Report for end-semester evaluation of CE 499 course

Detecting Ecological Changes with Remote Sensing based Ecological Index (RSEI)

Submitted

By

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CERTIFICATE

It is certified that the work contained in the project report entitled "**Detecting Ecological Changes with Remote Sensing based Ecological Index (RSEI)**", by **Debanshi Mishra** (180104028) has been carried out under my/our supervision and that this work has not been submitted elsewhere for the award of a degree or diploma.

Date: 04-05-2022

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DECLARATION

I Ms. Debanshi Mishra (180104028) hereby declare that the comments and suggestions received during BTP evaluation/examination are duly incorporated at suitable places in this report in consultation with my supervisor(s).

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ABSTRACT

Increasing human activities have caused significant global ecosystem disturbances at various scales. There is an increasing need for effective techniques to quantify and detect ecological changes.

Ecology involves the investigation of organisms and their environmental setting. Generally, such investigation requires spatially explicit data, given the basic need for knowledge about the location and distribution of species. The traditional means of collecting ecological data is through manual, field-based observation. This approach has the benefit of generating highly accurate measurements but, because of its labor-intensive nature, it is generally impractical for anything other than local-scale studies.

The implications of ecological analysis, however, extend well beyond the local scale and there is considerable need for and interest in, ecological investigation at wider spatial scales, from the landscape to the entire globe. Consequently, remote sensing has become common in much ecological investigation, providing the only realistic, cost-effective means of acquiring data over large areas. Recent developments in technology and modelling techniques mean that remote sensing is in a stronger position than ever to benefit ecology.

ACKNOWLEDGEMENT

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Debanshi Mishra

Date: 04-05-2022 Signature of the student

Debanshi Mishra

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Chapter 1

Introduction

1.1 Motivation

Human health and existence are inextricably linked to the natural environment. There have been major global ecosystem disturbances at various scales as a result of increased human activities such as urbanisation and industrialization. Human activities have resulted in a huge expansion in the area inhabited by natural landscapes, causing ecological disruptions on various scales and having a significant impact on the global carbon cycle, putting the world's ecosystems under unprecedented stress. Ecosystem deterioration and transition have a negative impact on urban construction and the global climate, limiting national, regional, and global economic development.

Traditional discrete point sampling is difficult to suit the needs of large-scale and high dynamic ecological monitoring because human-induced ecological disturbances fluctuate substantially in duration, intensity, and area. As a result, finding a quick, effective, and accurate monitoring method for environmental quality is becoming increasingly important. Ecosystem disturbances on a large scale have a significant impact on the global carbon cycle and can exacerbate global climate change. Human-induced ecological disturbances occur over a wide range of distances, magnitudes, and durations, and hence must be carefully monitored and quantified. Because the pace of change in land use and land cover is quicker than the ecosystem's self-regulation speed, there is an increasing need for effective ways to quantify and identify ecological changes. This is putting huge pressure on and destroying the ecological environment.

Remote sensing technology can obtain different components of large-area near-surface ecosystems, such as vegetation, moisture, temperature, and soil, by measuring surface reflectance and radiation values. As a result, remote sensing has become increasingly popular in environmental research and management. Previously, researchers used variables such as atmosphere, precipitation, climate, and land use to undertake a qualitative assessment of area eco-environmental quality. Some remote sensing indices were constructed to quantify a variety of eco-environmental attributes such as vegetation covering, land adaptability, and urban heat island to eliminate the influence of subjective elements in qualitative investigations.

1.2 Objective

The goal is to examine a location's ecological changes through time by first assigning an ecological index to each year and then studying it. Greenness, wetness, dryness, and heat are used as indicators, and they are combined into a single data point using principal component analysis (PCA). Then we must look at RSEI's seasonal variability and how it affects the assessment. We may use this to assess whether or not there has been any environmental deterioration and take the required steps to mitigate it.

1.3 Thesis Outline

The report consists of four chapters, with the following titles:

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Methodology

Chapter 4: Summary and Future Scope of Work

Chapter 2

Literature Review

2.1 Ecological indicators

To assess the state of ecosystem health, a number of ecological indicators have been proposed. For instances, the Normalized Difference Vegetation Index (NDVI) or leaf area index were used to monitor environmental change; land surface temperature (LST) was adopted to assess the urban heat island effects; the normalized difference built-up index (NDBI), an index-based built-up index (IBI) and the normalized difference impervious surface index (NDISI) were applied to delineate the built-up and impervious surface area; the normalized difference water index (NDWI) and the modified NDWI (MNDWI) were used to extract water bodies; NDVI and LST were applied to monitor drought or soil moisture; a bare-soil index (BI) and dry bare-soil index (DBSI) was employed to map bare soil areas. Due to the complexity and diversity of the influence variables, using simply one or two ecological indicators to assess the state of the ecosystem is insufficient.

2.2 Remote Sensing Based Ecological Index

The practice of identifying and monitoring an area's physical features by measuring its reflected and emitted radiation from a distance is known as remote sensing (typically, from satellite or aircraft).

RSEI is a newly designed aggregated index that uses remotely sensed data to quickly detect ecological conditions. The method's features include the incorporation of four ecological indicators into the model's conceptual framework and the use of Principal Components Analysis to integrate the four indicators. This type of RSEI can be used to determine the state of the environment. Higher vegetation coverage, higher soil-plant moisture, lower summer temperature, and less surface dryness are the most desired ecological circumstances, according to RSEI's indicators.

