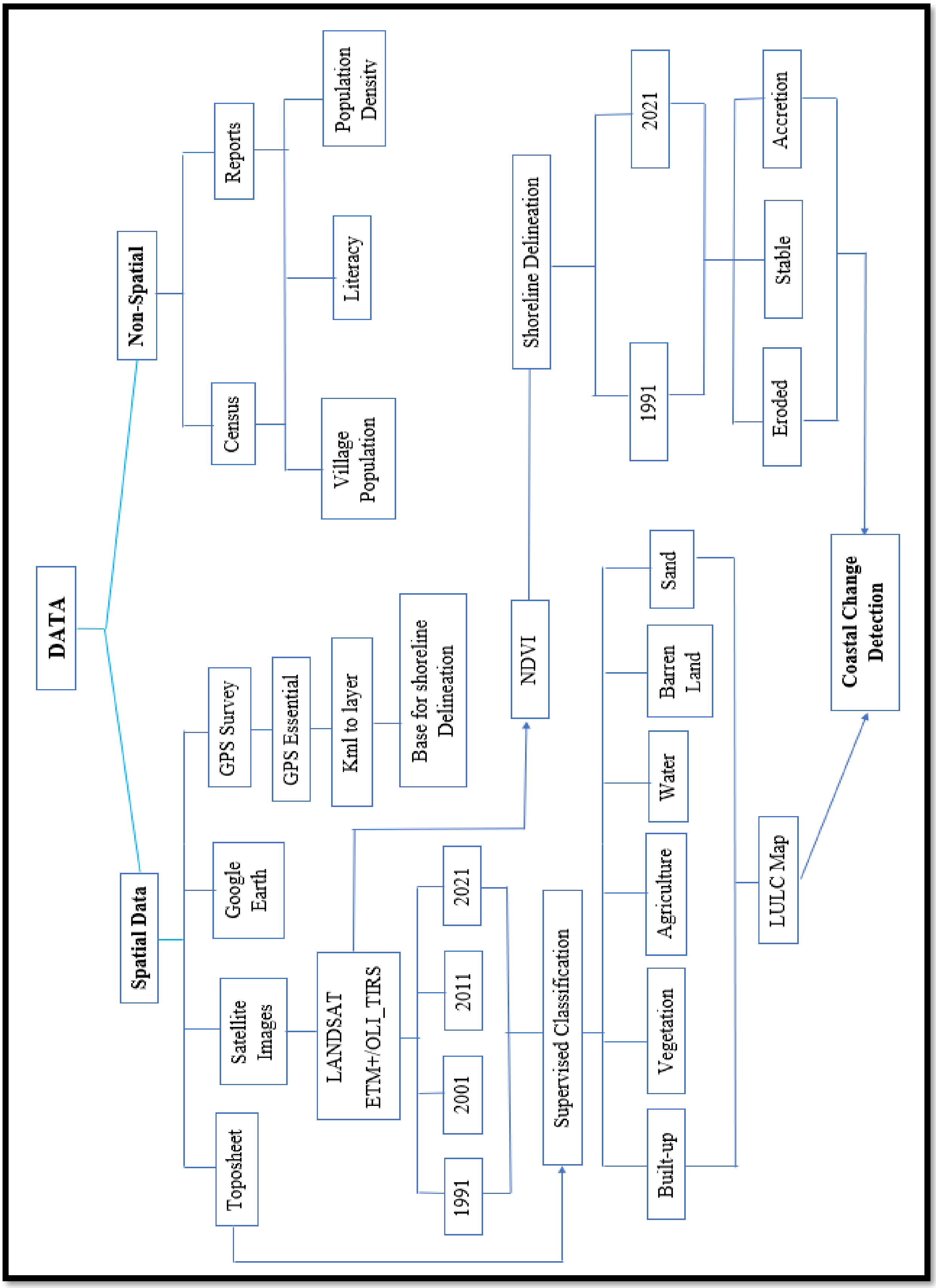


Figure 3.13: Methodology flowchart of work (Compiled by Researchers)

On-screen digitization was performed to carry out Spatio-temporal changes for the decadal years from 1991 to 2021, using Anderson Classification level I. Since, on-screen digitization is more accurate as compare to manual digitization (Dvortsin et al., 2008). Because the on-screen digitizer has a higher resolution image, it can zoom the image to the original raster's scale and digitize the feature more accurately. On-screen digitization is predominantly used in GIS industries (Carstensen et al., 1991). The classification is defined by the following classes as built-up, vegetation, agriculture, sand, barren land and water. Decadal datasets were assigned a projected coordinate system i.e. WGS1984UTMZONE43N. Standard colors were used to make a map layout. Further, the area was calculated by performing calculations of attribute data of each decade class-wise with an option of "Calculate Geometry" in ArcMap 10.5. Further, geometry calculation was used to analyze the numerical decadal changes that has occurred over a period of time in the study region. Analysis was portrayed using table and visual data representation techniques.

For the shoreline analysis, three analyses were performed to check the validity. First and foremost, NDVI, land-water divide and thirdly, google earth reference were taken into consideration. NDVI was performed using raster calculator in ArcMap10.5 with formula as (NIR-RED)/ (NIR+RED) to understand the land- water boundary divide. The analysis was performed to understand the erosion, deposition and stable structure of coast from 1991 to 2021.

Chapter 4

CHAPTER 4: ANALYSIS AND CONCLUSIONS

This chapter includes two sections: Section A- Spatio-temporal Analysis and Section B- Shoreline Change Analysis. The chapter deals with an in-depth study of the changes that occurred in the study region over some time.

SECTION A

4.1 Spatio-temporal analysis

4.1.1 Introduction

The most noticeable change taking place around us is the change in LULC. Detecting LULC change has become a major concern for geographers, ecologists, earth scientists and land-use architects due to its impact on physical ecosystems. People have been using resources in hilly terrain for millennia, but little is known about the extent and durability of these changes in land use (Nadaf, 2021).

Land use defines the human activities that are directly related to land, making use of its resources or having an impact on them (Briassoulis, H. 2009). In simple terms, land cover is what covers the surface of the earth and land use describes how the land is used. Water, snow, grassland, deciduous forest, and bare soil are a few types of land cover. Examples of land uses are urban areas, agricultural land, wildlife management areas, and recreational areas, among others.

Land-use/landcover map shows the spatial distribution of various land-use/land-cover classes in the region. The land-use/land-cover classes have been classified into three broad categories, that is, Level I, Level II, and Level III. The Level I classification scheme encompasses built-up land, agricultural land, forest, wasteland, water bodies, and others (Sonak, 2006).

LULC maps also aid in our understanding of the environmental and ecological changes that are taking place. If we have an inch-by-inch information about Land Use/Land Cover of the study unit we can make policies and launch programs to save our environment.

The National Oceanic and Atmospheric Administration states that land cover maps and data are used by coastal managers to gain a better understanding of the effects of both human activity and natural phenomena on the environment. Managers can use maps to prioritize areas for conservation efforts, model water quality issues, predict and assess the effects of floods and storm surges, track wetland losses and potential sea level rise impacts, prioritize urban growth, and compare changes in land cover with environmental effects or with links to socioeconomic changes like population growth.

