

MAPPING AND MONITORING OF NETTOOR MANGROVES

*Project Report submitted as a requirement for the partial fulfilment of the Degree of
Master of Science in Environmental Science*

By

SNEHA TERESA GEORGE

18PEVS7871



**Indian National Centre for Ocean Information Services
Hyderabad**

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SACRED HEART COLLEGE (AUTONOMOUS),
THEVARA, KOCHI –13
KERALA, INDIA**



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DECLARATION

I, SNEHA TERESA GEORGE, hereby declare that the Project work entitled as “**MAPPING AND MONITORING OF NETTOOR MANGROVES**”, submitted to Centre for Environmental Studies, Sacred Heart College (Autonomous), Thevara, in partial fulfillment of the requirements for the award of Master of Science in Environmental Science, is an authentic record of the work done by me to the best of my ability on the basis of available literature under the guidance of **Dr. Prakash Chandra Mohanty, Project Scientist B, Indian National Centre for Ocean Information Services (INCOIS), Hyderabad** and no part of this work has formed the basis for the award of any other degree in any university or published anywhere.



Hyderabad

SNEHA TERESA GEORGE

20-05-2020



ईएसएसओ - भारतीय राष्ट्रीय महासागर सूचना सेवा केन्द्र

पृथ्वी विज्ञान मंत्रालय, भारत सरकार

"ओशियन वैली", प्रगति नगर (बी.ओ.) निजामपेट (एस.ओ.), हैदराबाद - 500 090, तेलंगाना, भारत.

ESSO - INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

(Ministry of Earth Sciences, Govt. of India)

"Ocean Valley", Pragathi Nagar (B.O.), Nizampet (S.O.), Hyderabad - 500 090, Telangana, India.



CERTIFICATE

This is to certify that the project work entitled, "MAPPING AND MONITORING OF NETTOOR MANGROVES" submitted by **Ms. Sneha Teresa George (18PEVS7871)**, student of M.Sc Environmental Science, fourth semester of the Centre for Environmental Studies, Dept. of Zoology, Sacred Heart College (Autonomous), Thevara, in partial fulfillment for the award of Degree of Master in Science, is a record of bonafide work carried out by her in our organization, Indian National Centre for Ocean Information Services (INCOIS), Hyderabad during January 2019 to March 2020.

This project was done under my guidance and supervision and was found worthy of acceptance.

Date:

Place: Hyderabad



Dr. PRAKASH CHANDRA MOHANTY

Project Scientist-B,
Coastal Geo-application Team
Tsunami and Storm Surge Group
INCOIS, Hyderabad

Thevara, Kochi 682013, Kerala, India Tel: +91-484 870504, 9447178494, Fax: +91-484 2663813

Email: office@shcollege.ac.in, envtscience@gmail.com, www.shcollege.ac.in

CERTIFICATE

This is to certify that the project work entitled, “**MAPPING AND MONITORING OF NETTOOR MANGROVES**” is an authentic record of the work carried out by Sansu Elsa Sunny of M.Sc Environmental Science, Centre for Environmental Science, Sacred Heart College (Autonomous), Thevara, Kochi, Kerala, India, under the guidance of **Dr. Prakash Chandra Mohanty, Project Scientist B, Indian National Centre for Ocean Information Services (INCOIS), Hyderabad**, in partial fulfillment of the requirements for the Master of Science in Environmental Science.

Thevara
20-05-2020



Dr. T. J. James
Co-ordinator
Centre for Environmental Studies
Sacred Heart College (Autonomous)
Thevara, Kochi - 13

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ABSTRACT

Mangroves are the most productive and diverse wetlands in the planet and are found in tropical and subtropical wetlands. These are among the most threatened and vulnerable ecosystems worldwide. Mutations in the extent of mangroves will have many consequences to nature. The present study was aimed to analyse the vegetation change of **Nettoor mangrove** located in Kochi, Kerala by calculating the **Normalized Difference Vegetation Index (NDVI)**. The changes in Nettoor Mangroves over the years 1992 to 2019 was examined using the application of GIS in this study. As these forests are sensitive and fragile to atmospheric behaviour, expansion of industrial and agricultural activities will bounce to many environmental and ecological disorders. Assessment of mangrove ecosystem is the most important factor in analysing the impact of human interventions on Coastal Ecosystem. Reliable and timely information is required in order to monitor and manage the Mangrove ecosystem. Landsat images of Nettoor mangroves were downloaded using USGS (United States Geological Survey) Earth Explorer and then analysed using ArcGIS to calculate NDVI. The formula to calculate NDVI is $(IR-R) / (IR+R)$. NDVI was calculated using Raster Calculator in Arc Toolbox. The study area was then classified into five classes based on the variation of NDVI. Vegetation change over the years was observed and then graphs were plotted. Nettoor Mangroves are severely suffering from a reduction in their extent due to various social, environmental and economic factors.

Chapter 1

INTRODUCTION

Mangroves are those trees, shrubs or palms that grow at the riparian zone. They thrive in conditions of high salinity, extreme tides, strong winds, high temperatures and muddy, anaerobic soils. There could even be no other group of plants with such highly developed morphological and physiological adaptations to extreme conditions (Miththapala, 2008). Majority have root systems that enable the plants to breathe despite being anchored in saturated, non-porous soils depleted of oxygen. Mangroves are the most productive and diverse wetlands in the planet and are found in tropical and subtropical wetlands. These are among the most threatened and vulnerable ecosystems worldwide. Alongi (2002) analysed a number of ecosystem properties of mangroves. He observed that:

- 1) Rates of mangrove primary productivity rivals those of other tropical forests
- 2) Mangrove forests are architecturally simple, but they possess a complex system of factors regulating their structure, recruitment and growth
- 3) Mangrove growth is not constant but related to climatic patterns
- 4) Tree diversity is low, but faunal and microbial diversity can be high
- 5) Plant –microbe soil relations are highly advanced and efficient
- 6) Crabs are keystone species influencing mangrove function and structure.
- 7) Important players in animal-plant relations are arboreal community.
- 8) Algae and not just detritus are a significant food resource.
- 9) Mangroves are an important link to fisheries.
- 10) Mangroves are chemically diverse and a good source of natural products.

1.1.IMPORTANCE OF MANGROVES

Mangroves are necessarily tolerant of high salt levels and have mechanisms to require up water despite strong osmotic potentials thanks to their environment. Some mangroves also take up salts, but excrete them through specialized glands in the leaves. Others transfer salts into senescent leaves or store them within the bark or the wood. Mangroves create unique ecological environments that harbour rich assemblages of species. The marshy sediments of the mangroves are habitat to a large number of epibenthic, infaunal, and meiofaunal invertebrates. Channels within the mangals support the habitat of phytoplankton, zooplankton and fish. The mangroves play a special role as nursery habitat for juveniles of fish whose adults occupy other habitats (e.g. coral reefs and seagrass beds).

The submerged mangroves roots, trunks and branches are islands of habitat having capability to draw in rich epifaunal communities including bacteria, fungi, macroalgae and invertebrates since they're surrounded by loose sediments. The aerial roots, trunks, leaves and branches anchor other groups of organisms. A number of crab species live among the roots, on the trunks or maybe forage within the canopy. Insects, reptiles, amphibians, birds and mammals flourish within the habitat and contribute to its unique character.

The mangrove area worldwide has now fallen below 15 million hectares, down from 19.8 million ha in 1980. 5 million ha of mangroves were lost over the last twenty years, or 25 percent of the extent found in 1980. The Sunderbans is that the largest mangrove forest within the world, located within the Ganges delta in Bangladesh and West Bengal, India.

1.2 DISTRIBUTION OF MANGROVES IN INDIA

Mangroves in India account for about 5 per cent of the World's mangrove vegetation (Pillai and Harilal, 2015). Indian mangrove vegetation extends in an area of about 6,749 km² along the 7516.6 km long coast line, including Island territories. The entire mangrove

ecosystem is situated in three zones: (1) East Coast, which is about 4700 km², (2) West Coast, covering an area of 850 km², and (3) Andaman & Nicobar Islands, with an extent of 1190 km². These three zones are further categorized into Deltaic, Coastal, and Island habitats following Thom's classification of estuarine habitats. Studies reveal that mangrove species in the world range from 48 to 90 and in India from 50-60. It has been estimated 82 species of mangroves distributed in 52 genera and 36 families from all the 12 habitats in India.

1.3 DISTRIBUTION OF MANGROVES IN KERALA

The species diversity of mangroves and their associates are comparatively rich in Kerala. Mangroves are confined to estuaries, lagoons, backwaters and creeks. In Kerala mangroves are distributed in all districts except Idukki, Pathanamthitta, Palakkad and Wayanad and the maximum extent is reported from Kannur district (1100 ha.), Ernakulam (600 ha.) and Kasaragod (315 ha.) and the minimum extend was represented by three districts, Malappuram (26 ha.), Thiruvanthapuram (28 ha.) and Thrissur (30 ha.) (Vidyasagaran and Madhusoodaran, 2014). An overall of 24 pure mangroves were recorded belonging to 15 genera and 9 families. 8 species representing Rhizophoraceae, Acanthaceae represented by 4 species, 1 species each from Myrsinaceae (Primulaceae), Malvaceae, Combretaceae and Pteridaceae, two species representing Euphorbiaceae, three each from families Lythraceae and Arecaceae.

1.4 THREATS FACED BY MANGROVES

Living at the riparian zones, mangroves are well adapted to deal with natural stressors (e.g. temperature, salinity, anoxia, UV). However, because they live close to their resilience limits, they are prone to disturbances created by human activities. Because of their proximity to population centers, mangroves have historically been preferred sites for waste disposal. Industrial effluents, oil spills and e-waste have contributed to heavy metal contamination in the sediments. These abuses have had significant negative effects on the mangroves.

Human interferences of various types including pollution, destruction and conversions had resulted in the shrinkage of mangrove habitats (Basha, 1991). Human encroachment has caused great damage to mangrove ecosystem. Habitat destruction and habitat fragmentation has been the primary cause of mangrove loss (Sandilyan and Kathiresan, 2012). Land

reclamation, conversion of tracts of mangrove for aquaculture. These impacts will continue as human populations expand further into the mangals. Overexploitation of mangroves has left many remaining habitats severely damaged. It is estimated that mangroves are degrading at a global rate of one million ha per year. Efforts are underway to launch mangrove agroforestry and agriculture projects where mangroves require intensive care to save threatened areas. So far, safeguarding and management efforts straggle behind the destruction; there is still much to explore about proper management and sustainable harvesting of mangrove forests.

1.5 ROLE OF REMOTE SENSING AND GIS IN THE MANGROVE ECOSYSTEM

Remote Sensing and GIS provide quantitative information on understanding the spatial distribution of mangroves. Remote sensing is useful in various ways to characterize mangrove ecosystem like mapping, detection of individual species, providing estimates of canopy based on the extent of leaf area, canopy height and biomass. Remotely sensed data served as one of the best sources of information that can show the location of all areas that have been deforested or degraded or still healthy (Hossain et. al., 2009).

Remote sensing technique, due to its synoptic, multi-temporal, coverage and multi-spectral ability in whole range from visible to microwave wavelengths; can effectively act as a tool providing advance and reliable information on mangrove extent and status of its growth along the coastal areas. Remote sensing data for the estimation of various natural parameters like rainfall, land surface temperature, soil moisture content etc. on the earth surface will help in the estimation of various parameters and application of the human activities.

1.6 NDVI (Normalized Difference Vegetation Index)

The reflectance pattern of the vegetation in visible & NIR spectral region gives information on condition of vegetation cover. The various satellite-derived indices such as Normalized Difference Vegetation Index (NDVI) and Ratio of NIR & Red wavelengths can also be effectively used to monitor the vegetation status and condition of the mangrove ecosystem. NDVI is based on the difference between maximum absorption of radiation in red due to chlorophyll and maximum reflection of radiation in NIR due to leaf cellular structure.

The combination of red and Infrared (IR) bands along with vegetation indices help in distinguishing between mangroves, swamps and other vegetation in the wetland zones. The

NDVI is developed for estimating vegetation cover from the reflective bands over satellite data. NDVI (Normalized Difference Vegetation Index) is the absorption in the red spectrum and reflectance in near infra-red. Healthy vegetation reflects more near-infrared and green light, but absorbs more red and blue light. If NDVI close to +1, high possibility that it is dense green leaves, whereas when NDVI value is negative, it is highly likely that it is water. The formula for calculating NDVI is $(IR-R) / (IR+R)$.