2.2.1 Components of RSEI

Greenness (representing vegetation), moisture (representing soil moisture), heat (representing temperature), and dryness (representing built area) are the four indicators used in RSEI, and they are frequently used in assessing ecological status because the four indicators are highly correlated with ecological status and can be directly perceived by people. Any ecological changes will have a substantial impact on these four fundamental properties of land surfaces, according to the RSEI paradigm.

NDVI represents the greenness indicator and is employed to manifest the environmental state in RSEI model. The wet component came from Tasseled Cap transformation stands for wetness and LST represents heat indicators, which are selected as indicators of the local climate changes in response to environmental changes in the RSEI model. NDBSI is the indicator of dryness which is adopted to indicate the pressures generated from human activities on the environment in the PSR model. Thus, the expression of RSEI can be rewritten as:

$$RSEI = f(NDVI, NDMI, LST, NDBSI)$$

2.2.1.1 Vegetation

NDVI is widely employed to indicate vegetation growth and coverage status, which can be expressed as:

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}}$$

Where ρ_{nir} and ρ_{red} represent the reflectance of the nearly infrared and red bands, respectively.

2.2.1.2 Land Surface Temperature

LST is an important metric frequently used to investigate ecological processes and climate change, as well as to study drought, evapotranspiration, vegetation density and surface energy balance. It can be evaluated as follows:

$$LST = \frac{T_{sensor}}{[1 + \left(\lambda \times \frac{T_{sensor}}{\rho}\right) \ln \varepsilon]}$$

where λ is the wavelength of the emitted radiance (11.435µm for Landsat 5/7 and 10.9µm for band 10 of Landsat 8); ρ is a constant (1.438×10^{-2} m K); ε is the land surface emissivity, which can be expressed as:

$$\varepsilon = \begin{cases} 0.995 & NDVI \leq 0 \\ 0.970 & 0 < NDVI \leq 0.157 \\ 1.0094 + 0.047 \ln NDVI & 0.157 < NDVI \leq 0.727 \\ 0.986 & x > 0.727 \end{cases}$$

T_{sensor} is the at-satellite brightness temperature in Kelvin and can be computed as follows:

$$T_{sensor} = \frac{K_2}{\ln(K_1/L_\lambda + 1)}$$

$$L_\lambda = Gain \times DN + Bias$$

where L_λ is the at-sensor spectral radiance. Gain and Bias are the band-specific multiplicative rescaling factor and the band-specific additive rescaling factor, respectively, which are available in the head file of the used image. DN represents the digital number of a given pixel. K1 and K2 are calibration coefficients for TM/ETM+/OLI sensor thermal band.

2.2.1.3 Moisture

Moisture was calculated by the wet component of a Tasseled Cap Transformation to represent soil moisture as the component was designed to understand important attributes of soil and plant moistures. The predominant attribute exhibited in the wet component was determined to be the soil moisture state. A normalised difference moisture index (NDMI) is constructed by taking the ratio between the difference and sum of the refracted radiations in the near infrared (NIR) and SWIR.. It is expressed as follows:

$$NDMI = \frac{NIR - SWIR}{NIR + SWIR}$$

2.2.1.4 Dryness

As the urbanization and human activities, the build-up and naked soil have gradually replaced the natural surface of the ecosystem, causing the earth to be ‘dry’, and deteriorate of the environmental quality. A normalized difference built-up and soil index (NDBSI) is constructed to represent the dryness indicator, composed of index-based built-up index (IBI) and bare soil index (BI) and the formula is expressed is:

$$NDBSI = \frac{BI + IBI}{2}$$

where,

$$BI = [(\rho_{swir1} + \rho_{red}) - (\rho_{nir} + \rho_{blue})]/[(\rho_{swir1} + \rho_{red}) + (\rho_{nir} + \rho_{blue})]$$

$$IBI = \frac{\frac{2\rho_{swir1}}{\rho_{swir1} + \rho_{nir}} - \left(\frac{\rho_{nir}}{\rho_{nir} + \rho_{red}} + \frac{\rho_{green}}{\rho_{green} + \rho_{swir1}}\right)}{\frac{2\rho_{swir1}}{\rho_{swir1} + \rho_{nir}} + \left(\frac{\rho_{nir}}{\rho_{nir} + \rho_{red}} + \frac{\rho_{green}}{\rho_{green} + \rho_{swir1}}\right)}$$

2.2.2 Principal Component Analysis

PCA is a technique that is used to reduce the dimensionality of the dataset. By assigning weights to each of the feature, it creates a new uncorrelated variable such that variance is maximized.

2.2.3 Acquisition of RSEI

After calculating all four components, principal component analysis (PCA) method is used to combine the four metrics to form RSEI. It can allocate the weight of each factor according to the load of each factor to the principal components. The first component of PCA (PC1), usually explains more than 80% of the characteristics of the dataset, is employed to represent RSEI. Accordingly, initial RSEI, RSEI0, is represented by PC1:

$$RSEI_0 = PC1[f(NDVI, Wet, LST, NDBSI)]$$

The four metrics can be combined into a four-band image and then calculated with image analysis software's PCA function utilising the covariance matrix for PC1 (such as ENVI, MATLAB, etc.). Because the data range and unit of the four metrics are different, the values of the four metrics should be standardised between 0 and 1 before using PCA. If the $RSEI_o$, i.e., PC1, has low values for good ecological conditions and high values for bad ones, the $RSEI_o$ is subtracted from one to allow greater values to reflect better ecological status, as is frequently the case:

$$RSEI = 1 - RSEI_0 = 1 - PC1[f(NDVI, Wet, LST, NDBSI)]$$

As a result, the final RSEI has higher positive values, indicating that favourable ecological circumstances are more likely. RSEI was then standardised to a range of 0 to 1. This approach compares RSEI values on a standard scale of 0 to 1, with 1 denoting perfect ecological status and 0 denoting extremely bad ecological status.