Coastal areas are some of the fastest-growing stretches in the world and they are prone to kinds of catastrophes (Nadaf, 2021). As a result of unregulated development, the LULC of coastal ecosystems has undergone tremendous change. Changes in land use in the coastal areas will influence the biological diversity and the quality of habitat (Zhang et al., 2020). The rapidly increasing tourism and in terms of providing various goods and services to tourists has put a lot of stress on Land demand and has altered Land Use and Land Cover which has resulted in the depletion of natural resources, increase in built up areas, decrease in vegetation, soil erosion, natural habitat loss etc (Dina Fernandes, 2022). To minimize the devastation along the shoreline, there has to be no development until some distance from the coast. The fields of environmental management (EM) and environmental impact assessment (EIA) frequently employ remote sensing techniques.

To detect and monitor temporal changes in a given area, Remote sensing procedures are extensively used. Remote Sensing techniques are distinctly used to identify land use/land cover transformations (Nadaf, 2021). Planners and land managers may find the censor, which operates at a wide range of imaging scales, to be of interest and importance due to the rapid evolution of remote sensing and GIS technologies and methods. Coupled with the ready availability of historical remote sensing data, the reduction in the data cost, and increased resolution from satellite platforms, remote sensing technologies appear poised to make an even greater impact on planning agencies and land management initiatives involved in monitoring land use and land cover change at a variety of spatial scales. This data is collected from aerial and satellite platforms.

Assigning a pixel (or groups of pixels) from a remote sensing image to a land cover class is the process of digital image classification (Rejaur Rahman, M. et al., 2008). The goal is to associate each pixel with multiple classes (fuzzy or soft classification) or to classify each pixel into only one class (hard or crisp classification). The classification techniques may be categorized either based on the training process (supervised and unsupervised) or based on the theoretical model (parametric and non-parametric). Under this categorization, several classification algorithms have been invented. For example, k-means clustering is an unsupervised parametric algorithm, while maximum likelihood classifier (MLC) is a supervised parametric algorithm (Mishra et al., 2020).

LULC classification using RS & GIS:

One of the most popular uses of remote sensing is LULC classification. Among the most widely employed methods are:

Unsupervised classification (software computation):

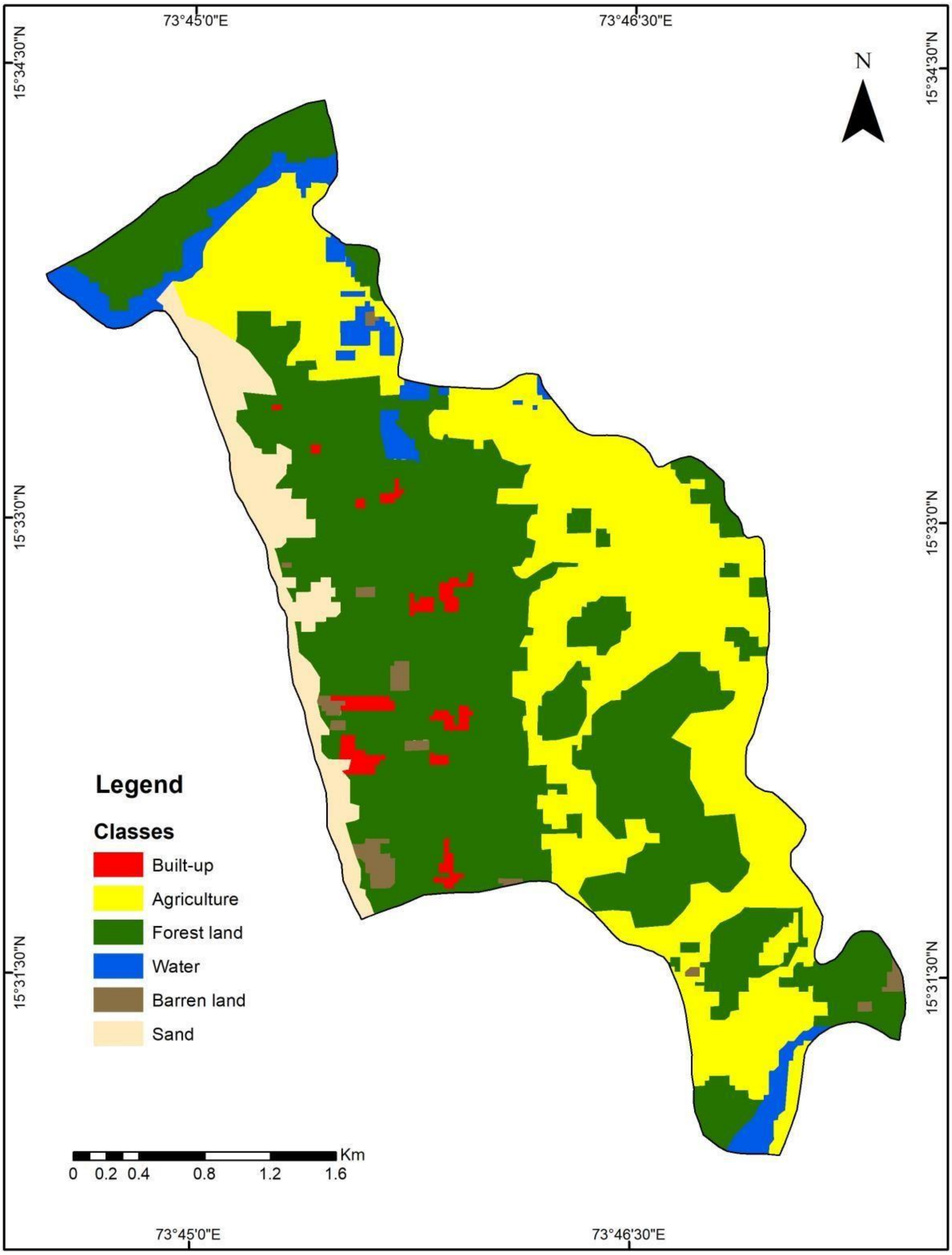
This kind of classification relies on an image's analysis by software without the user's input in the form of sample classes (Mishra et al., 2020). This entails assembling pixels that share similar attributes. The computer employs methods to classify the pixels into groups based on their relationships. The user doesn't help with the classification process other than choosing the algorithm the program will use and the number of output classes they want. The user must, however, be familiar with the region that is being classified (wetlands, developed areas, coniferous forests, etc.).

The concept of supervised classification, also known as human-guided classification, is based on the user's ability to choose individual pixels in an image that represent particular classes. The image processing software is then instructed to use these training sites as models for classifying all other pixels in the image. Training sites, sometimes referred to as testing sets or input classes are chosen according to the user's level of expertise (Rejaur Rahman, M. et al., 2008). To group other pixels together, the user also establishes the boundaries for their similarity. These limits are frequently determined by taking into account the training area's spectral properties, plus or minus a predetermined amount (typically determined by "brightness" or the strength of reflection in particular spectral bands). Additionally, the user specifies how many classes the image is assigned to.

In general, three distinct stages of training, assignment, and testing shall be followed in the supervision classification process. For known class members, training is the identification of a sample of pixels based on reference data like ground truth, existing maps, and airborne images. These training pixels shall be entered into the secondary classification stage to derive different statistics, such as average and standard deviation for each class of land cover. At this point, the image's pixels are classified according to the class in which the statistics indicate the highest degree of similarity (Rejaur Rahman, M. et al., 2008). To. The accuracy of the classification shall be determined at the end of the allocation phase. A sample or group of testing pixels is selected and their class identities are compared on both the classified image and the reference data. The pixels of agreement and disagreement for each testing sample are represented in the form of an error matrix, which can then be used to evaluate the classification accuracy.

