ASSESSING SPATIO-TEMPORAL CHANGES IN CUMBUM LAKE – A GEOSPATIAL APPROACH

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BACHELOR OF TECHNOLOGY

IN

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CERTIFICATE

This is to certify that the Internship Report entitled "Assessing spatio-temporal changes in Cumbum Lake – a geospatial approach" that is being submitted by

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This is to certify that Mr A. Vamsi Krishna student of Civil Engineering, Rajeev Gandhi Memorial College of Engineering and Technology, Nandyal, worked as intern from 9th January to 5th April 2023 at Lab for Spatial Informatics, IIIT-H. During his stay at IIIT-H, he worked on "Assessing s*patio-temporal changes in Cumbum Lake – a geospatial approach".*

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Dedicated to my beloved parents, and teachers who have worked hard throughout my education.

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ABSTRACT

The present study aims to determine the changes in the Cumbum lake, which is the second largest man made irrigation lake in entire Asia. The subsets of the study area are made from Landsat TM and OLI/TIRS images acquired in the years 2001, 2003, 2010, 2016 and 2022, respectively. ERDAS IMAGINE is used for processing of the images. The images are processed using maximum likelihood supervised classification technique, which is the most accurate method. Five classes are detected including lake water, cultivated land, forest cover, settlement areas and the rest of the categories like fallow lands, cliffs and rocks, marshy lands are categorized as other class. The variations in each class are to be studied, with in the study area.

The Cumbum Lake is a heritage symbol representing the awareness of our ancestral rulers towards the irrigation management by constructing the reservoirs in the necessary regions. Hence, this lake is made as study area and the report is prepared. The results based on the report show that the overall lake area by 2022 reduced nearly by 7% as compared to the area with the reference considered.

KEY WORDS: Spatio-Temporal changes, Cumbum lake, ERDAS imagine, False Color Composite(FCC), Supervised classification, Maximum likelihood classification etc.

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Chapter 1

INTRODUCTION

1.1 Introduction

Many researchers denoted that land cover is attributes of earth surface features that are of water, vegetation, ice and desert and also the immediate sub surfaces, including soil, topography, groundwater, and it also includes these structures created solely by human activities such as settlements and mine exposures. Hydrological components of a watershed have been directly influenced by surface runoff, stream flow, groundwater recharge, and evapotranspiration. Nowadays human activity is the primary source of land use/land cover change. However, climatic change is expected to exacerbate and accelerate impacts on hydrological, terrestrial and climatic regimes, as well as increase the weakness of species and cultural resources. Water balance and water flow paths are changing with respect to spatial and temporal changes of urbanization, agriculture, deforestation and daily activities of human beings, Hydrological processes are dynamic and its availability in river basins is involved by a dynamic change in climate and land use climate.

Current human actions are big causing the most of the changes in the surface of the earth. Modifications of earth surface cover bring about change in energy balance, water, and the geochemical fluxes at the global, regional, and local level, and these alterations will necessarily affect the socioeconomic activities and sustainability of natural resources. Worldwide population has been increasing gradually, ultimately rising pressure on the natural resource of a country to the changes in land cover. The dynamic process of Change detection or the land use land cover is important along with their social and environmental inference at various spatio-temporal scales.

The current study delivers the spatial-temporal changes over the considered time period to the latest data available, vegetation and agricultural area is influenced on the surface water of the lake during the particular time period, where the crops are cultivated. Remote sensing satellite data gives continuous photographs of earth's surface over a long time. Landsat thematic mapper and OLI imagery has a reasonable spatial resolution (30 m), and make available multi spectral images, high temporal resolution, i.e., short revisit interval (16 days) and includes decades of records are available in free of cost [6]. Therefore remote sensing and geospatial techniques are playing an imperative role in the analysis of Spatio-temporal changes or land use and land cover change.

1.2 Study area

The Cumbum Lake also called as the Gundlakamma Lake, is one of the oldest man made lakes in the Asia, this lake is present in the Cumbum Mandal, Prakasam dist., Andhra Pradesh, India. The longitude and lattitude of the lake are 79°05' E and 15°34' N respectively. This lake is the second largest man-made irrigation tank in the Asia. This lake is a Rivulet which is built 450 years back formed by damming a gorge through which the Gundlakamma and Jampaleru rivers flow (details are in Anonymous 2020a). Gundlakkama River is the largest river that is originated in the Nallamala hills, it is a seasonal river of which the flow is dependent entirely on the rain water. It acquired the name Gundlakamma from its birth place, Gundla Bramheshwaram which is an ancient temple built deep inside the Nallamala region. Gundla Bramheshwaram wild life sanctuary is very well known for the Tiger Reserve in the northern part of this region. The Jampaleru River is a small stream flow which is also almost originated near Gundla Bramheshwaram (Sai Krishna Kesanapalli et al.2018). The lake is constructed in a way that the waters of the both rivers are made to store in a single area, so that the floods can be controlled as well as the water stored can be utilized during the summer. This Lake is almost 7 KM long and 3.5 KM wide(Anonymous 2015). This lake officially serves 6944 acres of land for the irrigation and more than 16000 acres of land unofficially. There are almost 19 nearby villages which are primarily dependent on that lake for agriculture as well as domestic water usage(Figure 1.2: Puli Srinivasa Prasad 2018, Anonymous 2020a).
Recently, in the year 2020, The International Commission of Irrigation and Drainage (ICID) recognized the Cumbum tank as one of the World Heritage Irrigation structures in the 71st IEC virtual meet, New Delhi, 2020 (Anonymous 2020a, Anonymous The Hans India 2020).