This type of RSEI can be used to determine the state of the environment. Higher vegetation coverage, higher soil-plant moisture, lower summer temperature, and less land surface dryness are the most desired ecological circumstances, according to RSEI's indicators. Extremely bad ecological conditions can be found mostly in deserts and places of high soil erosion, which have little vegetation and are extremely hot and dry.

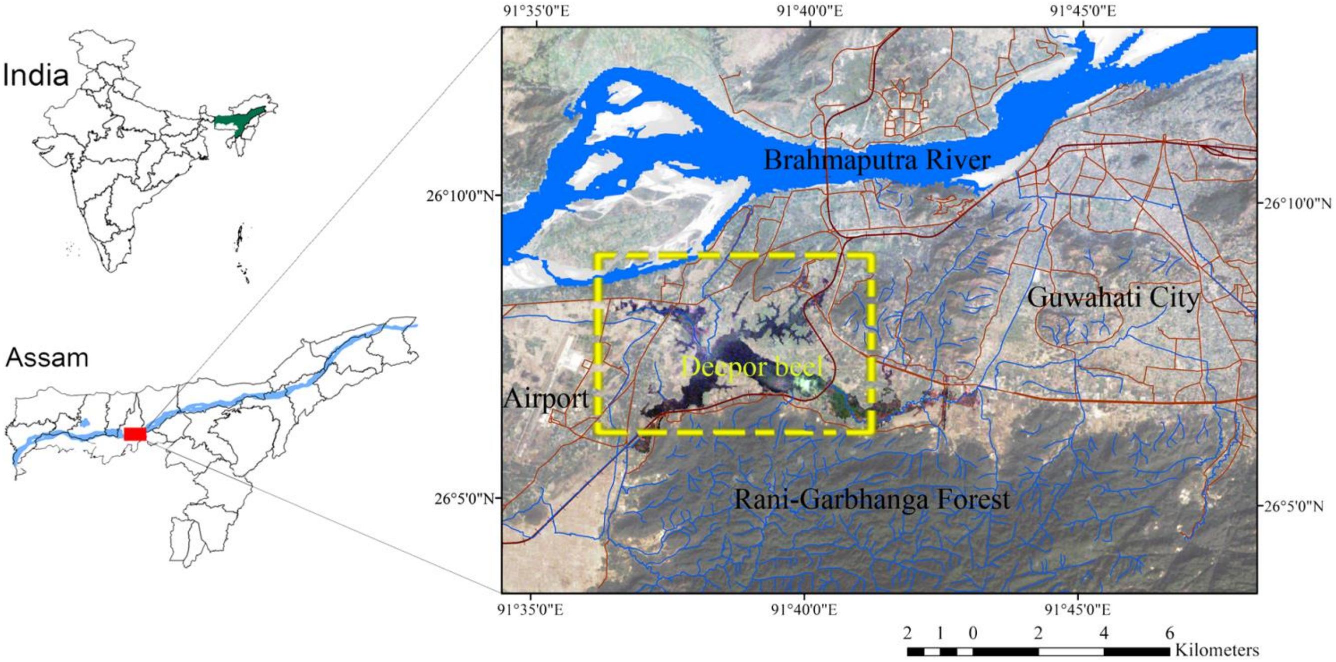
Chapter 3

Methodology

3.1 Study Area

Dipor Bil, a large storm water basin and ecological site in the Brahmaputra Valley in lower Assam, is the project's primary focus. It lies about 10 kilometres southwest of Guwahati City, the state's and region's main city, a significant metropolis in eastern India, and one of the country's fastest-growing cities. Jalukbari to the north and east, Rani and Garbhanga reserve forest to the south, and two tiny settlements, Azara and Kahkuchi, to the west, encircle Dipor Bil. One of the major causes of the wetland's isolation from the river Brahmaputra is National Highway 37, which travels through the north of the wetland on its way to the east. In addition, the national railway line cuts through the wetland towards its south east side, dividing it into two sections.

This wetland is known as the "Paradise of Birds" since it is home to a great variety of birds. Not only that, but during the rainy season, the lake is covered in a variety of aquatic flora, including water hyacinth, aquatic grasses, and other aquatic plants.