Hence, the changing Earth's surface can be effectively monitored using remote sensing technologies as they are equipped with spatial, spectral, and temporal resolutions. Remote sensing technologies have many advantages concerning time, cost and re-visit time. For the extraction of land use/land cover material, remote sensing has a huge data source, which at times freely available (Nadaf, 2021)

4.1.2 Result



Map 4.1: Land use Land Cover map of Calangute in 1991

(Source: Researchers)

Table 4.1: LULC of Calangute in hectares and in percentage (TM image1991)

Classes	Areas in hectares	Area in percentage (%)
Built-up	17.22	1.42
Agriculture	433.78	35.69
Forest	626.13	51.51
Water	52.73	4.34
Barren land	14.44	1.19
Sand	71.18	5.86

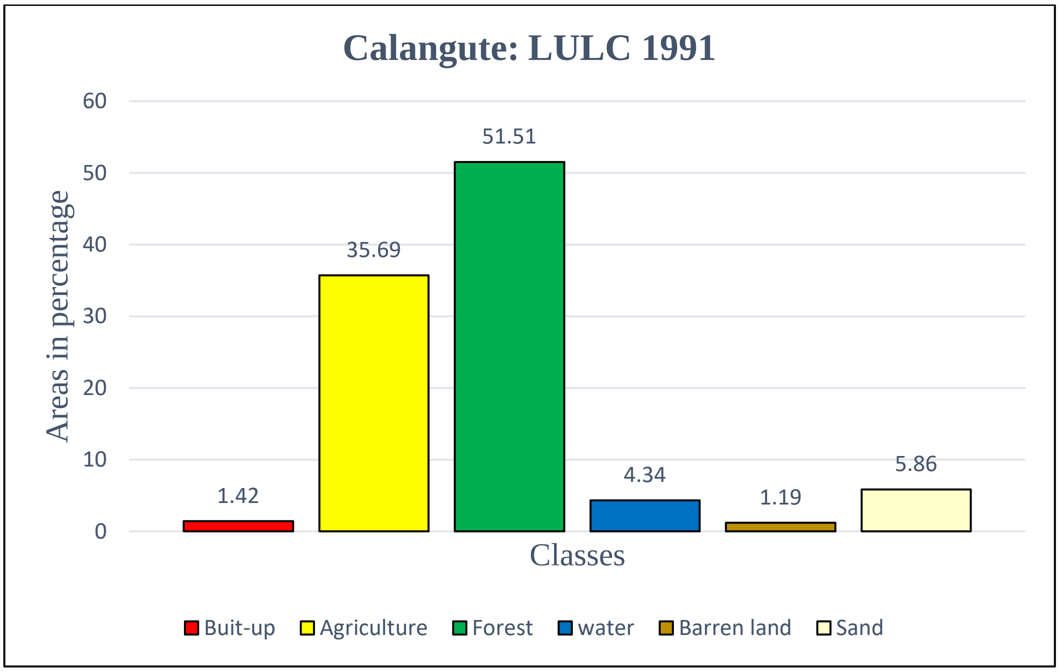
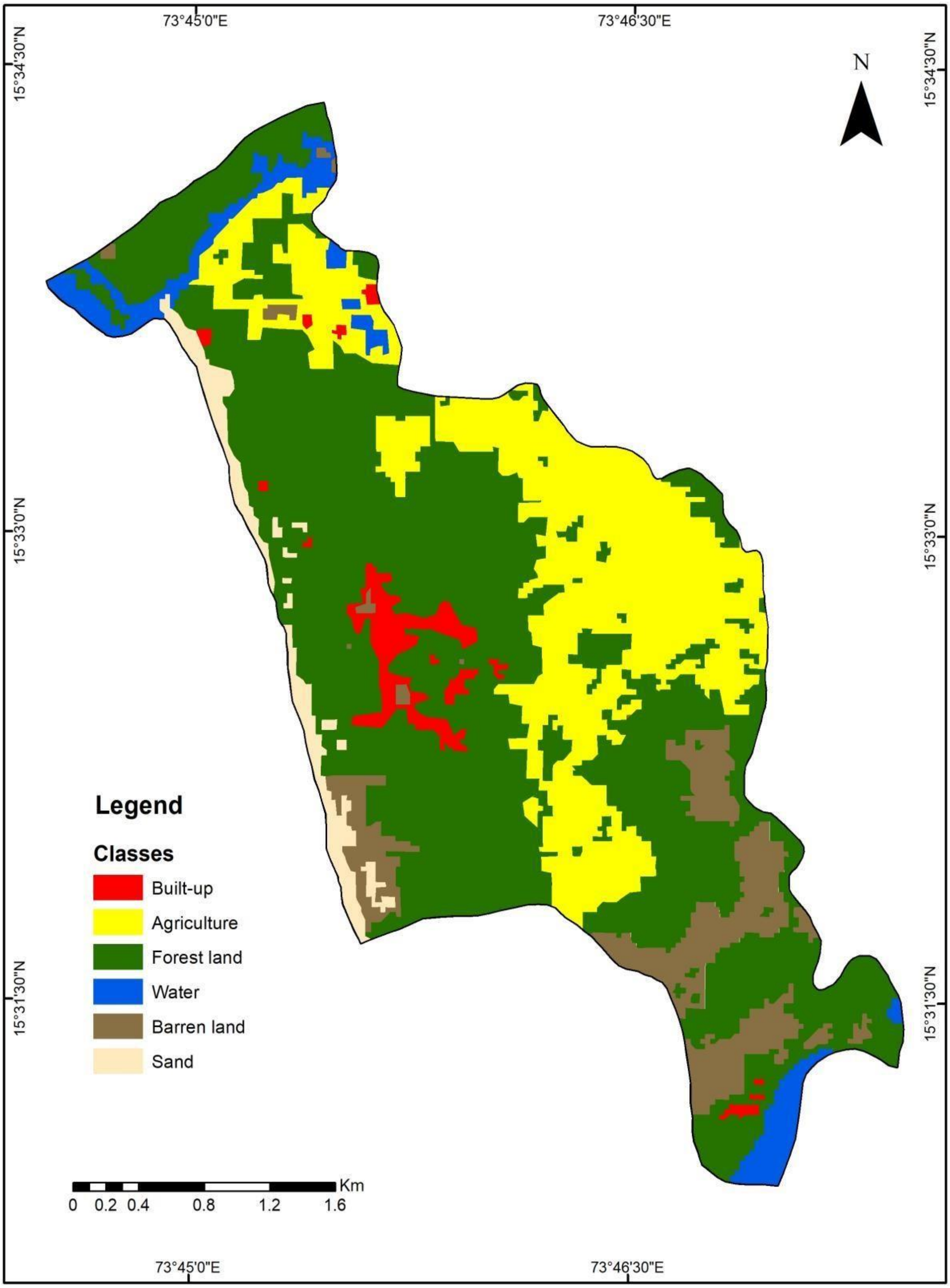


Figure 4.1: Bar graph representing LULC of Calangute in 1991

a. TM image Interpretation (Calangute 1991)

The tabulated data i.e. table 4.1, figure 4.1, and map 4.1, were generated and used for further analysis to understand the changes taking place in land use land cover in Calangute for the year 1991. In 1991, the majority of Calangute's land area was covered by forest (51.51%) and agriculture (35.69%). This indicates a substantial portion of the land being used for natural vegetation and farming activities. Built-up areas accounted for only 1.42% of the total land area in 1991, suggesting minimal urbanization or development of infrastructure at that time.

Water bodies occupied 4.34% of the land area, indicating the presence of rivers, lakes, or other water sources within Calangute. Barren land, sand, and other minor land cover types collectively accounted for a relatively small percentage (approximately 7.04%) of the total land area in 1991.