1.7 DESCRIPTION OF STUDY AREA

Nettoor, which is a part of Maradu Municipality, is located on Panangad Island. Both NH 66 and NH 966B passes through Nettoor as well as Tirunettur Railway Station on Kochi-Alappuzha railway line is situated on the northern end of Nettoor. The average annual temperature of this region is 27.3 °C / 81.1 °F. The annual rainfall is 3289 mm / 129.5 inch. Nettoor region is blessed with profuse mangrove forests (Figure 1). Nettoor mangroves are situated between 09° 56' 08'' N and 76° 18' 26'' E. A number of creeks and canals are found to traverse the area fringed with mangrove plants. *Avicennia officianalis*, *Acanthus ilicifolius*, *Bruguiera gymnorhiza*, *Bruguiera cylindrica*, *Rhizophora mucronata*, *Kandelia candel* and *Sonneratia caseolaris* are the mangrove species found in this region. *Acanthus ilicifolius* is the dominant species in Nettoor with 1560 in number per ha. *Acrostichum aureum* is the semi-mangrove species present in this ecosystem. Mangrove associates like *Scaevola sericea* and *Ipomoea* are also seen associated with Nettoor Mangroves. This area is slightly polluted as it is left unattended or not protected by anyone in and around that area.



Figure 1: Nettoor Mangroves in Kerala

Chapter 2

REVIEW OF LITERATURE

Mangroves are forested wetlands that represent a functional link between the terrestrial and oceanic carbon cycles storing up to four percent of carbon per unit area in comparison with terrestrial forest and the maximum height of the mangrove canopy is around 62m+/-6.8m (Simard et. al., 2019).

Avicennia officianalis, *Acanthus ilicifolius*, *Bruguiera cylindrica*, *Rhizophora mucronata*, *Kandelia candel*, *Bruguiera gymnorhiza*, *Sonneratia caseolaris* are the mangrove species found in Nettoor. *Acanthus ilicifolius* is the dominant species in Nettoor with 1560 in number per ha. (Field Study Report, Centre for Environmental Studies, SH College, Thevara, 2019).

Approximately 75% of mangroves distributed in 15 countries of the world and out of which 50% are under serious threat (Giri et.al., 2010).

Quader et.al... (2017) performed unsupervised classification of Mangrove density to identify the special temporal evolution of Mangroves. Quader et.al... (2017) used Normalized Difference Vegetation Index as an indicator for the analysis of extent of the Mangroves.

Polluting heavy metals like copper and chromium were estimated in Nettoor Mangroves. (Nettoor Mangrove Ecosystem Field Study Report, Centre for Environmental Studies, SH College, Thevara, 2019).

Higher organic carbon content was estimated in the sediment samples of Nettoor Mangroves, which can be attributed to the high vegetation and dumping of organic waste in and around the region.(Nettoor Mangrove Ecosystem Field Study Report, Centre for Environmental Studies, SH College, Thevara, 2019).

Hamilton and Casey 2016, synthesized the Global forest change database and extracted Mangrove forest database at the high spatial and temporal resolution. He identified high amounts of mangrove loss seen in Myanmar, Malaysia, Cambodia, Indonesia and Guatemala.

Lillesand et.al., 2015, gave the variation of the spectral signature curve for all naturally occurring elements on the earth surface. The curve is varying with electromagnetic spectrum wavelength to reflectance. For the vegetation, there is a sharp rise in the wavelength range of 0.7 μm which is the main source for the estimation of changes in the vegetation cover. Spectral signature helps in identifying the abnormal changes on the land surface by using satellite data.

Sea level rise has a potential impact on the mangroves and this is one of the factors for destruction in the extent of the forest. (Doyle, 1997)

Spalding (2010) had highlighted the intense utilization of mangroves by people for timber, fuelwood and fisheries.

Alatorre et.al... (2016) demonstrated the applicability of NDVI for the environmental assessment of mangroves.

Chapter 3

OBJECTIVES OF THE STUDY

The major objectives of the study are:

- To map and calculate **Normalized Difference Vegetation Index (NDVI)** of Nettoor Mangroves using the application of GIS.
- To compare the mangrove vegetation of Nettoor between the years **1992 to 2019** by finding the **difference between NDVI**.
- To estimate the change in Nettoor mangroves over the years using **different classes** based on their NDVI variation.
- To **determine the factors** for the increase or decrease in Nettoor mangroves.

Chapter 4

METHODOLOGY

4.1 DATA PRODUCTS AND SOFTWARE USED

4.1.1 Data Used:

In the present study, three satellite data LANDSAT-5, LANDSAT-7 and LANDSAT-8 was used for the monitoring and mapping of mangrove ecosystem.

Year	Satellite Id	Sensor	Number of Bands	Data Acquired
1992	LANDSAT-5	TM	7	31.12.1992
1997	LANDSAT-5	TM	7	01.04.1997
2001	LANDSAT-7	ETM	8	30.11.2001
2008	LANDSAT-7	ETM	8	27.12.2008
2014	LANDSAT-8	OLI TIRS	11	11.02.2014
2019	LANDSAT-8	OLI TIRS	11	13.03.2019

4.1.2 Software Used:

ArcGIS (Arc Map) 10.5, Google Earth Pro

4.2 DESCRIPTION OF METHODS FOLLOWED

4.2.1 Collection of Data

Satellite Images were downloaded from United States Geological Survey (USGS) Earth Explorer of the years 1992, 1997, 2001, 2008, 2014, 2019. The changes in Nettoor Mangroves were analysed using these Satellite Images.

4.2.2 Layer stacking of the landsat images in Arc GIS

Layer stacking is done in order to combine multiple images into a single image.

- Data Management Tool was selected from ArcToolBox of ArcGIS and clicked Raster option.
- Selected Raster Processing and then Composite bands option was chosen.
- Bands from 1 to 5 of the landsat images were inputted for layer stacking.
- Repeated the same steps for layer stacking each landsat image.

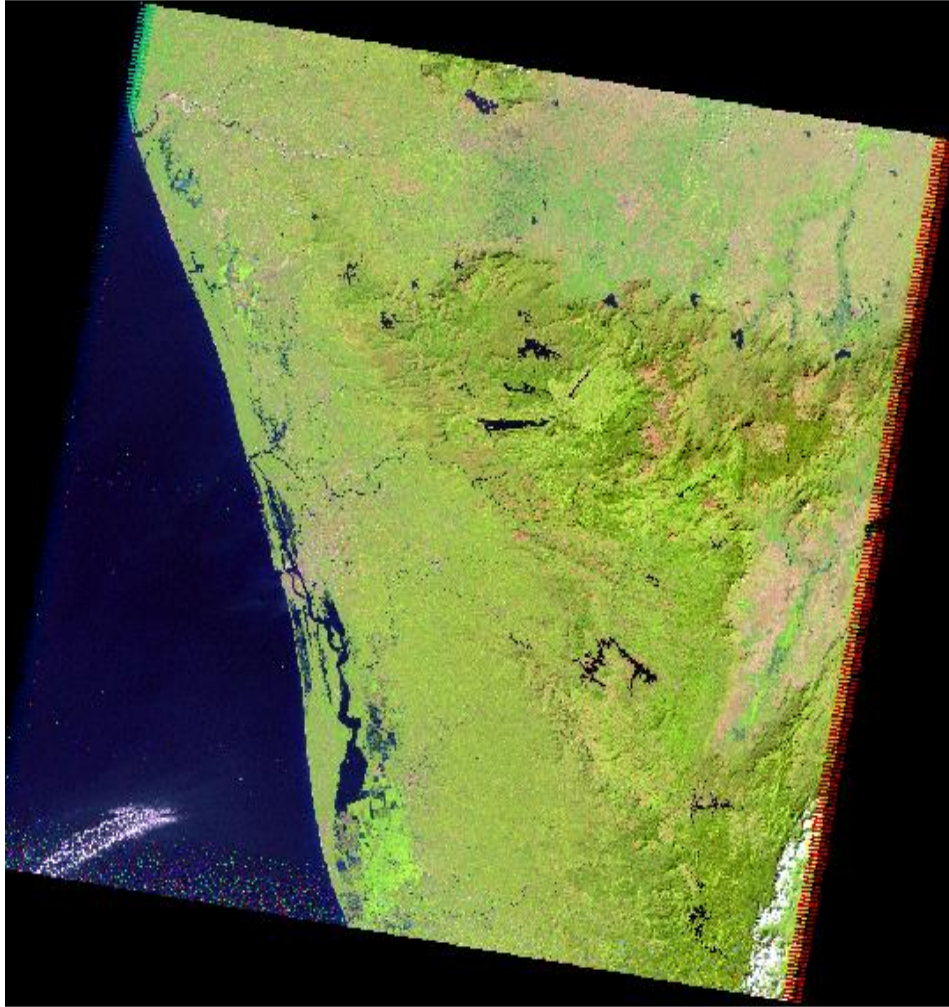


Figure 2: LAYERSTACKED IMAGE

4.2.3 Digitization of Nettoor Mangroves in Google Earth

Digitization in Google Earth is important as it marks the boundaries of the study area and digitizes the spatial features.

- Identified the study area in Google Earth and then drawn a polygon over this area using the polygon option.
- This file was then saved as KML file using save option.



Figure 3: DIGITIZATION OF STUDY AREA

4.2.4 Conversion of the KML file to layer in ArcMAP

- After opening the layerstacked image, chosen Conversion tools from ArcToolBox of Arc GIS and then selected 'From KML' option.
- Clicked on 'KML to Layer' option and then inputted the appropriate KML file and given the output name.
- A new layer was created.

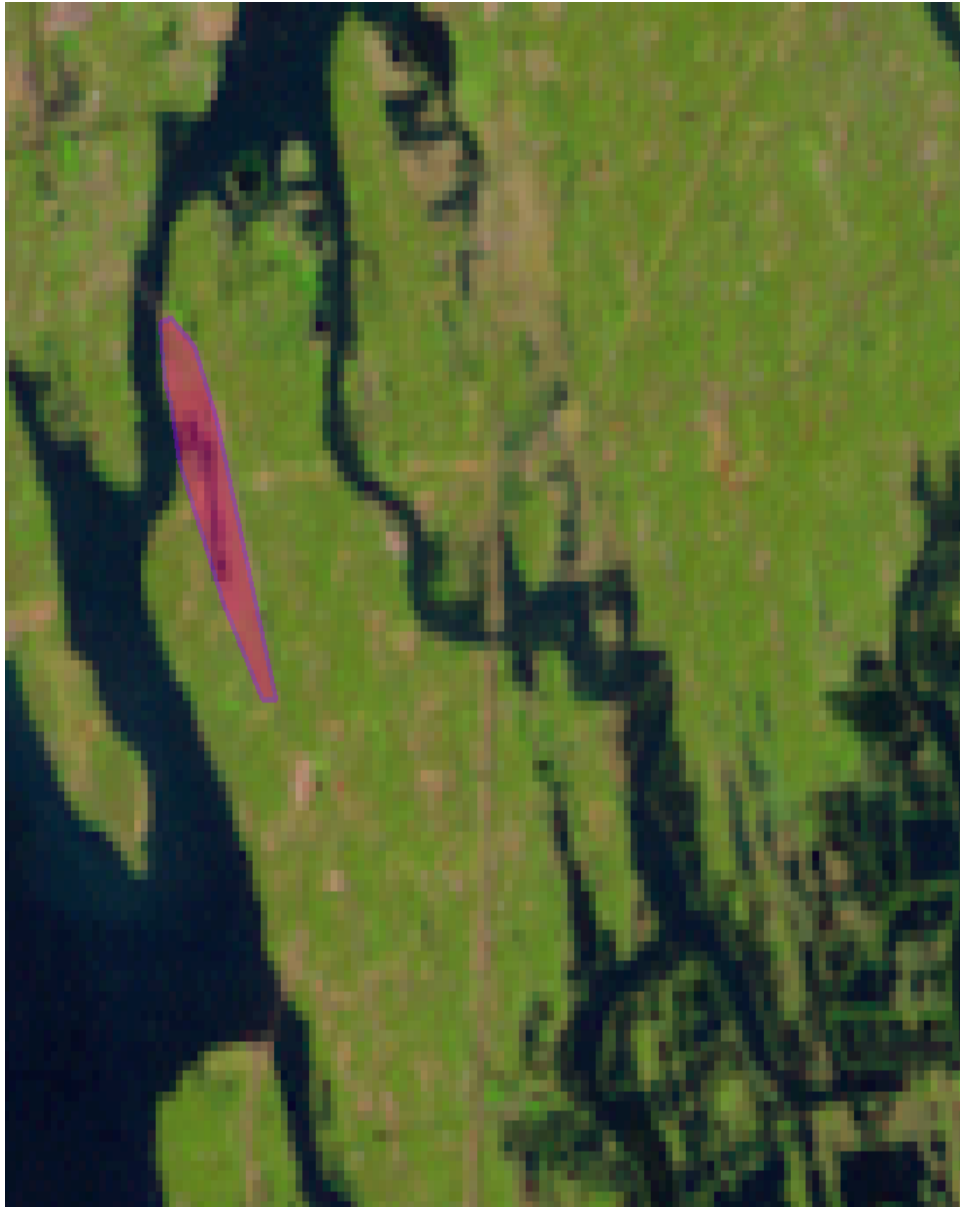


Figure 4: KML FILE TO LAYER

4.2.5 Creation of Shapefile

A Shapefile is a digital vector storage format for storing geometric location and associated attribute information. The shapefile format can spatially describe vector features: points, lines, and polygons.