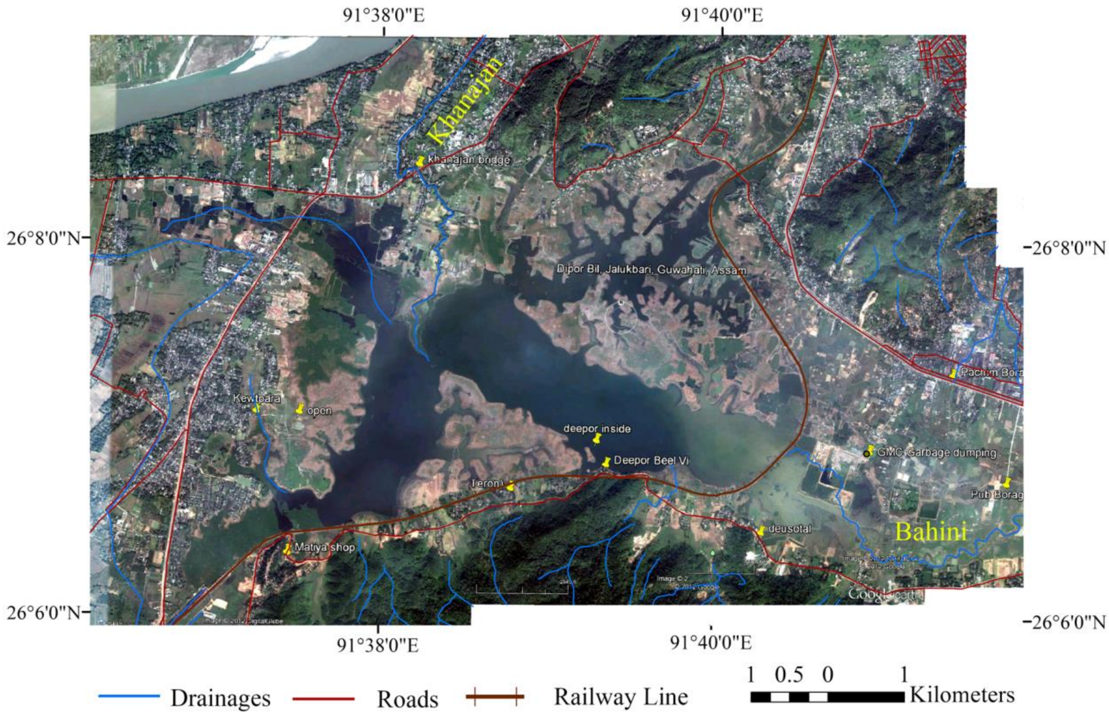


Fig 3.1 Location of Dipor Bil, Assam, India

3.2 Acquisition of Data

The Landsat-8 GeoTiff data as of 22nd Nov 2013, 9th Nov 2014, 30th Dec 2015, 16th Dec 2016, 3rd Dec 2017, 22nd Dec 2018, 9th Dec 2019, 27th Dec 2020 were taken from United States Geological Survey (USGS) to obtain RSEI maps over a period of 8 years. After this the four different indicators are calculated using the stated formulas and an areal mean was taken for the entire area.

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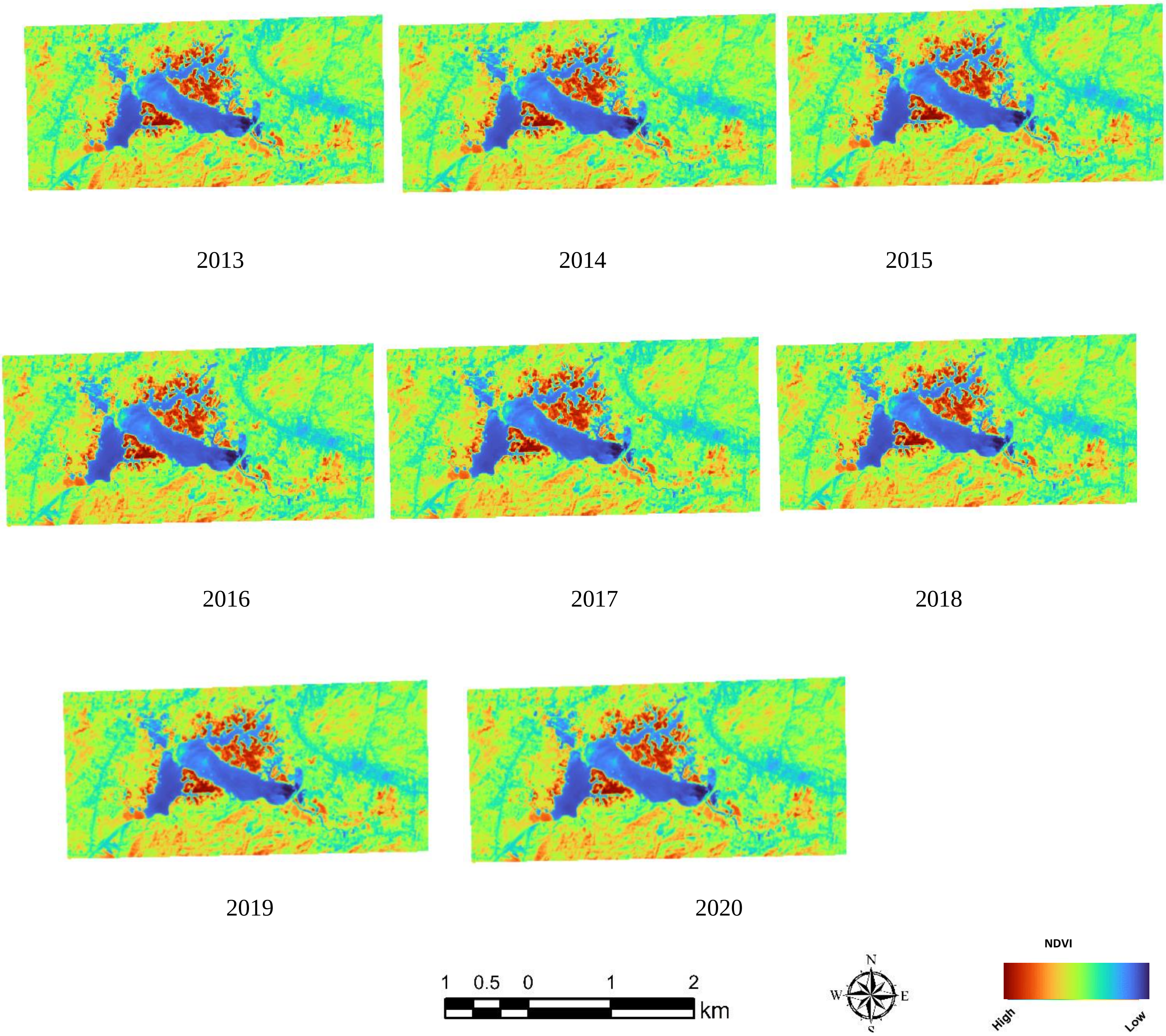