Map 4.2: Land use Land Cover map of Calangute in 2001

(Source: Researchers)

Table 4.2: LULC of Calangute in hectares and in percentage (ETM image 2001)

Classes	Areas in hectares	Area in percentage (%)
Built-up	55.53	4.57
Agriculture	335.01	27.56
Forest	686.02	56.44
water	52.72	4.34
Barren land	50.57	4.16
Sand	36.41	3

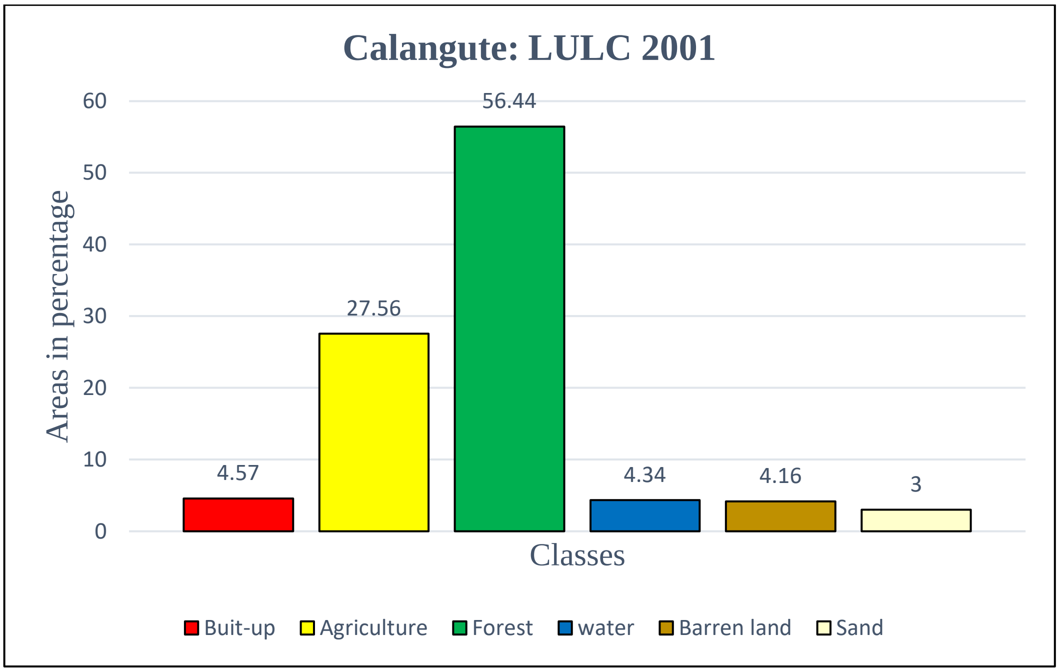
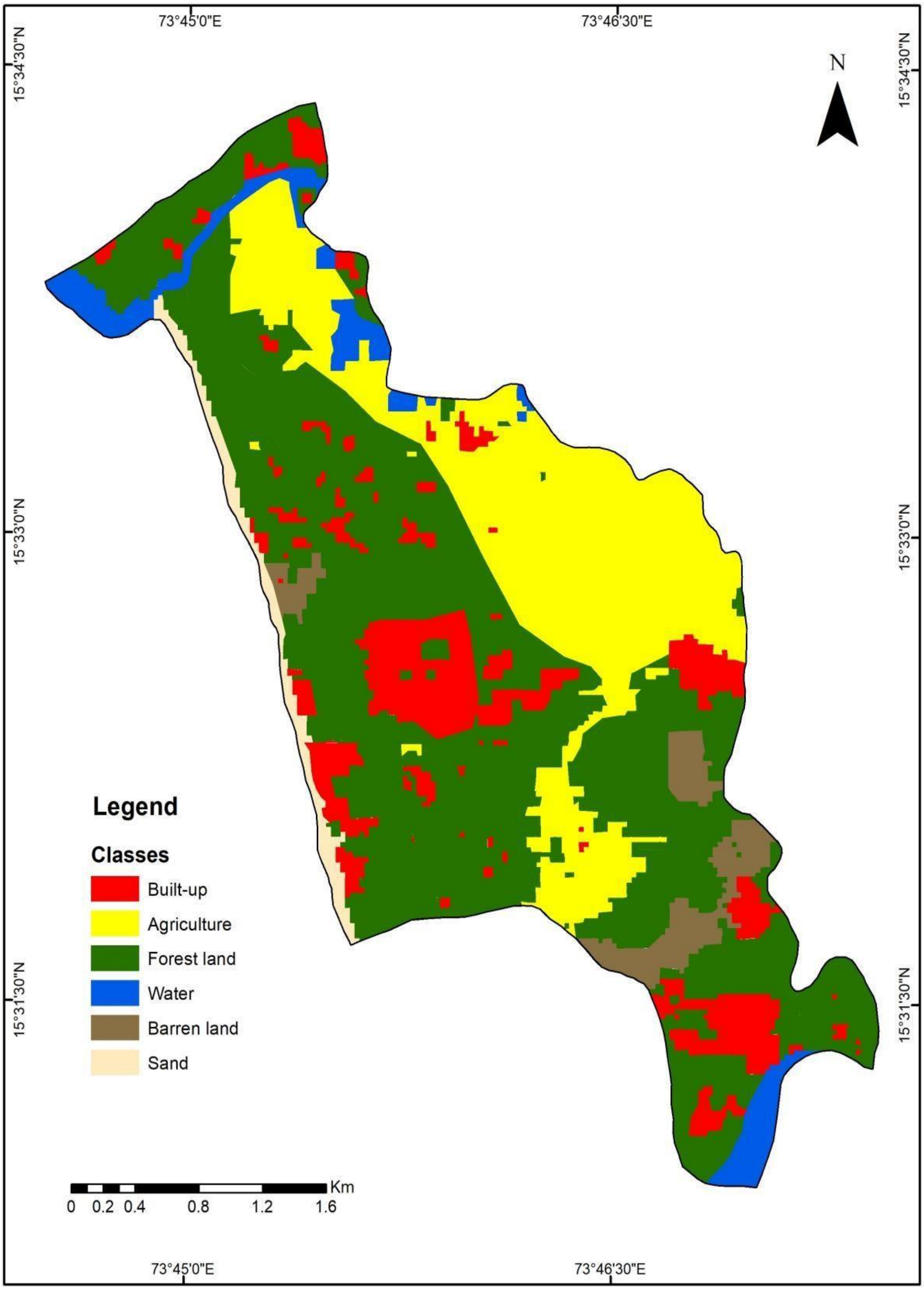


Figure 4.2: Bar graph representing LULC of Calangute in 2001

b. ETM image Interpretation (Calangute 2001)

From the above images it is quite visible that the Built-up areas increased slightly to 4.57% of the total land area, indicating limited urban expansion or development during the decade. The area under agriculture decreased to 27.56%, suggesting a reduction in agricultural activities or land use changes during the period. Also, might be due to the conversion of agricultural land to built-up can be seen in Table 4.2, figure 4.2, and map 4.2. The area under forest was increased by 4.93 percent.

The percentage of land covered by water bodies remained consistent at 4.34%, indicating the preservation of existing water resources within Calangute. There has been an increase in barren land that is up to 4.16 percent. A tremendous decrease can be seen in areas covered with sand (3%) due to excess erosion.