- Right clicked on the polygon feature of layer file in the table of contents of ArcGIS.
- Selected Data option.
- Then opted Export data.

- Given appropriate output file name and then clicked OK.

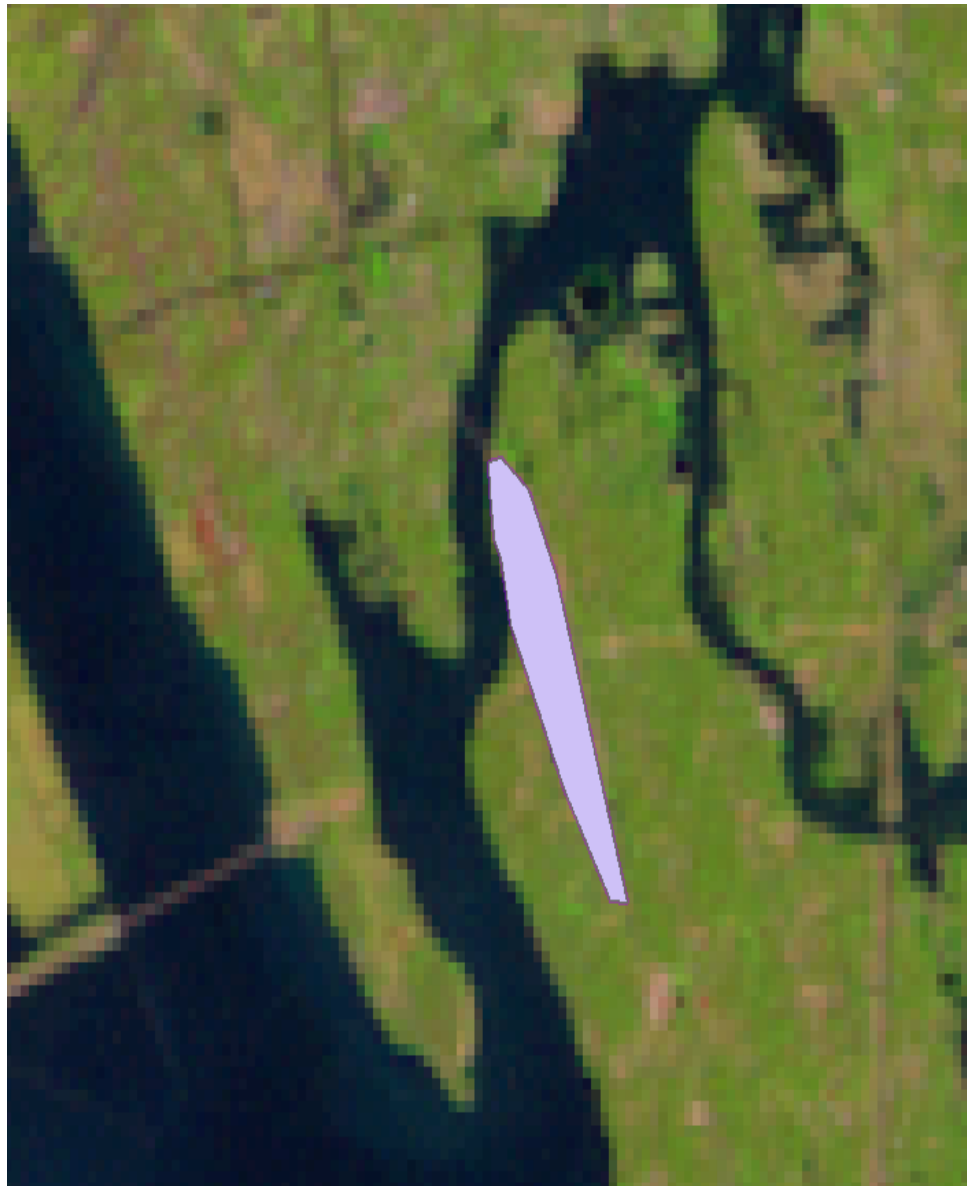


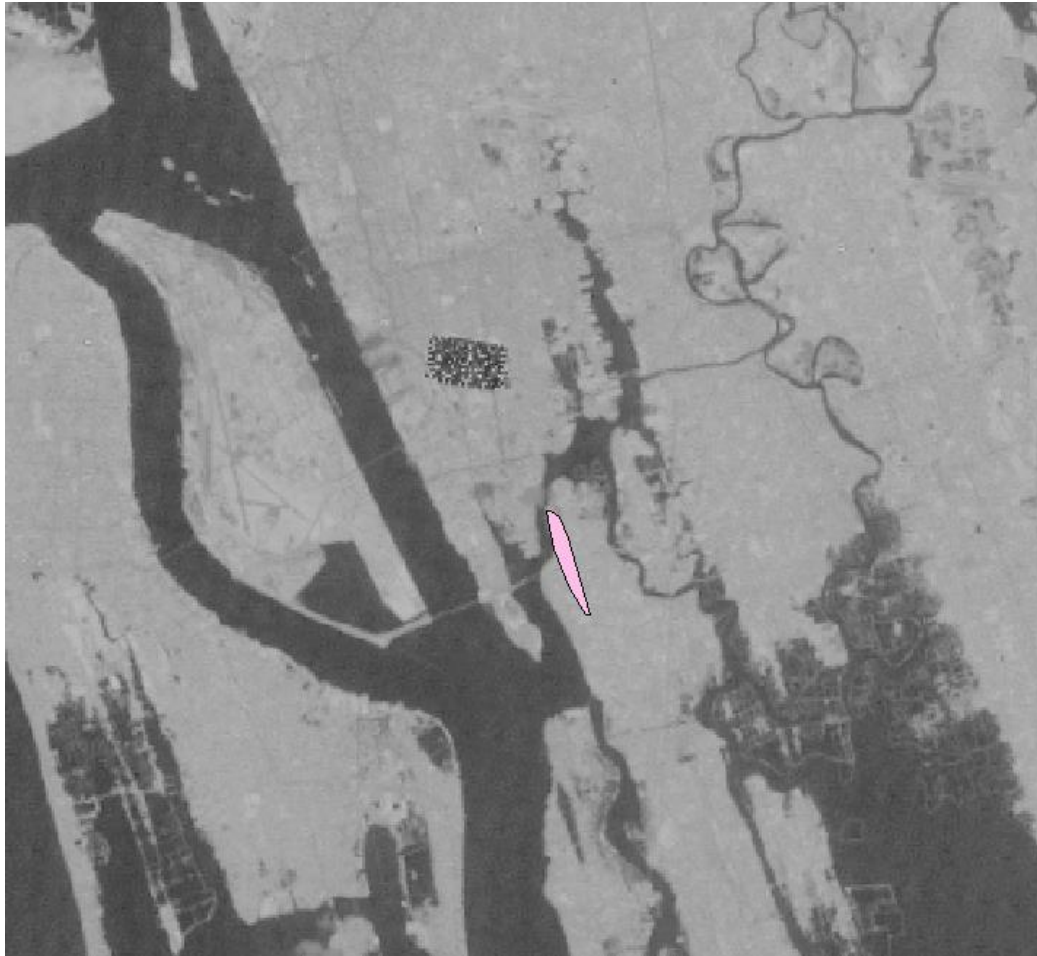
Figure 5: CREATION OF SHAPE FILE

4.2.6 Calculation of Area of the study region

- Right clicked on the newly created shapefile and then selected 'Open attribute table' option.
- Add a field named 'Area' to the table and then calculate the area using the 'calculate geometry' option by right clicking on the new field.

4.2.7 Calculation of NDVI

NDVI is the measure of indication of healthiness of vegetation. It ranges between -1 to +1. The negative values of NDVI approaching to -1 represent the deep-water regions while the low, positive values indicate scrub and grasslands. The high values of NDVI represent temperate and tropical type of forests. The mathematical equation for the calculation of NDVI is: $NDVI = (NIR - R) / (NIR + R)$ where, NIR is Near Infrared and R is Red. Raster calculator in ArcGIS was used to calculate the Normalized Difference Vegetation Index (NDVI).



4.2.8 Masking of non-vegetation *Figure 6: NDVI OF LANDSAT IMAGE*

Masking of non-vegetation areas is necessary as the study area also contains features like waterbody other than vegetation. After the calculation of NDVI, features other than vegetation was masked.

Using the Raster calculator, non-vegetated areas were masked by giving the first condition as: if (**NDVI Value** < = **0.2**), then give the value as **0**, and then the second condition as: if (**NDVI Value** > = **0.8**), give the value as **1**.

4.2.9 Finding difference

In order to compare the mangrove vegetation over the years 1989 to 2019, the difference of NDVI value of Landsat images was processed using the Raster calculator.

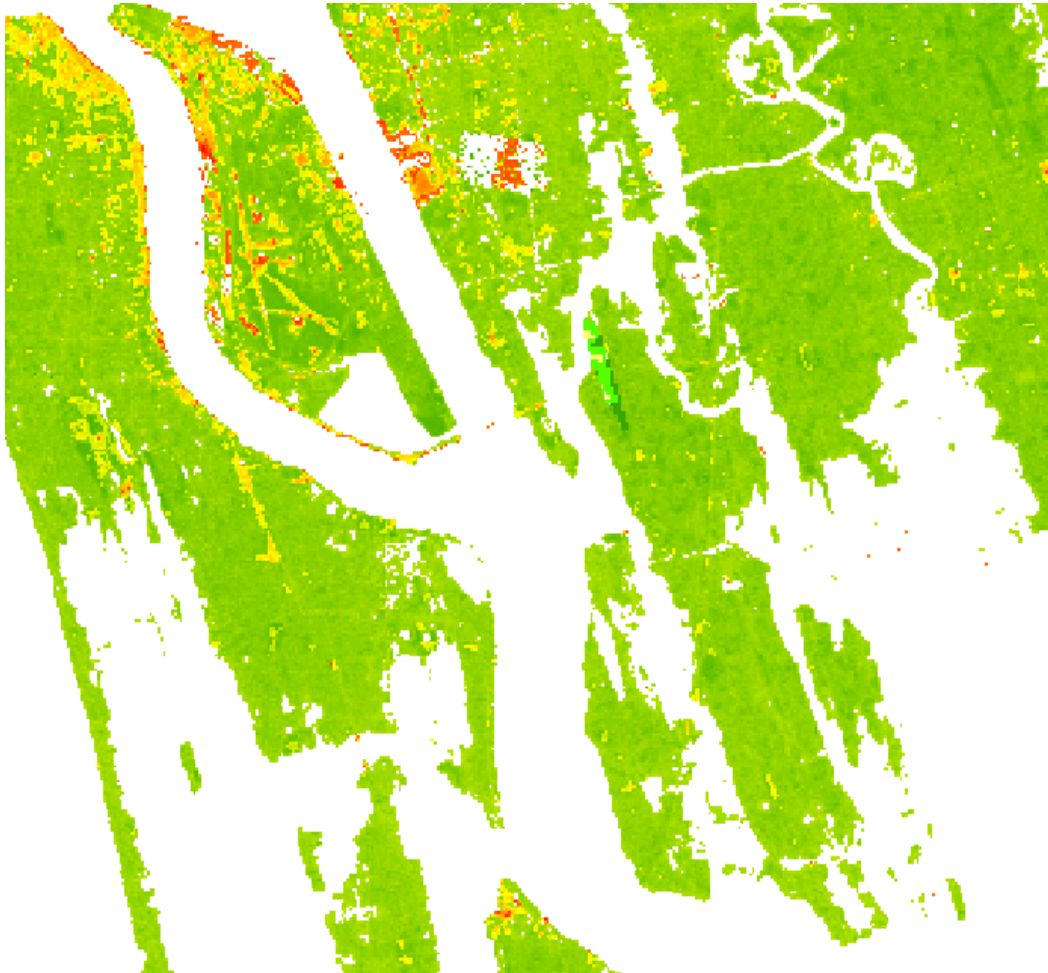


Figure 7: NDVI DIFFERENCE BETWEEN TWO YEARS

4.2.10 C

This is done in order to convert a raster dataset to point features. For each cell of the dataset, a point will be created in the output feature class. The points will be positioned at the centers of cells that they represent.