Fig 3.2 Variation of NDVI over the years of study

Table 3.1 Mean NDVI

	NDVI_Data
NDVI_2013	0.084045108
NDVI_2014	0.23519062
NDVI_2015	0.140316934
NDVI_2016	0.162437653
NDVI_2017	0.117265497
NDVI_2018	0.177642706
NDVI_2019	0.162594418
NDVI_2020	0.149886361

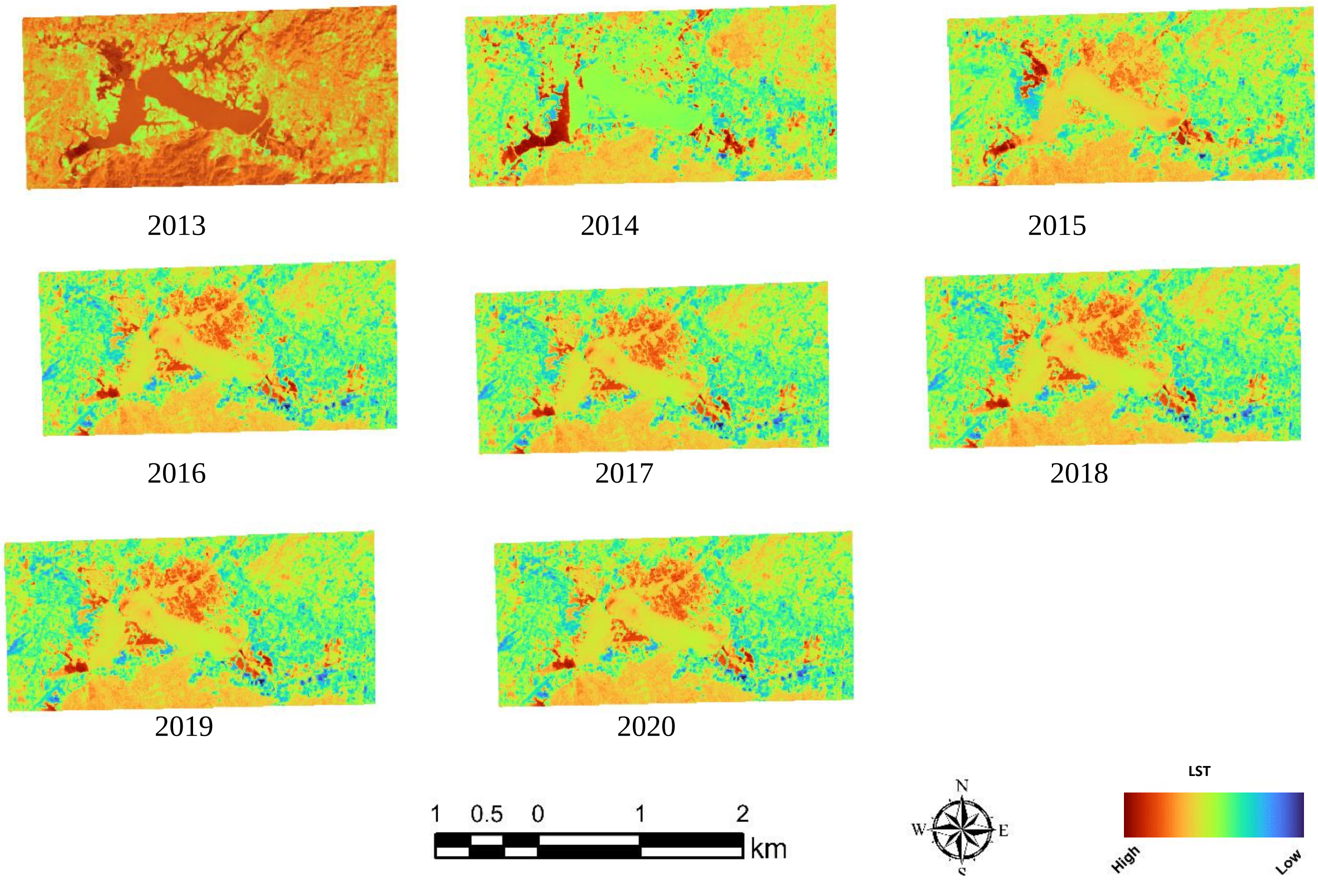

Fig 3.3 Variation of LST over the years of study

Table 3.2 Mean LST

	LST_Data
LST_2013	17.41245
LST_2014	24.27822
LST_2015	19.10074
LST_2016	21.5482
LST_2017	18.75298
LST_2018	20.12339
LST_2019	19.63853
LST_2020	19.12638