Map 4.3: Land use Land Cover map of Calangute in 2011

(Source: Researchers)

Table 4.3: LULC of Calangute in hectares and in percentage (ETM image 2011)

Classes	Areas in hectares	Area in percentage (%)
Built-up	112.65	9.27
Agriculture	307.41	25.50
Forest	670.27	55.14
water	52.78	4.34
Barren land	48.52	3.99
Sand	35.65	2.93

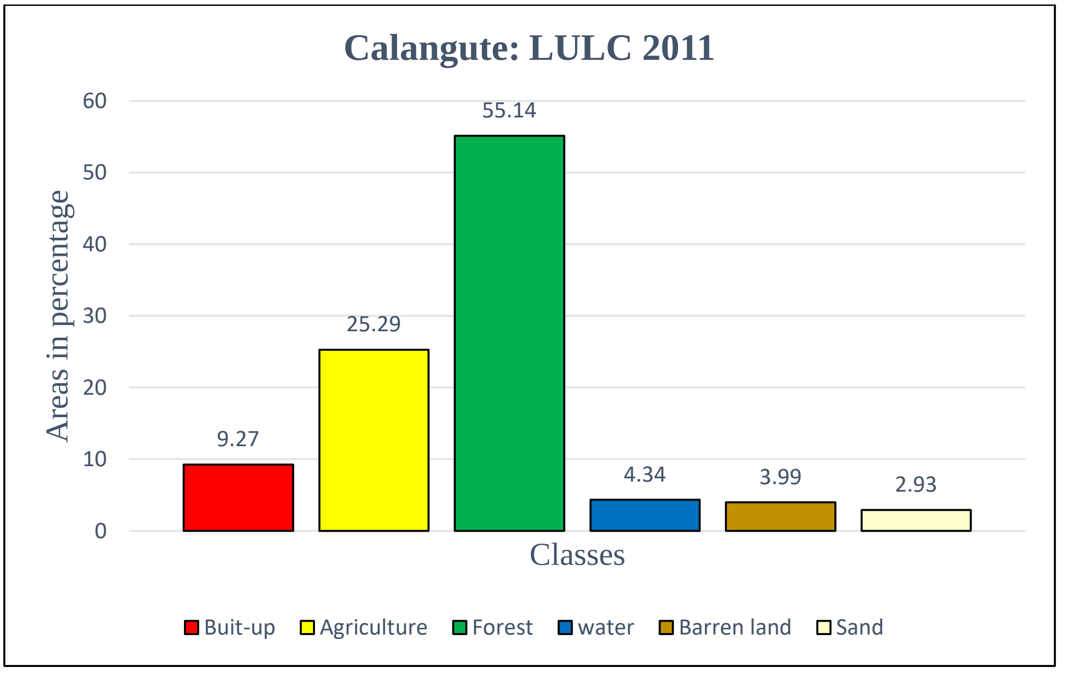
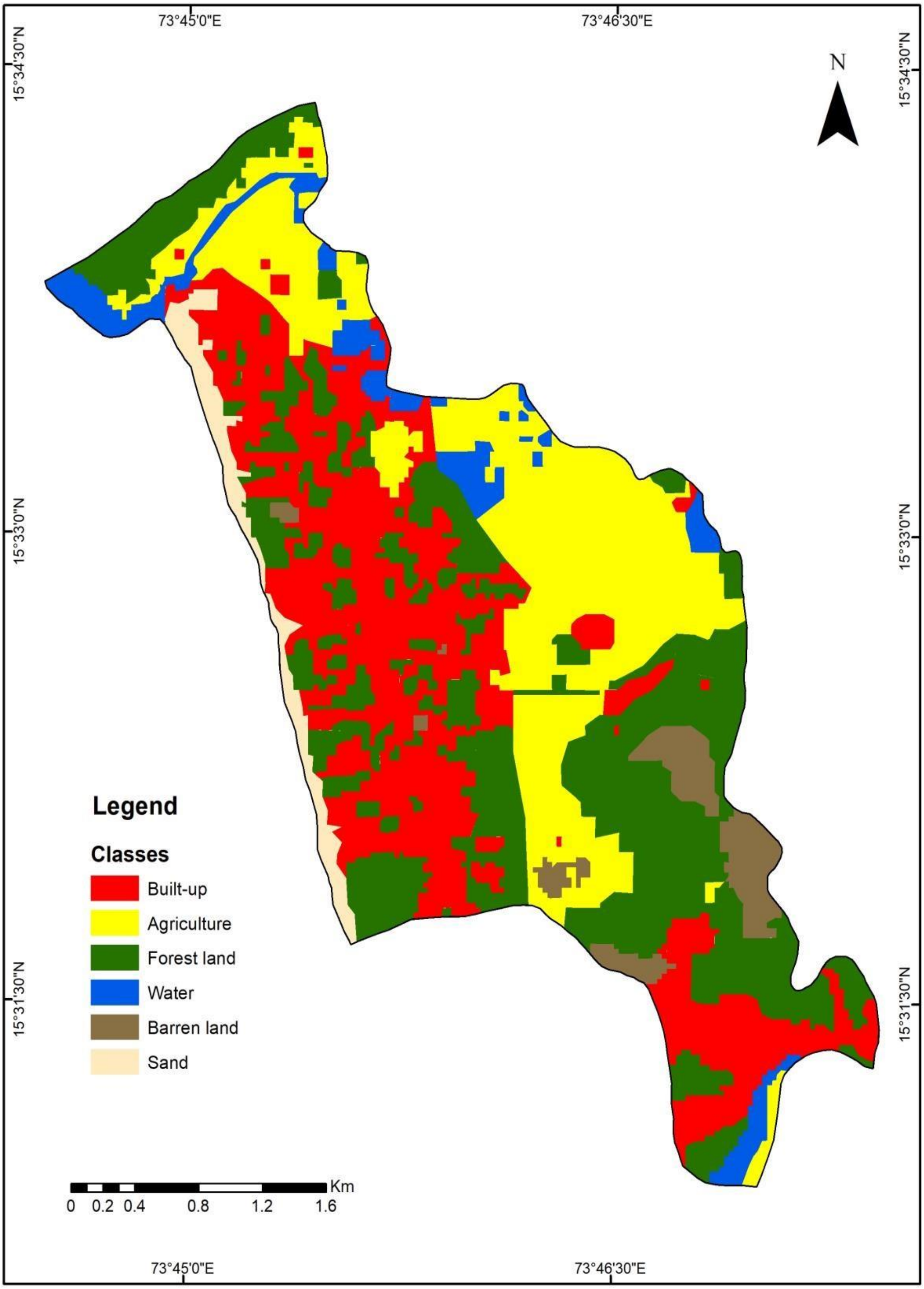


Figure 4.3: Bar graph representing LULC of Calangute in 2011

c. ETM image Interpretation (Calangute 2011)

Table 4.3, figure 4.3, and map 4.3, it reflects that in 2011 there was a tremendous increase in tourism activities, Calangute became an international tourist destination which led to the development of facilities such as roads, resorts, restaurants, etc., therefore area under built-up was increased to 9.27 percent. Forest area decreased to 55.14 percent. The area under agriculture decreased to 25.29%, indicating a reduction in agricultural activities or land use changes during the period.

The percentage of land covered by water bodies remained consistent at 4.34%. The slight decrease in barren land (3.99 percent) shows that this area was used for construction purposes.