- Selected Conversion tools from ArcToolBox.
- Chosen 'From Raster' option from Conversion tools and then opted 'Raster to Point'.
- Inputted the NDVI Difference file and given an appropriate output file. Then OK was selected.

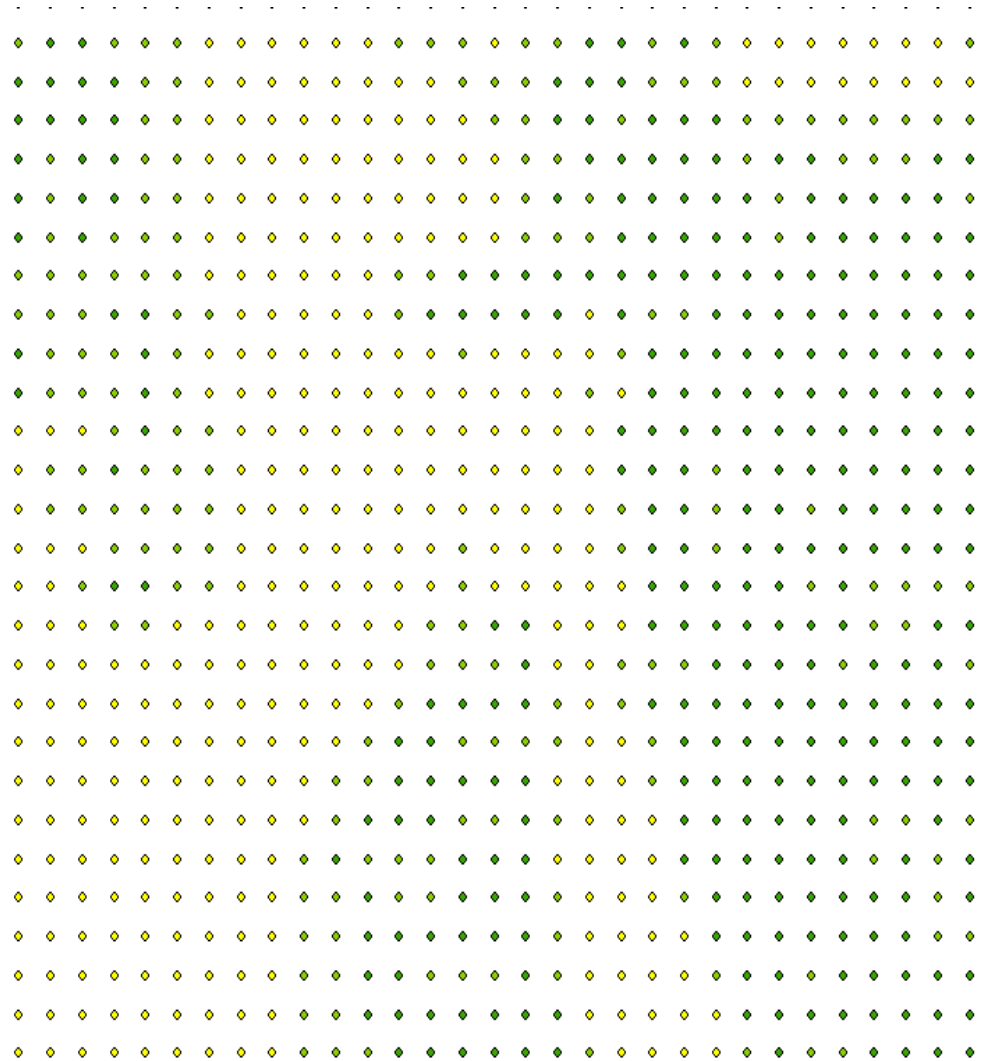


Figure 8: CONVERSION OF RASTER TO POINT

4.2.11 Classification using Index

Different classes were assigned to different range of grid_ code.

Table 1: Classification of Mangroves based on grid_ code

Range	Class
grid_ code > 0.3	Class 1 (Densely increased)
grid_ code < = 0.3 & grid_ code > 0.1	Class 2 (Sparsely increased)

grid_code ≤ 0.1 & grid_code > -0.1	Class 3 (No vegetation)
grid_code > -0.3 & grid_code ≤ -0.1	Class 4 (Densely decreased)
grid_code ≤ -0.3	Class 5 (Sparsely decreased)

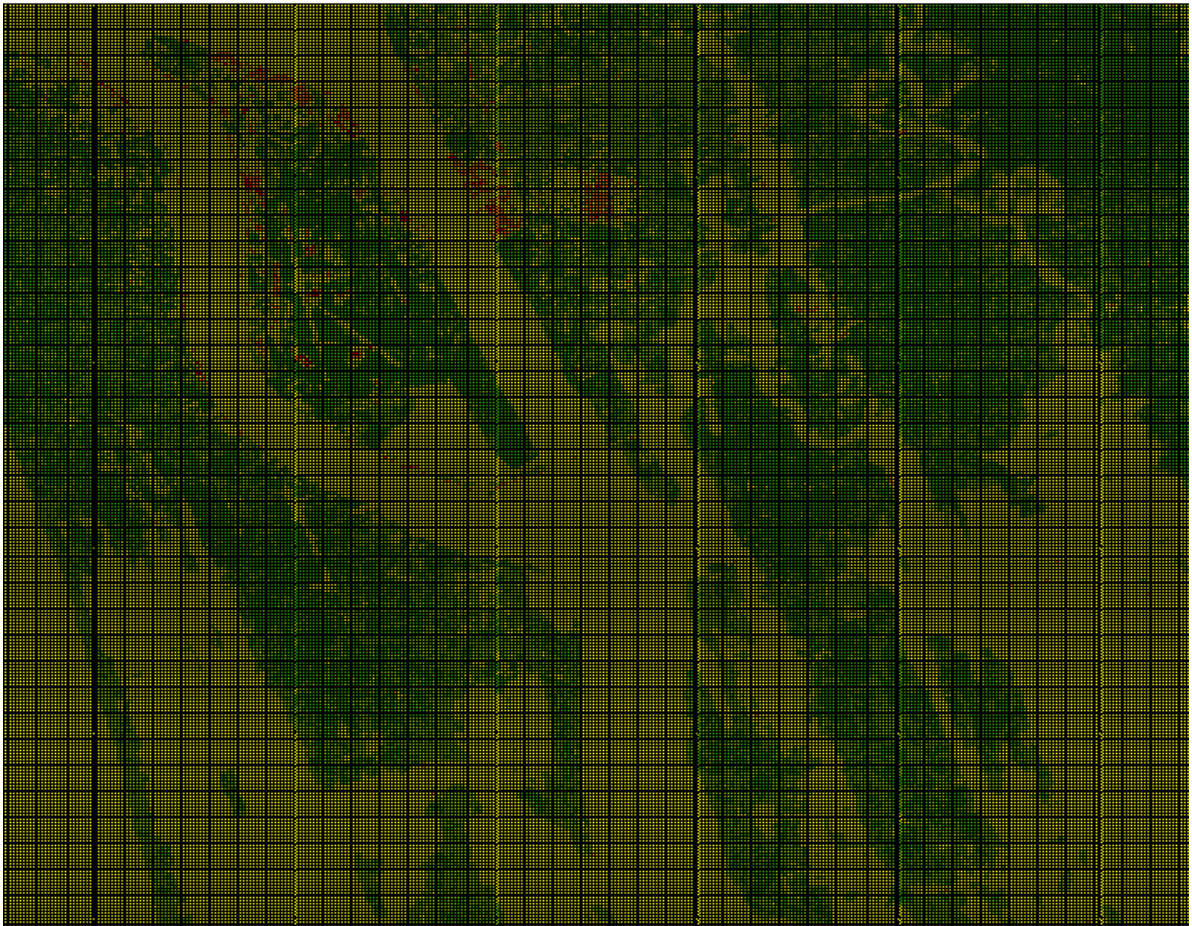


Figure 9: CLASSIFICATION

4.2.12 Interpolation

- Selected Interpolation option from ‘Spatial Analyst Tools’ of ArcToolBox.
- Chosen ‘Kriging’ and then inputted point features.
- Class was chosen as the Zvalue field.
- After giving the appropriate output raster, clicked OK.

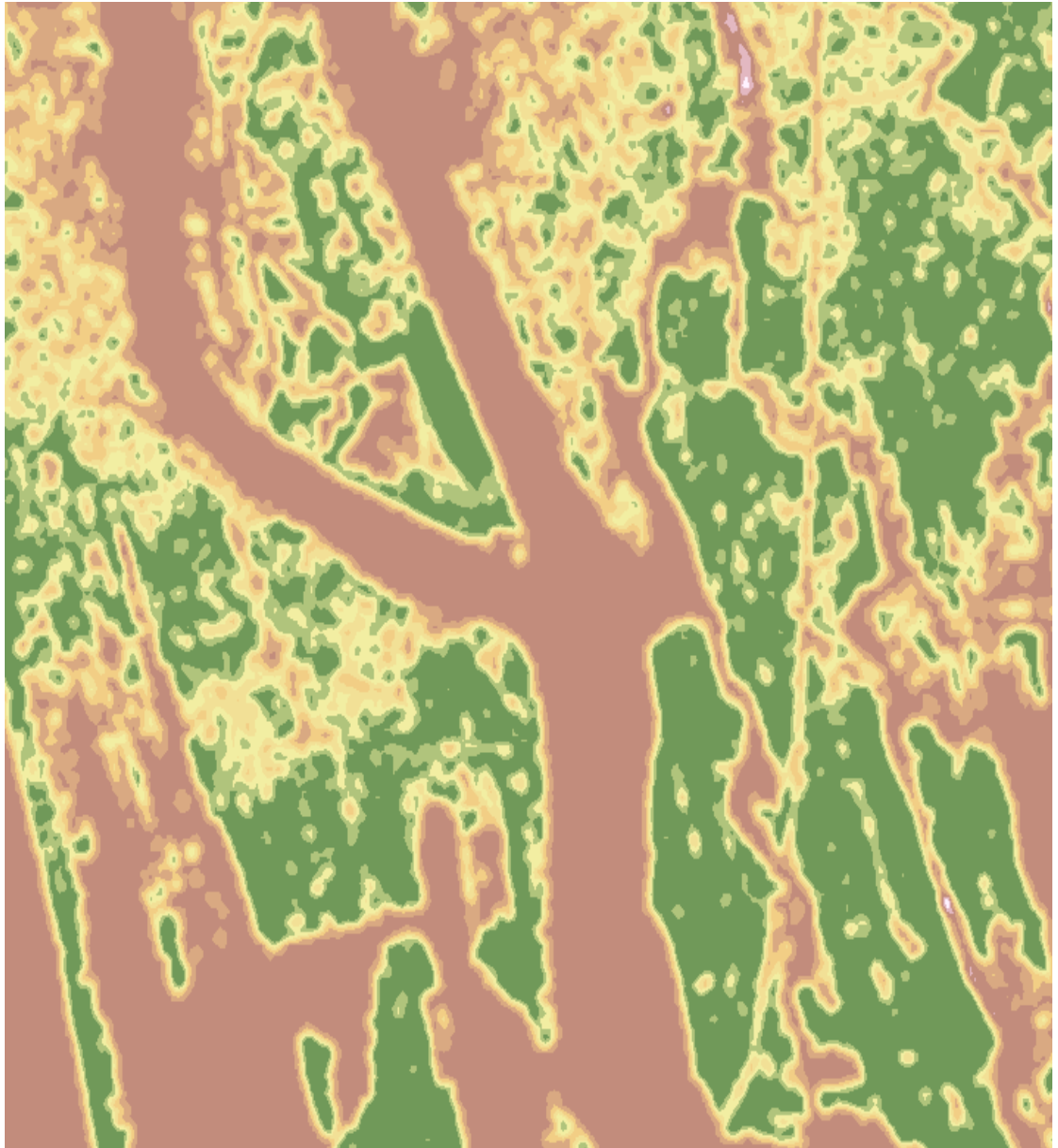


Figure 10: KRIGING

4.2.13 Conversion to Integer

- 'Math' option was chosen from 'Spatial Analyst Tools' of ArcToolBox.
- Opted 'Int' tool from the set of tools displayed on Math.
- Inputted appropriate file and then clicked OK.