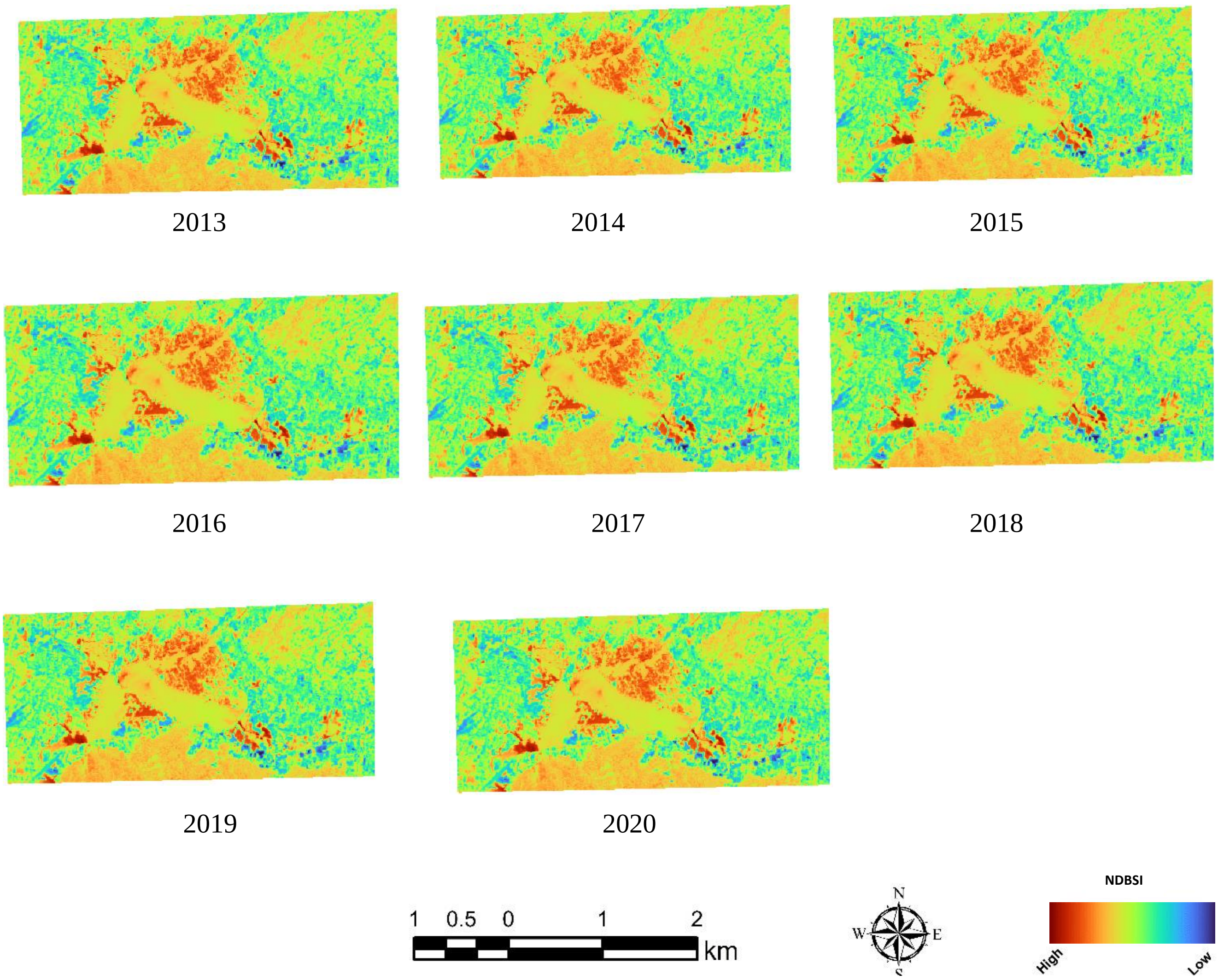

Fig 3.4 Variation of NDBSI over the years of study

Table 3.3 Mean NDBSI

	NDBSI_Data
NDBSI_2013	-0.07021761
NDBSI_2014	-0.10350461
NDBSI_2015	-0.07137497
NDBSI_2016	-0.06760518
NDBSI_2017	-0.06106717
NDBSI_2018	-0.07768264
NDBSI_2019	-0.06448705
NDBSI_2020	-0.07651871