Map 4.4: Land use Land Cover map of Calangute in 2021

(Source: Researchers)

Table 4.4: LULC of Calangute in hectares and in percentage (OLI-TIRS image 2021)

Classes	Areas in hectares	Area in percentage (%)
Built-up	360.97	29.70
Agriculture	310.01	25.29
Forest	396.15	32.59
Water	62.80	5.17
Barren land	49.15	4.04
Sand	23.84	1.96

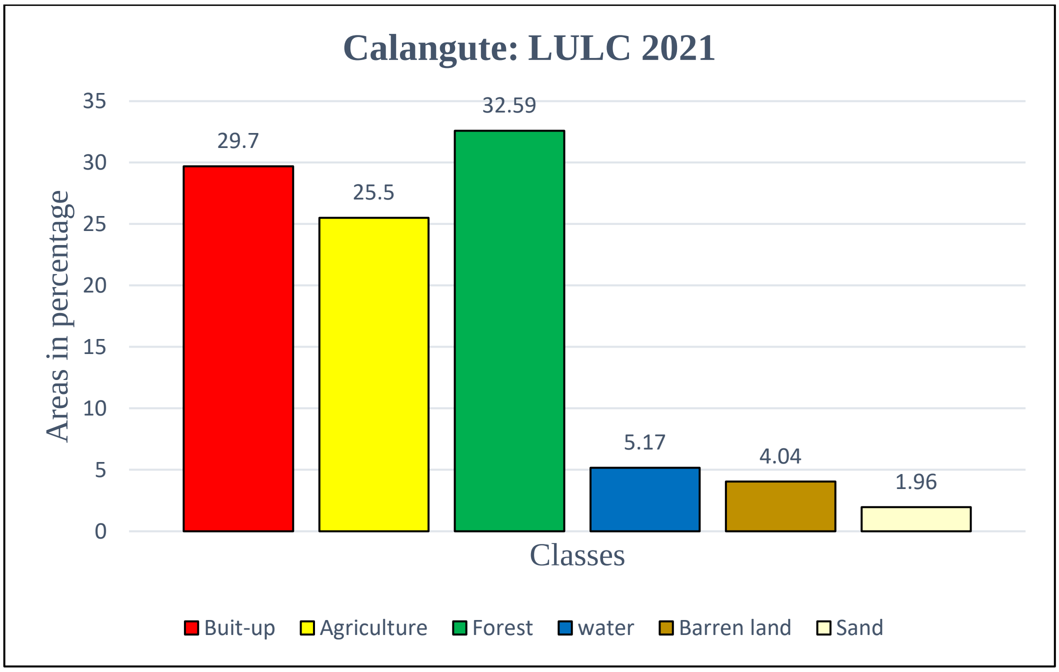


Figure 4.4: Bar graph representing LULC of Calangute in 2021

d. OLI-TIRS image Interpretation (Calangute 2021)

From table 4.4, figure 4.4, and map 4.4, it can be seen that the forested areas have extremely decreased to 32.59 percent of the land area, indicating potential deforestation or land conversion for other purposes such as urban development. The area under agriculture was decreased by 0.21 percent. The major increase was observed in the built-up area which is 29.70 percent due to high tourism activities as compared to past years and better lodging facilities.

There was a slight increase in barren land that is 4.04 percent. The area under sand has decreased to 1.96% percent. From the given data it can be seen that major coastal erosion has taken place due to increasing tourism activities. Over the past years, there is a sudden increase in the area under water by 5.17 percent because of erosion of the river bank.

e. Rate of Change (1991 to 2021)

Table 4.5: Rate of Change in Land Use Land Cover from 1991 to 2021

Classes	Rate of change (1991 to 2021)
Built-up	28.28
Agriculture	-10.18
Forest	-18.92
Water	0.83
Barren land	2.86
Sand	-2.86

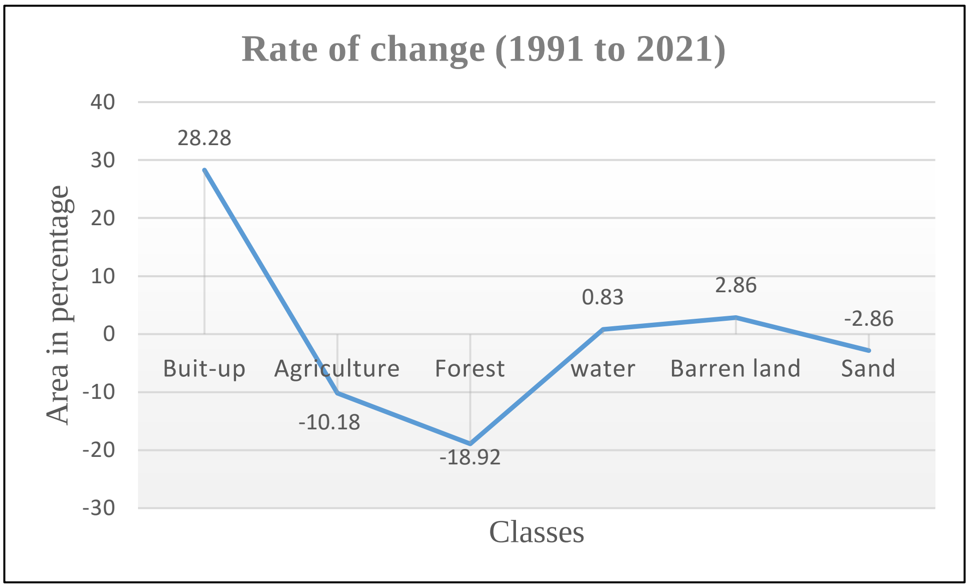


Figure 4.5: Line graph representing Rate of Change in LULC from 1991 to 2021

According to the above line graph, which shows the rate of change in land use and cover from 1991 to 2021, there has been a significant increase in built-up area of 28.28 percent. Over time, areas under forest and agricultural land have decreased by 18.92 percent and 10.18 percent, respectively. The area under barren land has increased to 2.86 percent. There has been an increase in water volume of 2.86 percent. Significant shoreline erosion has been observed over time, amounting to 2.86 percent.

SECTION B

4.2 <u>Shoreline Change Analysis</u>

4.2.1 Introduction

The interface of the land, ocean, and atmosphere is the coast. It acts as a buffer between the land and the sea and is an important global parameter (Fernandes et al., 2020). The coastal region is rich in scenic beauty and abundant valuable natural resources. The coastal zone supports a dense population and contains sensitive ecosystems such as mangrove forests, breeding grounds of several endangered marine and estuarine species and low-lying areas susceptible to sea level rise (Thomas, 2010).

In many parts of the Indian coast, beach erosion is an ongoing problem (Panda et al., 2023). Accurate information about historical and contemporary trends and rates of shoreline movement is in greater demand as the population along the coast grows and erosion threatens community infrastructures (Hapke et al., 2006). A comprehensive analysis of shoreline movements, which differ from one coastal area to another, is also needed.

Goa is a coastal paradise with a 105 km long coastline made up of numerous immaculate beaches. Goa's extensive coastline has made it a well-known tourist destination across the globe.

Shoreline of Goa

India has 7516.6 km long coastline, of which the length of west coast accounts for 3040 kms (Nadaf, F. M. 2019). Goa is gifted with 105 kms long coastline from Tiracol (Pernem) in the North to Polem (Canacona) in the South with a complex shoreline. As a result, Ahmad E. (1972) categorized the Goan coast as a "submergent rocky indented coastline.". Sandy beaches, rocky shores, sea caves, estuaries, mangrove forests, bays, capes, cliffs, hills, coral reefs, ports, harbors and coastal islands characterize the coastline of Goa.

If we visited the beach as a kid and then went back with our children 30 years later, chances are the beach and shoreline would look different. This is because the impact of waves causes coastal areas to constantly change in form and shape. Interesting shoreline features are produced by the waves' constant eroding of the shoreline.