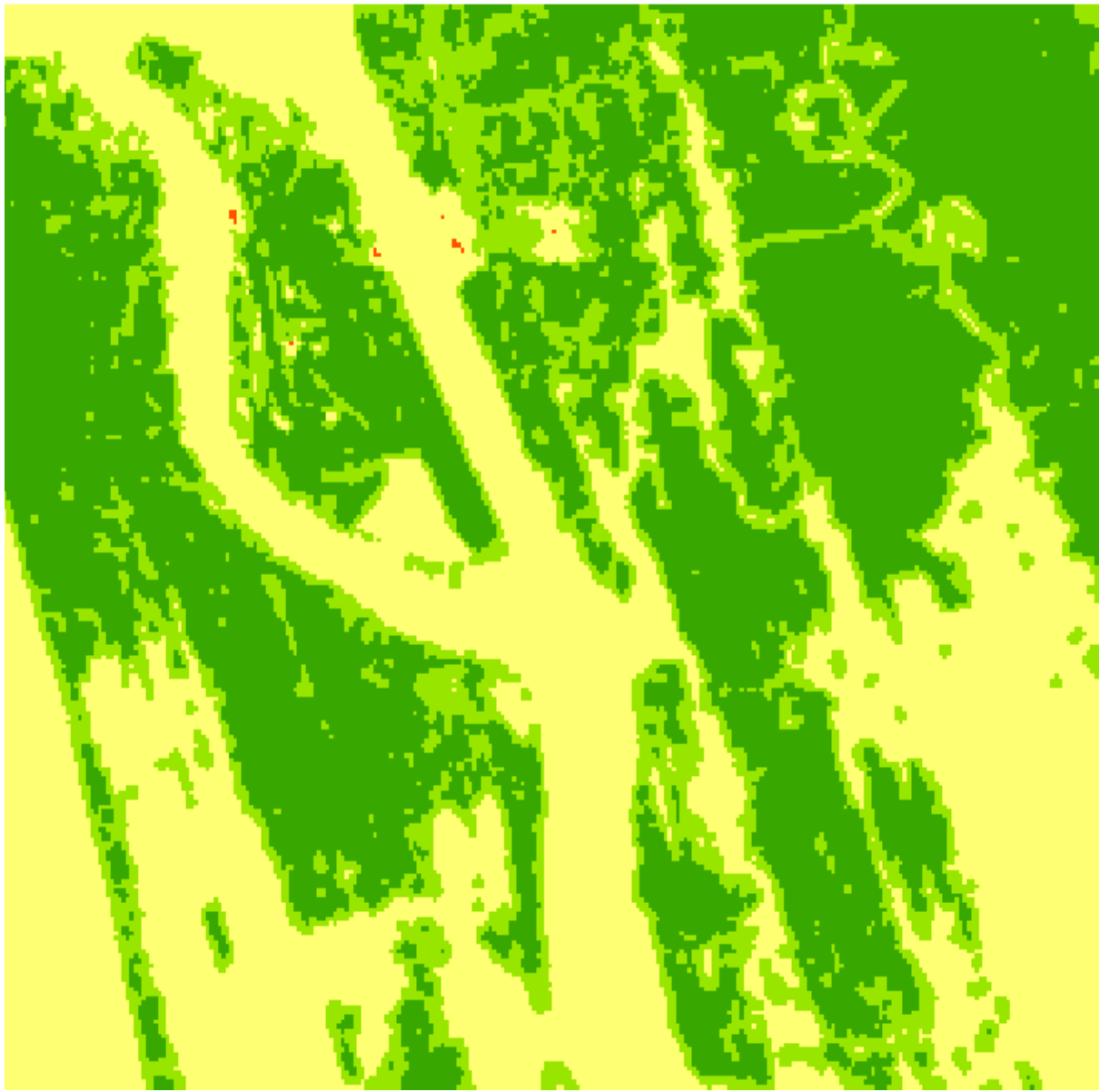


Figure 11: CONVERSION TO INTEGER

4.2.14 Conversion of Raster to Polygon

- Selected Conversion tools from ArcToolBox.
- Chosen 'From Raster' option from Conversion tools and then opted 'Raster to Polygon'.
- Inputted the Integer file and given appropriate output file. Then selected OK.

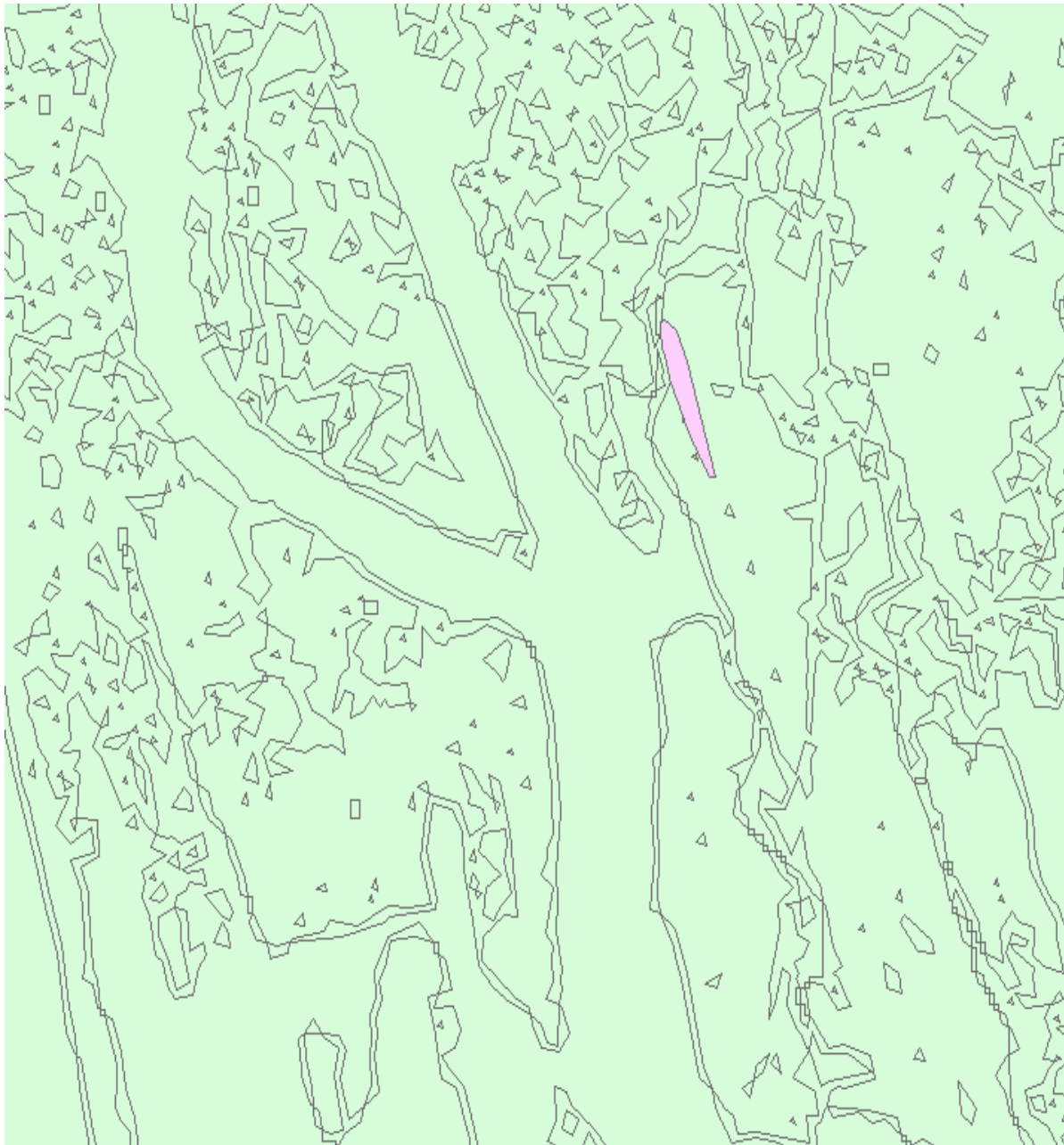


Figure 12: CONVERSION OF RASTER TO POLYGON

4.2.15 Extraction of Study Region

- Chosen ‘Spatial Analyst Tools’ option from ArcToolbox.
- ‘Extraction’ tool was opted and then selected ‘Extract by Mask’ option.
- Inputted the shape file created before and then given appropriate output file.

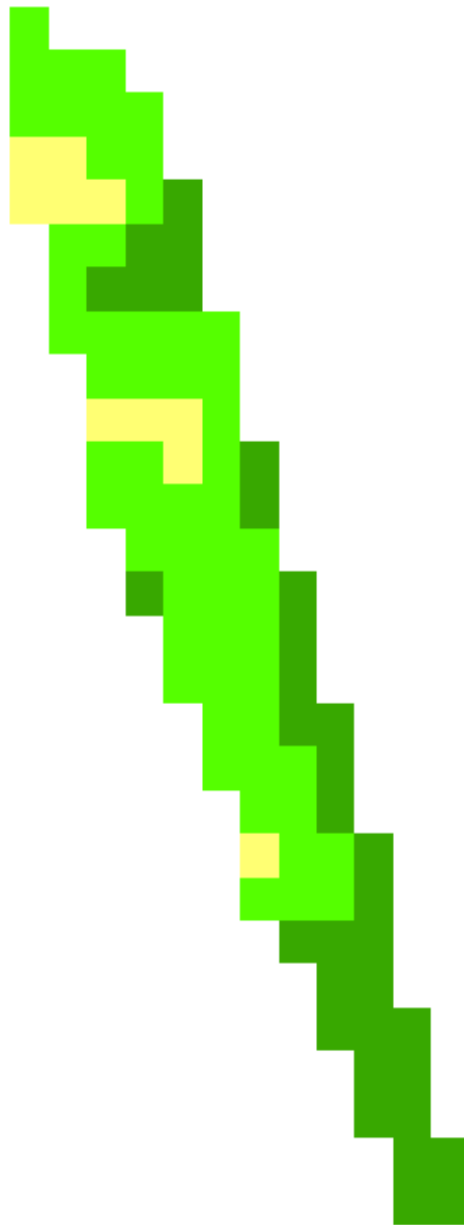


Figure 13: EXTRACTION OF STUDY REGION

Chapter 5

RESULTS AND DISCUSSION

Present study was dealt with analysing the vegetation change in Nettoor Mangroves over the years 1992-2019. Lack of knowledge and high degree of ignorance among people caused prominent loss to the thick and lush mangrove forest of Nettoor. Climatic changes and human activities had diminished the beauty of these mangroves. The variation in Nettoor Mangrove vegetation from 1992-2019 is as follows:

Table 2: Percentage of the changes occurred during the years

Year	Densely Increased	Sparsely Increased	No Vegetation Change	Densely Decreased	Sparsely Decreased
1992-1997	34%	56%	10%	0%	0%
1997-2001	0%	2%	63%	24%	11%
2001-2008	86%	14%	0%	0%	0%
2008-2014	0%	0%	21%	78%	1%
2014-2019	69%	31%	0%	0%	0%