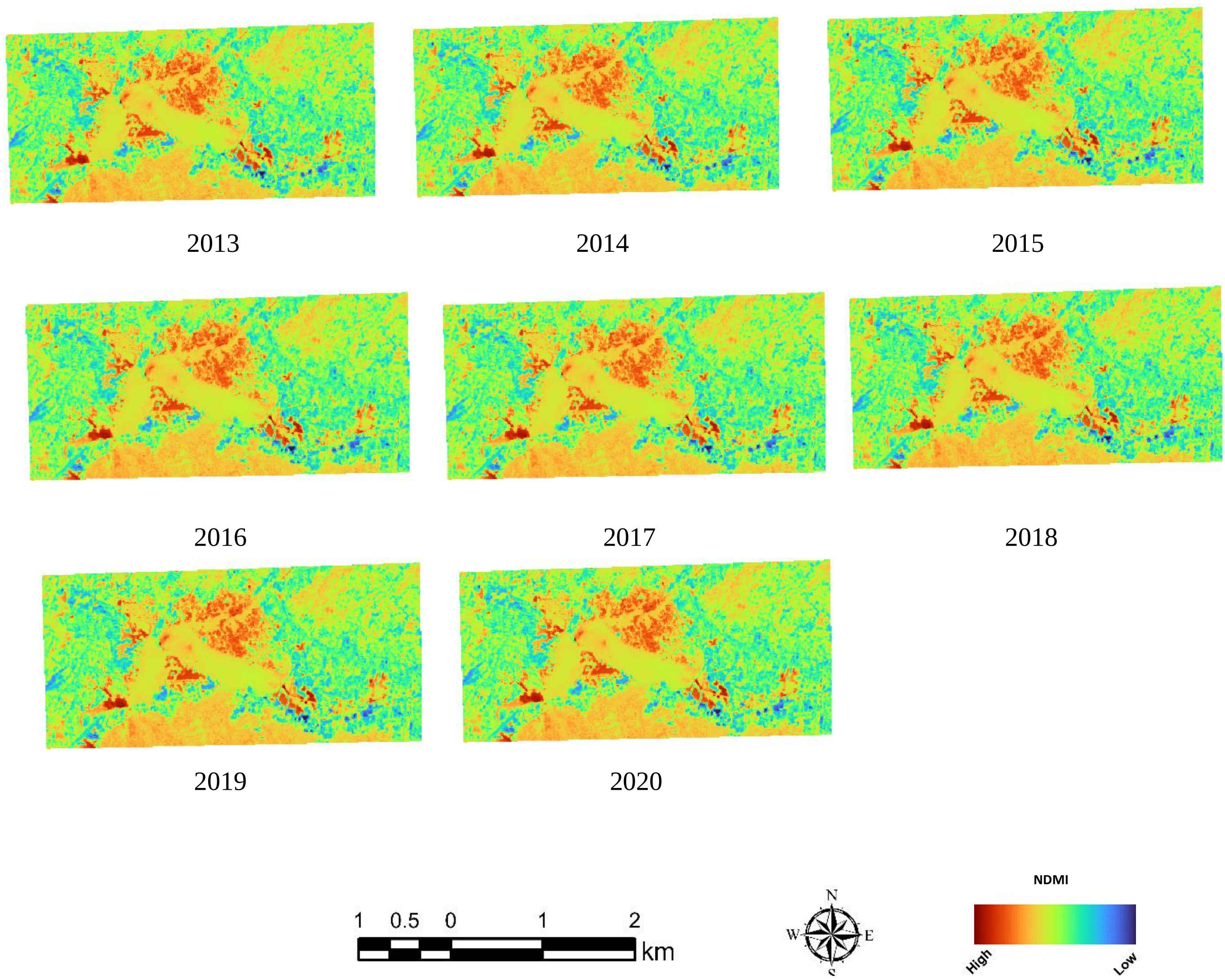

Fig 3.5 Variation of NDMI over the years of study

Table 3.4 Mean NDMI

	NDMI_Data
NDMI_2013	0.077355368
NDMI_2014	0.120180846
NDMI_2015	0.076453225
NDMI_2016	0.072738217
NDMI_2017	0.062565101
NDMI_2018	0.08598228
NDMI_2019	0.068499974
NDMI_2020	0.083153595

3.3 Results

The trend as seen in different indicators over the years are proof that the ecological conditions of this wetland are degrading. Over the span of 8 years the forest cover has reduced, urbanization has increased causing a rise in pollution and thus affecting the air and water quality

Fig 3.6 demonstrates the varying RSEI over the eight years of Dipor Bil. As it can be seen, in 2013 the lake is showing a bright blue patch and over the years it has been degrading. From the Table 3.5 it can be seen that there has been continuous fluctuation of RSEI values. But overall, there has been a decline in the ecological status (Fig 3.6).