Goa's coastline has taken all kinds of beatings. The damage to some of the beaches has been serious. In this light, a comprehensive study on erosion along the coastline of Goa by the National Institute of Oceanography (NIO) could point to the government how they should move to remedy the situation. Over the past few decades, several beaches along the state's 105-km coastline have been affected by erosion. The coastal beaches of North Goa are mostly stressed with development and infrastructure in order to boost tourism in the State (Fernandes et al., 2020). Beaches in Pernem and Bardez talukas in North Goa were more prone to erosion. Coastal erosion is there at Morjim, Baga, Calangute, Sinquerim, Anjuna, Candolim, Coco, and Dona Paula in North Goa and Colva, Polem and Palolem in South Goa. Experts believe that if immediate action is not taken to safeguard them, some beaches in Goa might vanish. Anjuna, which used to be one of the most beautiful beaches with platforms of rocks, today presents a horrid picture.

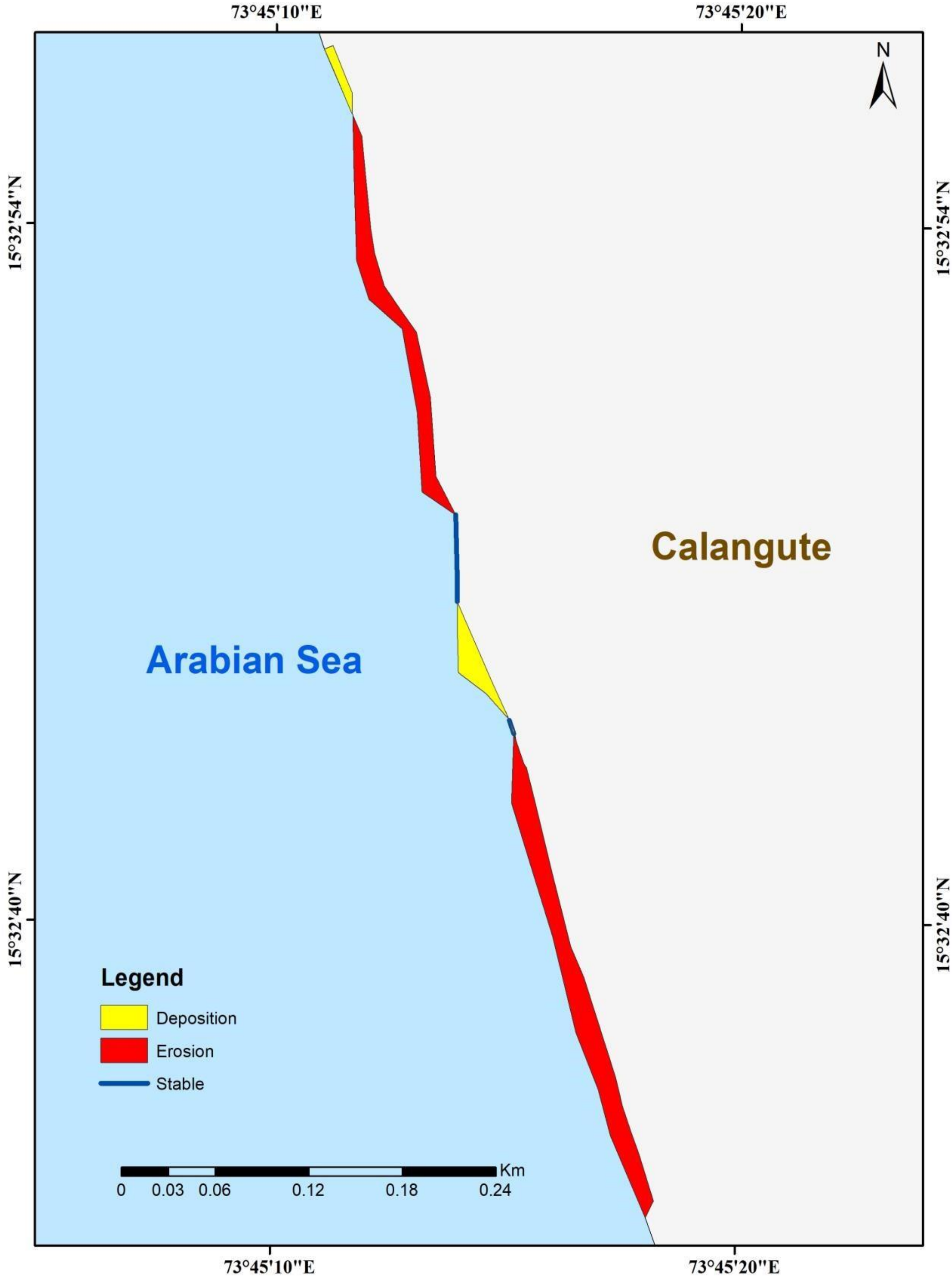
The coastal resources are subjected to variety of increasing impacts due to rapid demands and developments in the region. Therefore, to protect and preserve them, it was imperative to manage the Coastal zone, and hence, it was decided to introduce a plan of action towards sustained utilization of the Coastal Zone. (Anwar,2019). It was with this objective the Coastal Regulation Zone was introduced (1991) for coastal zone management.

It is necessary to properly implement plans and take action regarding CRZ in order to sustain long-term tourism in the State. In addition to dividing coastal zones according to population density along rural areas and eliminating traditional fishing communities, the shifting CRZ will result in the growth of Goa and turn the coastline into a concrete jungle. In the coastal zone, the interaction between the land and the ocean results in a complex range of landforms and organisms that evolve unique forms of adaptation (Nayak, 2004).

The MoEF's 2019 notification, which suggests lowering the current HTL from 200 meters to 50 meters, could alter Goa's vulnerable coastal zone and jeopardize tourism (Fernandes et al., 2020). A Development will cause the pristine beaches to disappear, creating coastal risks. A question that comes up is whether a small state like Goa, with a population far smaller than its own, will be able to handle the pressures of managing CRZ regulations given the influx of tourists. Moreover, over whether the State can afford to do away with the biggest industry called tourism.

Scientists have pointed to the fact that erosion along the state’s coast has intensified over the years, which poses risks to the ecology of the coastline as well as human life. The consequences of erosion can range from simple loss of coastal areas to irreparable damage to of houses and other structures near the shore. Beaches are the lifeline of tourism in Goa. If they go, the main attraction to tourists goes.

4.2.2 Result



Map 4.5: Shoreline changes of Calangute beach (1991-2021)

Table 4.6: Shoreline change of Calangute in 1991-2021

Sr. No.	Coastal change	Area (in sq. mt.)	Area (in percent)
1	Eroded Area	9146.58	79.22
2	Deposited Coast	853.91	7.40
3	Stable Coast	11546.16	13.39