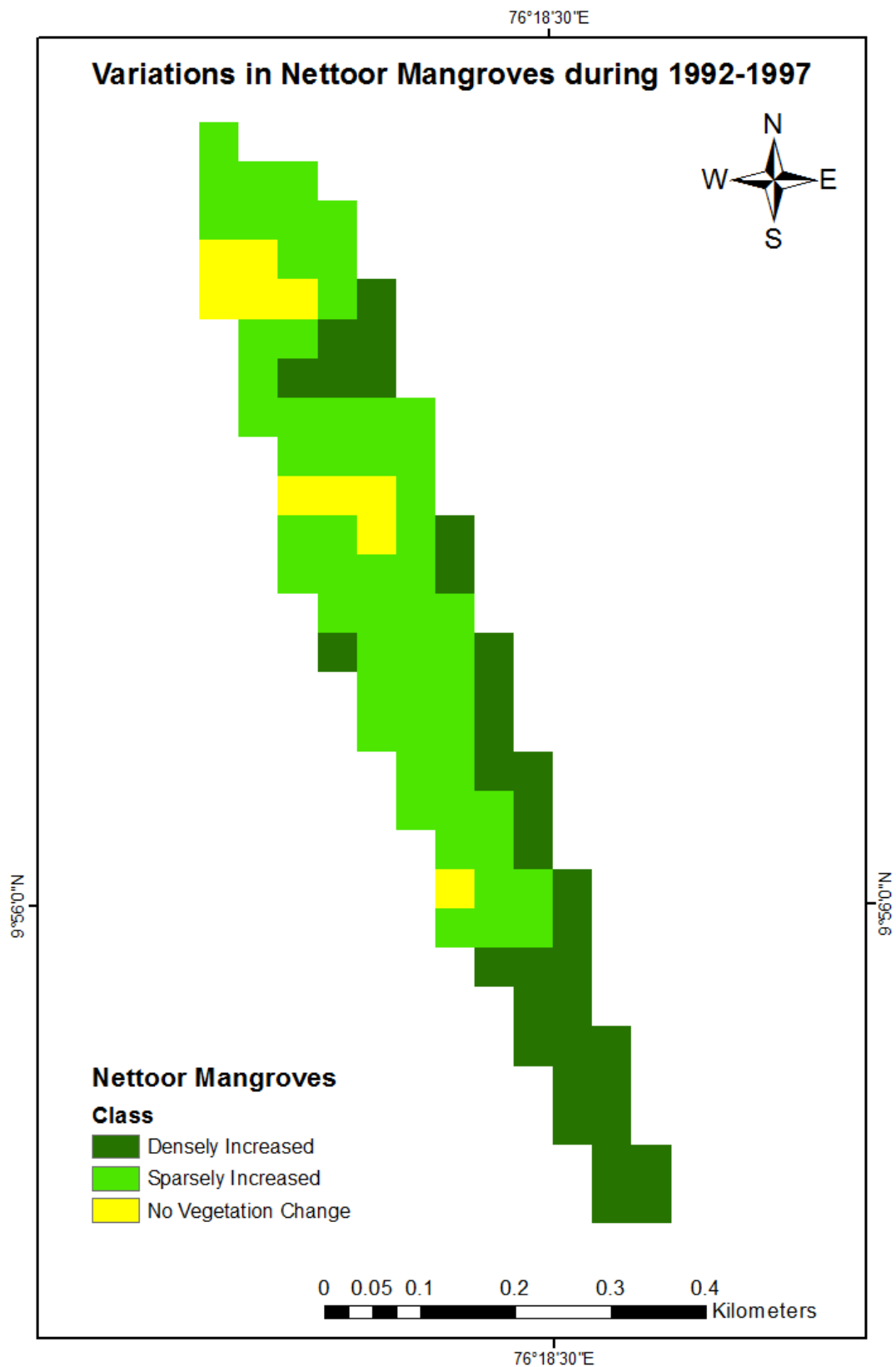


Figure 14: Variation of Nettoor Mangroves during 1992-1997

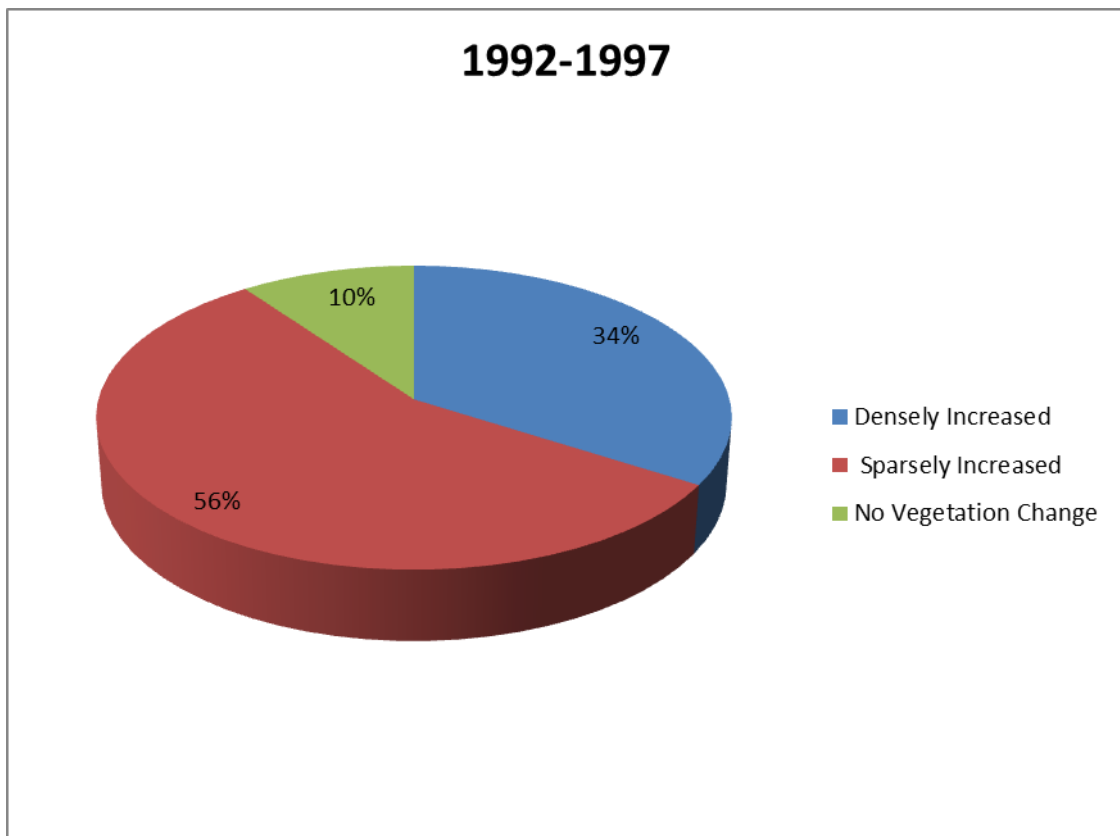


Figure 15: Pie chart showing the variation of each class during 1992-1997

There was a dense increase in Nettoor Mangroves for about 56% of the total area during 1992-1997. 1992 was marked as a ‘WET year’ in Kerala (Prakash, 2004) due to the reason that Kerala was blessed with abundant rainfall. This might be the accelerating factor for the increment in vegetation cover. Moreover as human intrusion was not found in this area during that time period, this had also acted as a protection cover to mangroves within their natural ecosystem.

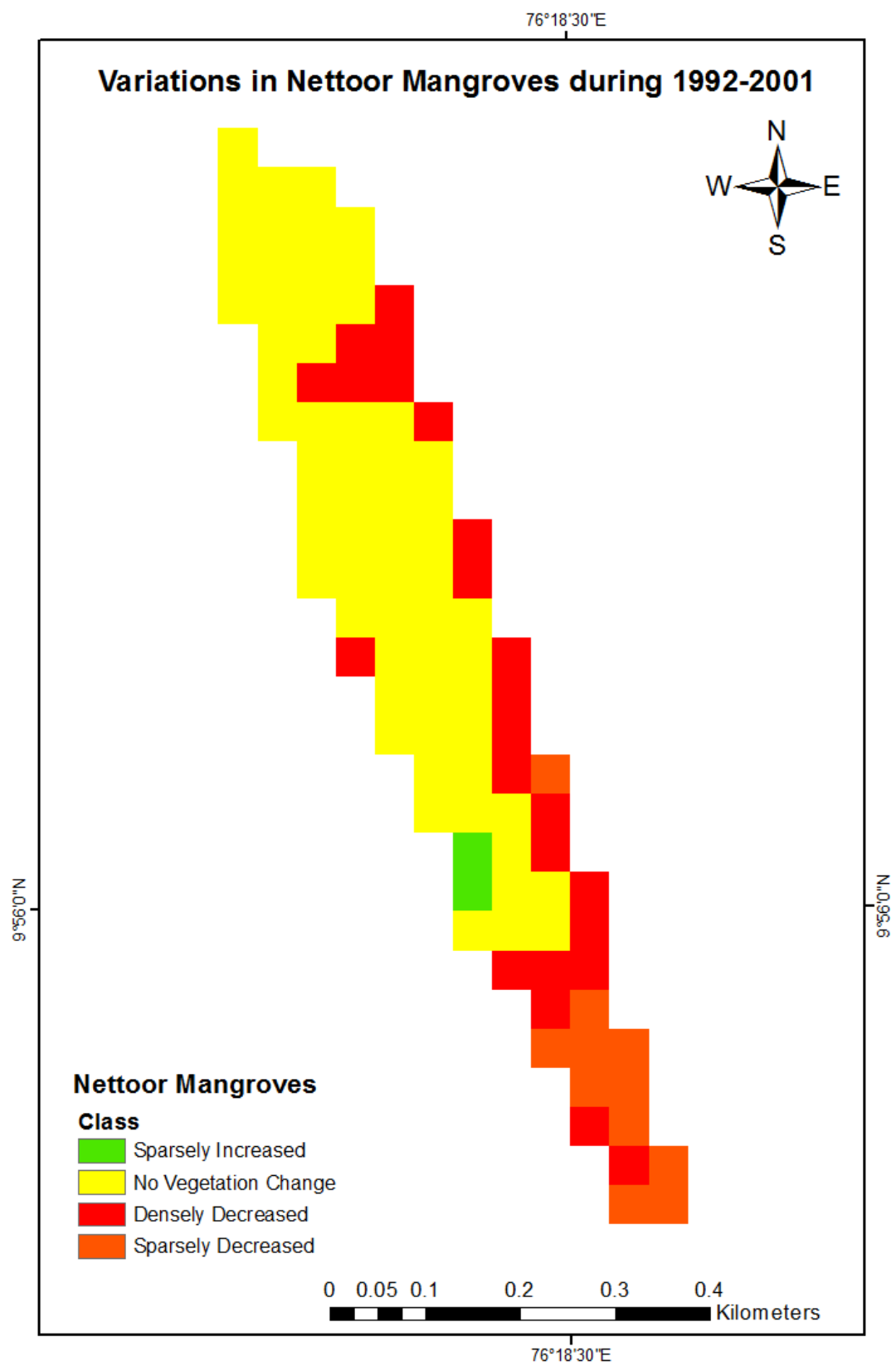


Figure 16: Variation of Nettoor Mangroves during 1997-2001

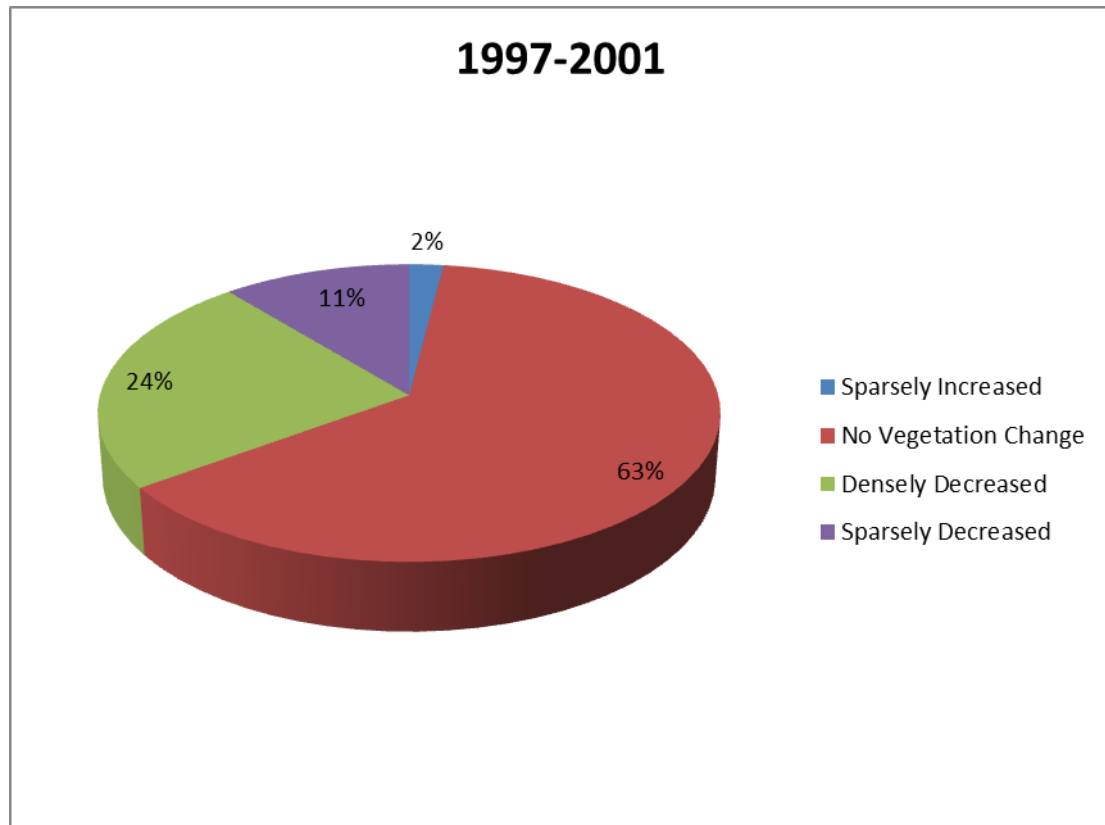


Figure 17: Pie chart showing the variation of each class during 1997-2001

A considerable loss in mangrove vegetation can be noted during the years 1997 to 2001. Dense decrease of about 24% in the mangrove cover might be due to the decrease in precipitation from 1997-1999(Narayana, 2006). Infrastructure development had caused great havoc to the mangroves present here. The national highway bypass and the Alappuzha railway tract traverse through mangrove patches. All this area is under the pressure of landfilling, and construction of human settlements.