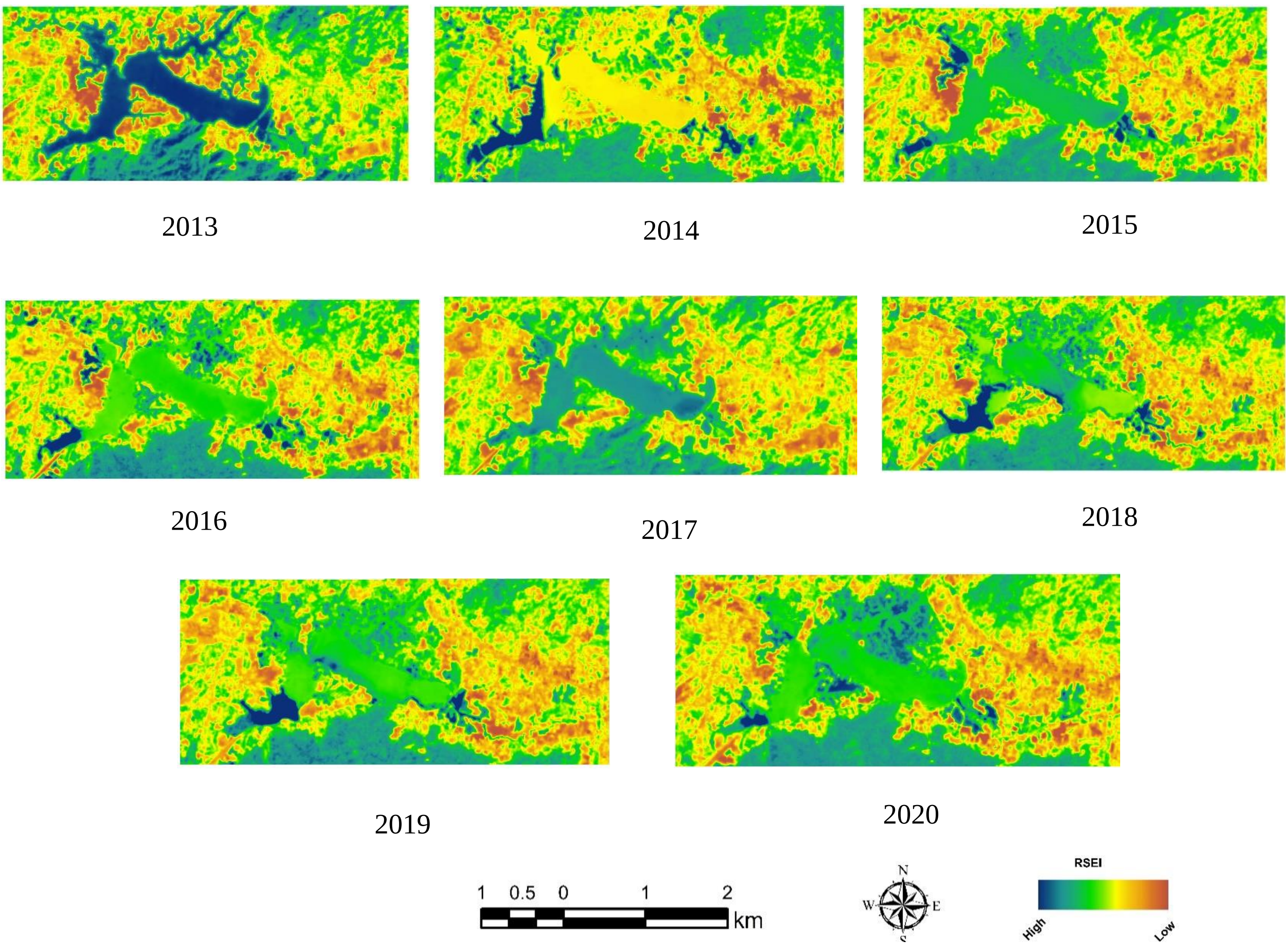

Fig 3.6 The time series of RSEI images showing the ecological status of Dipor Bil in each study year and the degradation of the overall ecological condition of the wetland during the study period

Table 3.5 Mean RSEI

YEAR	M_RSEI
2013	0.7110690
2014	0.5139235
2015	0.5332958
2016	0.5131842
2017	0.6033513
2018	0.5720385
2019	0.5109997
2020	0.5253428

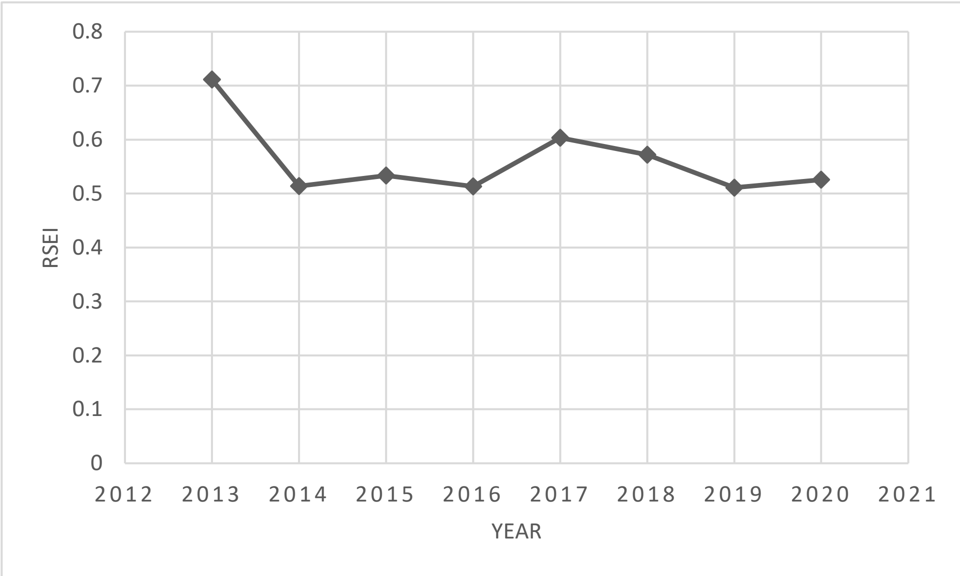

Fig 3.7 Trend of RSEI for the years 2013-2020 in Dipor Bil

Chapter 4

Conclusion

4.1 Summary

This work used a digital technique to establish rules utilising satellite-derived indices to detect changes in key cover categories inside Deepor Beel, a Ramsar wetland in northeastern India. The use of multiple indices to modify these rules resulted in increased accuracy and helped to solve the problem of intra-mixing of cover types in a dynamic wetland ecosystem.

The remote-sensing ecological index (RSEI), which is built with greenness, moisture, dryness, and heat, has become increasingly recognized for its use in urban eco-environment quality assessment. The model helped in recognizing how urbanization is negatively affecting our ecosystem and the steps that should be taken to combat that.
To improve the reliability of such assessment, we propose a new RSEI-based urban eco-environment quality assessment method where the impact of RSEI indicators on the eco-environment quality and the seasonal change of RSEI are examined and considered.

4.2 Future Scope of Work

RSEI has many important applications in different spheres. Not only can it be used to detect ecological changes, it can also be used for the assessment of urban ecological quality. The spatial and temporal change detection for a region's ecological status is a challenge due to the difficulty in producing the time series of ecological images showing comprehensive ecological status

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Tables and figures in the text should be presented preferably in portrait orientation. Tables and figures (less than half of writing area of a page) should be incorporated within the text, while, the larger ones may be presented in separate pages. The numbering of tables and the figures shall be done according to the chapter number. For example, the fourth figure in Chapter 5 will have the number Figure 5.4.

Table number and the title shall be placed above the table while the figure number and caption should be located below the figure. Tables and Figures, borrowed and reproduced from other documents, shall be cited properly in the title of the table or the caption of the figure. Positions of the tables and figures should be either at the top and/or the bottom of the any page. Two examples are shown below for illustration.