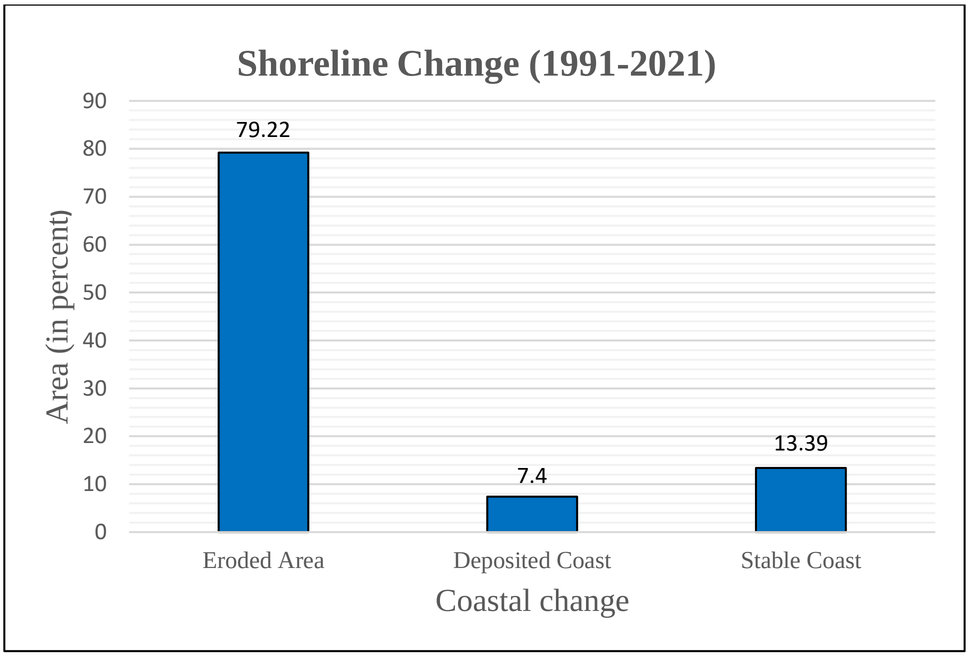


Figure 4.6: Bar graph representing Rate of Change in Shoreline of 1991-2021

A comparative study conducted on Calangute Beach between 1991 and 2021 found that 79.22 percent of the shoreline had eroded. The action of waves and winds caused 7:40% of the sand to be deposited on the shoreline. According to table 4.6, graph 4.6, and map 4.5, respectively, 13.39 percent of the shoreline was stable over the past 30 years.

4.3 Discussion

The purpose of this study was to determine whether environmental change and tourism development are correlated. From the comparative study of the data from 1991 to 2021, it can be revealed that there is a tremendous increase in built-up area by 28.28 percent due to excessive tourism activities. Over the years, areas under forest and agriculture decreased by 18.92 and 10.18 percent respectively, this was due to urbanization of the Calangute area. The area under barren land increased to 2.86 percent due to the loss of fertility of the soil because of construction activities. The volume of water has increased by 2.86 percent due to lateral erosion of the river bank. The major shoreline erosion was observed over the years by 2.86 percent because of the construction of resorts at the Coastal Regulation Zone and excessive tourism and water sports activities.

The shoreline change in Calangute from 1991 to 2021 reveals significant transformations in coastal dynamics. Eroded areas have increased substantially, accounting for 79.22% of the shoreline change, indicating the loss of land to coastal erosion. The substantial proportion of eroded areas suggests ongoing coastal erosion processes, likely influenced by factors such as sea level rise, storm surges, and anthropogenic activities. Erosion can lead to the loss of valuable land, habitat degradation, and increased vulnerability to coastal hazards.

Conversely, deposited coast areas have seen a minor increase, representing 7.40% of the change. This is due to the action of waves and winds. Also, the minor increase in deposited coast areas indicates sediment accumulation in certain sections of the shoreline, potentially resulting from natural processes like sediment transport or anthropogenic interventions such as beach nourishment projects. Deposited coast areas can contribute to the stabilization of the shoreline and provide valuable habitat for coastal species.

From the past 30 years 13.39 percent of the shoreline was stable. Stable coast areas have remained relatively consistent. Stable coast areas, although representing a smaller proportion of the change, play a crucial role in maintaining coastal resilience and providing stability to the shoreline. These areas may serve as buffers against erosion and provide essential habitat for coastal flora and fauna.

4.4 Conclusions

The assessment of tourism development in Calangute utilizing geospatial techniques has provided valuable insights into the dynamic interaction between tourism activities and the coastal environment. Goa is a famous tourist destination that holds an eminent spot for coastal tourism. Coastal tourism has become the backbone of the state's economy. Rise in tourism sector has directly increased the demand for various services. Tourist demography includes local, regional, national and international. These services mainly include best hotels, resorts, restaurants, homestays, adventure activities etc. Travelers predominantly choose nearby services to the coast. Consequently, demand on coastal or beach tourism has led to increase in services along the coast, and thus resulted in CRZ violations.

A detailed study of Land Use Land Cover area of the Calangute has been carried out. The changes occurring in Land Use Land Cover Pattern have been studied using Geospatial techniques and comparison have been made for different time periods to understand the extent of changes and conclusions were been drawn. In Calangute, it can be concluded that there is tremendous increase in built-up area by 28.28 percent due to excessive tourism activities. Over the years, areas under forest and agriculture decreased by 18.92 and 10.18 percent respectively, this was due to urbanization of the Calangute area. Urban expansion, indicated by the increase in built-up areas, has significantly altered the landscape of Calangute. This expansion has encroached upon agricultural lands and natural habitats, leading to habitat fragmentation and loss of biodiversity. The decline in forest cover underscores the need for conservation efforts to safeguard critical ecosystems and mitigate the adverse effects of urbanization on biodiversity. Land Use Land Cover of 2031 indicates that built-up area would still increase further whereas areas under forest, agriculture and barren land would go down drastically. And the resultant data shows that increase in built-up areas in Calangute will increase by 10 percent in the year 2031.

The examination of coastal shoreline changes highlighted the vulnerability of Calangute's coastline to erosion. This could be attributed to water sport and tourism activities which are disturbing the near-shore sea bed. Water sport activities also modify the wave form and results in the dissipation of wave energy. This results in high erosion rates at the beach. The significant proportion of eroded areas underscores the urgency of implementing shoreline protection measures to safeguard coastal communities and infrastructure. Part of the beach also shows slight stability. At the same time, the identification of deposited coast areas offers opportunities for beach nourishment projects and habitat restoration initiatives to enhance coastal resilience and promote biodiversity conservation.

Hence, Tourism development has exerted considerable pressure on Calangute's coastal environment. The preservation of green spaces and biodiversity is essential for maintaining ecosystem health and supporting sustainable tourism practices in Calangute. Green spaces, such as parks, gardens, and natural reserves, offer recreational opportunities for tourists while providing essential habitat for wildlife. Protecting biodiversity hotspots and implementing habitat restoration initiatives can enhance ecosystem resilience and promote eco-tourism opportunities, contributing to the region's socio-economic development in a sustainable manner.

And lastly, the findings underscore the importance of adopting integrated approaches that balance tourism growth with biodiversity conservation, sustainable development, and community well-being. By prioritizing green spaces, biodiversity conservation, and responsible tourism practices, Calangute can chart a path towards sustainable tourism development that benefits both the environment and local communities. Collaborative efforts among government agencies, local stakeholders, and the tourism industry are essential to realize this vision and ensure the long-term prosperity of Calangute as a premier tourist destination in India.

Hence, last but not least it can be concluded that the extent of tourism development in Calangute, assessed using geospatial analysis, is significantly correlated with changes in land use and land cover over time.

4.5 Suggestions and Recommendations

a. Diversion of tourists from Calangute to alternate beaches. Promoting other beaches at points of entry in Goa.
b. Provision of regularized public transport to South Goan beaches to divert the excess from North Goa and also provide revenue opportunities to South Goans.
c. Limiting the points of entry into beaches and levying a nominal entry fee to assess the beach. These funds could be utilized to maintain the beach quality and lessen the burden on the beaches.
d. Implementation of existing rules to preserve the sanctity of the coastal stretch.
e. Regular monitoring and evaluation of the policies and laws pertaining to the coastal ecosystem.
f. The current information generated on Land Use and Land Cover pattern of the area could be very helpful in formulating the plans, policies, and also programmes for better development of the planning of the study area.

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