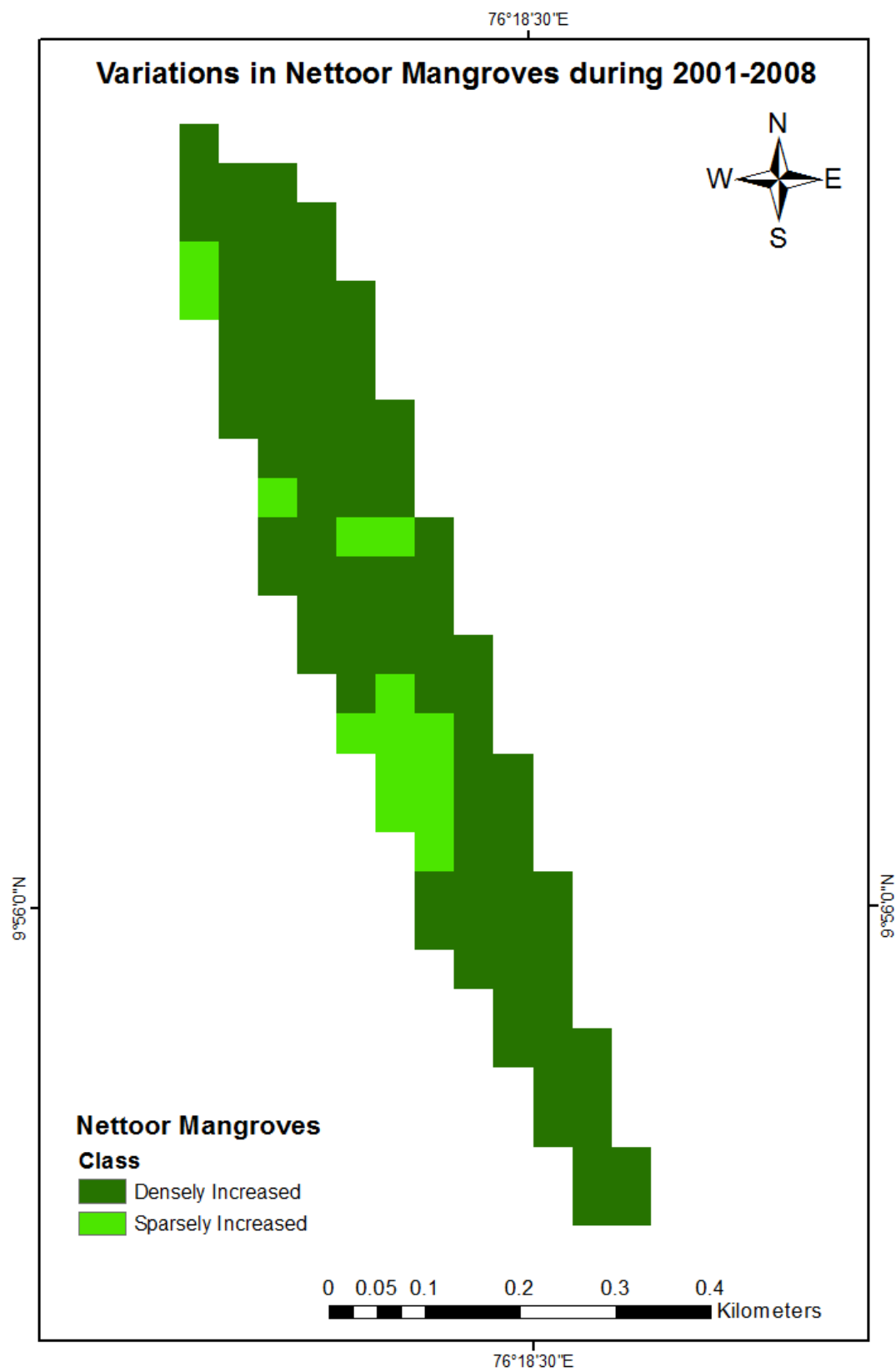


Figure 18: Variation of Nettoor Mangroves during 2001-2008

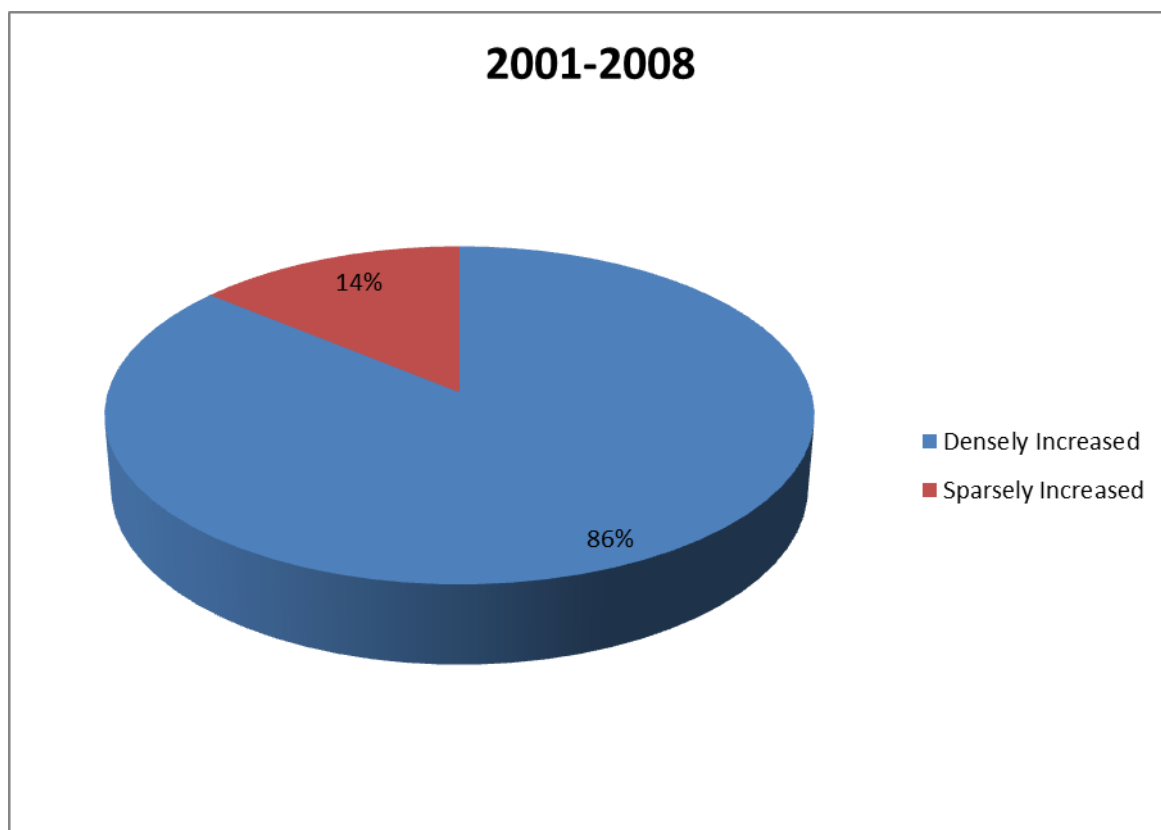


Figure 19: Pie chart showing the variation of each class during 2001-2008

During 2001 to 2008, there was a profuse increase in the cover of Nettoor Mangroves. The highest increase in mangrove vegetation was seen during this time period. The abundant rainfall that Kerala had received during three consecutive years 2005, 2006 and 2007 than its normal rainfall had multiplied the vegetation of Nettoor mangroves. Kerala was blessed with 3151 mm, 3297.7 mm and 3919.5 mm of rainfall during the years 2005, 2006 and 2007 respectively (Meteorological_Subdivision-wise_Annual_Rainfall_2002-2011).

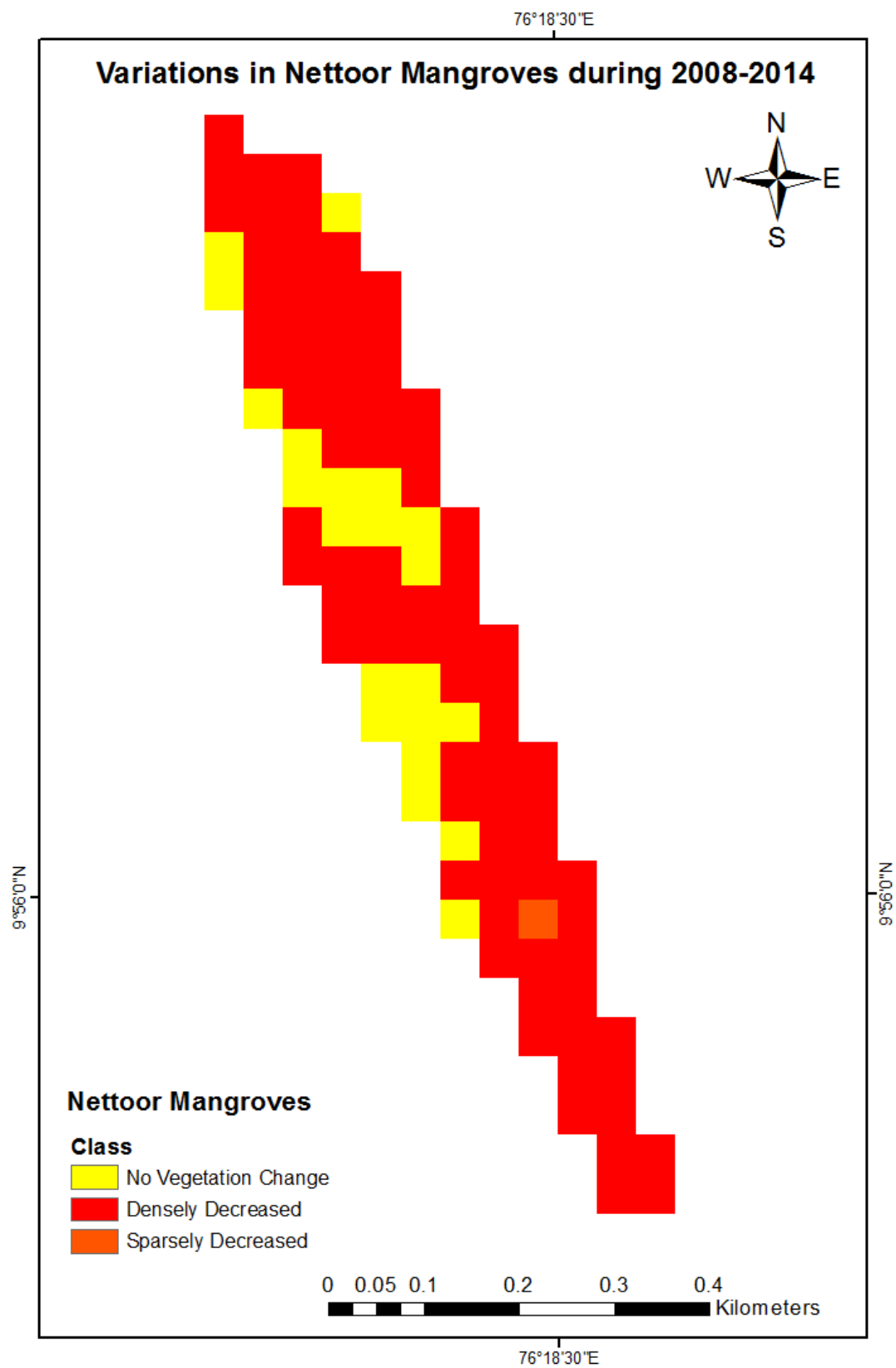


Figure 20: Variation of Nettoor Mangroves during 2008-2014

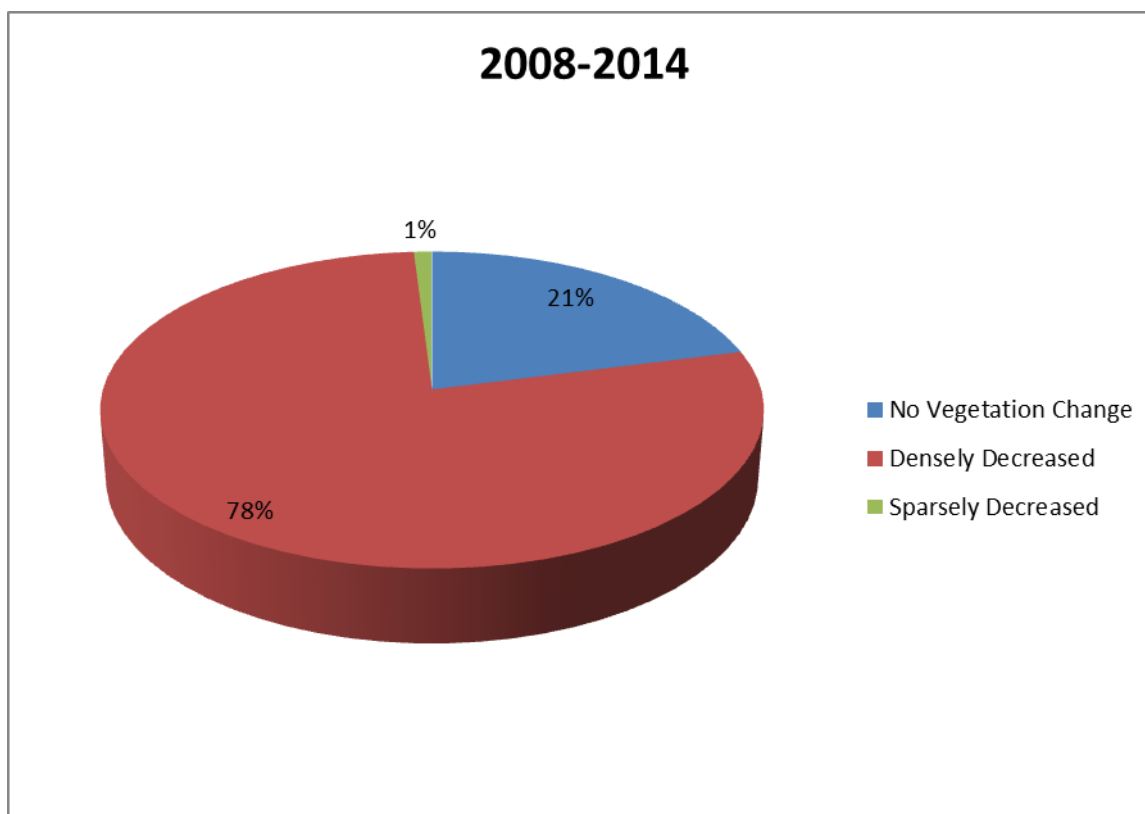


Figure 21: Pie chart showing the variation of each class during 2008-2014

A huge loss of mangrove ecosystem can be noticed during 2008 to 2014. Mangrove ecosystem showed 78 percent densely decrease in 2014 compared to 2008. This loss can be attributed to the climate change and intervention of local people residing there. Overharvesting of the mangrove forest for firewood, animal fodder, construction wood etc... by the local people had accelerated decrease in vegetation. The deficiency in precipitation in the year 2012 has also contributed to the dwindling of Nettoor mangroves. During 2012 South West monsoon, Kerala had received an actual rainfall of 1551.3 mm which was -24 percent deficient than the normal rainfall(ENVIS Centre, Kerala).

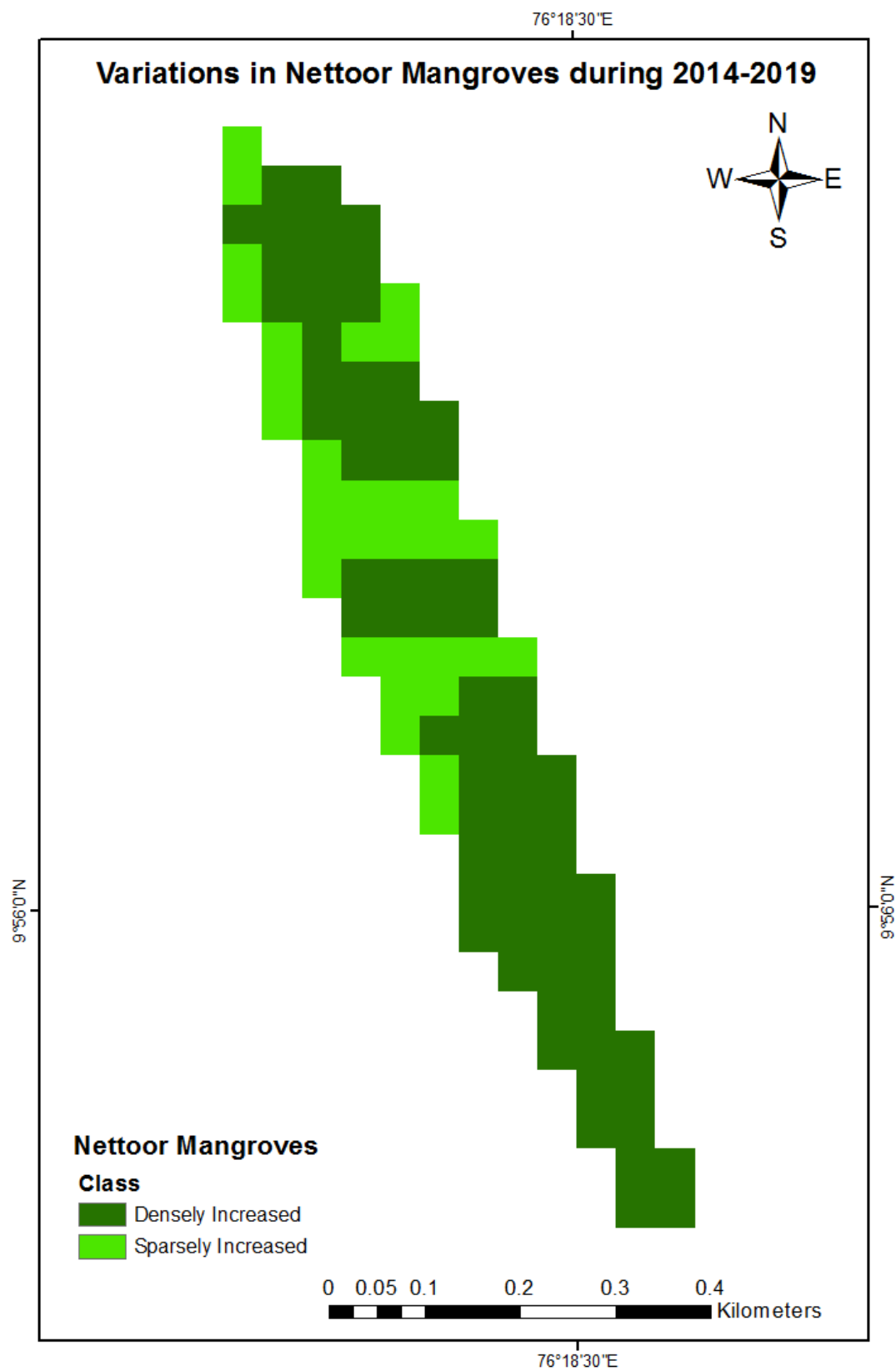


Figure 22: Variation of Nettoor Mangroves during 2014-2019

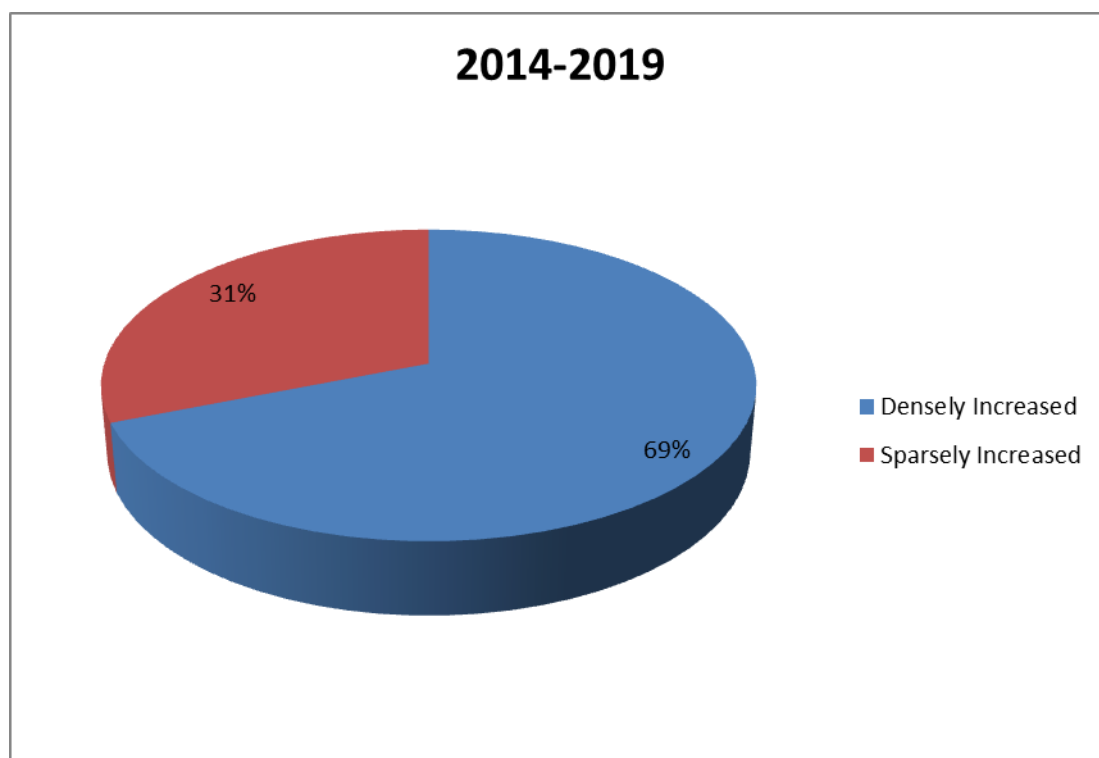


Figure 23: Pie chart showing the variation of each class during 2014-2019

There was an increase in the Nettoor mangrove vegetation during 2014 to 2019. There was 69 percent dense increase and 31 percent sparse increase in Nettoor mangrove vegetation over the years 2014 to 2019. This might be due to the heavy rainfall received in Kerala during the years 2018 and 2019. The actual rainfall received in Kerala during southwest monsoon season (June 1 to September 30, 2018) was 2,515.7 mm as against the normal rainfall of 2,039.7 mm showing (+)23 per cent departure from normal(ENVIS Centre, Kerala).

Table 3: Area of extent of Nettoor Mangroves of each class in km²

Year	Densely Increased	Sparsely Increased	No Vegetation Change	Densely Decreased	Sparsely Decreased
1992-1997	0.06 km ²	0.09 km ²	0.01 km ²	-	-
1997-2001	-	0.003 km ²	0.10 km ²	0.04 km ²	0.02 km ²
2001-2008	0.14 km ²	0.02 km ²	-	-	-
2008-2014	-	-	0.03 km ²	0.13 km ²	0.001 km ²
2014-2019	0.11 km ²	0.05 km ²	-	-	-

Total area of study region was calculated and found to be 0.16794 km². The highest increase of Nettoor Mangroves was seen during the period of 2001-2008 with an increment of about 0.14 km². The plentiful precipitation that Kerala had received during 2005, 2006 and 2007 had expanded the vegetation of Nettoor mangroves. The highest decrease in the extent of Mangroves had been seen during the period of 2008-2014. There was a dense decrease of about 0.13 km² in the mangrove vegetation during this period. Increase in human settlements that happened nearby the Nettoor mangroves was a contributing factor to the shrink in vegetation as overharvesting of the mangrove ecosystem took place. The decrease in precipitation during 2012 had also accelerated the curtailment of vegetation cover.

Chapter 6

CONCLUSION

Mangroves act as barriers in protecting the shoreline from storm, hurricane and winds. The varied satellite-derived indices like Normalized Difference Vegetation Index (NDVI) and Ratio of NIR & Red wavelengths can be effectively used to monitor the vegetation status and condition of the mangrove ecosystem. NDVI (Normalized Difference Vegetation Index) is the absorption within the red spectrum and reflectance in near infra-red. Healthy vegetation reflects more near-infrared and green light, but absorbs more red and blue light. From this study it is obvious that there is an alarming decrease in the extent of Nettoor Mangroves from 1992 to 2019 due to infrastructure development, human intervention and climatic changes. Various studies and analysis have been done in this area before but it will remain the same unless and until we are ready to initiate steps to protect this area. High degree of ignorance had caused great destruction of mangroves in this area. The results of this study strengthen the need to preserve Nettoor Mangroves and restore those degraded to guarantee the provision of goods and services needed to support the biodiversity and functioning of wide portions of the ecosystem. Unless and until we are ready to take steps to conserve this area, it will remain the same.

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