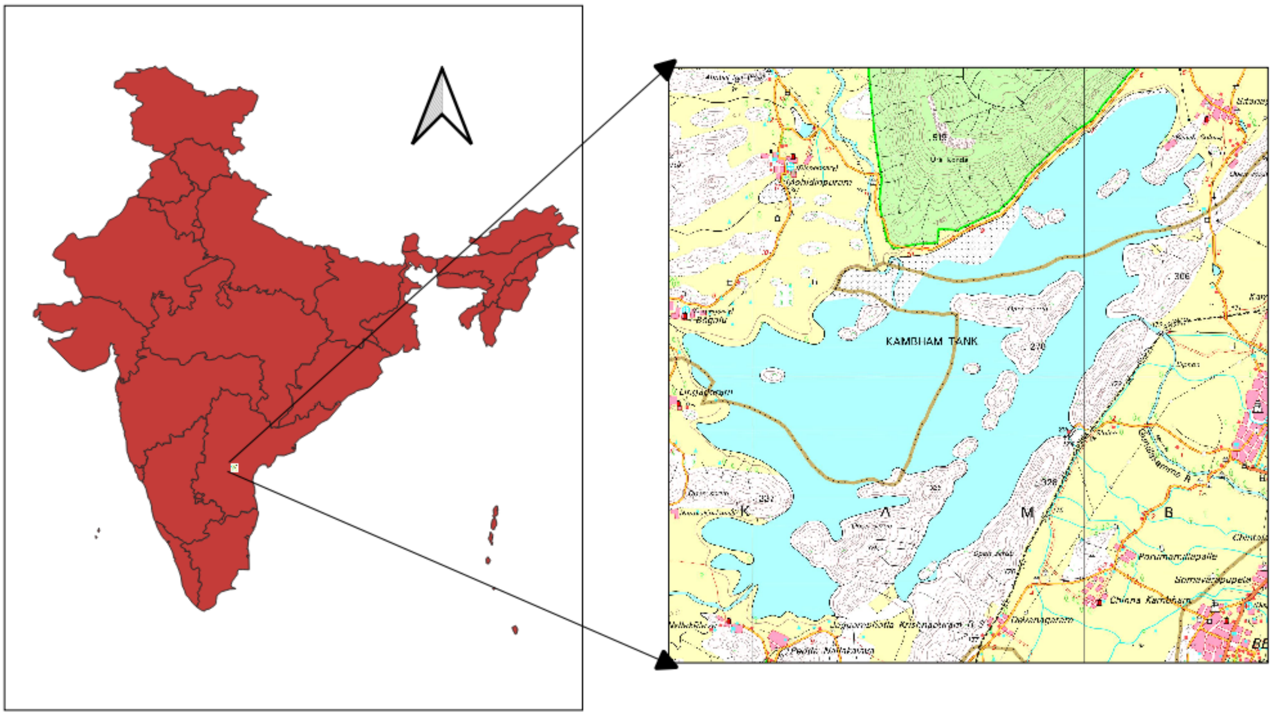

Figure 1.1: Location of the lake

1.3 History of the lake

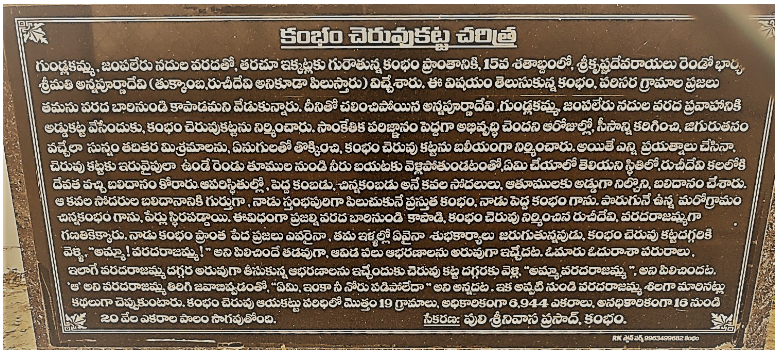

Figure 1.2: Engraved History of the Lake

The construction of this lake is completed in the 15th Century by the Gajapati rulers from Odisha. Later, the same lake is renovated by Ruchi devi aka 'Tukkamba', who is the second wife of the king 'Sri Krishnadevaraya' and also she was the daughter of a Gajapati king. It is believed that the tank construction took place during 1522-1524 AD, it has been in utilization from 1525 AD(Anonymous 2020). Tukkamba once visited Stambapuri, which is now called as Cumbum, then she insisted to renovate the tank that is started by her and also to build an anicut at one end of the lake. It is said that the stabilization of the lake bed, is done by using Pachyderms. The people have built a temple for Tukkamba on a embankment of the lake on her memory(Anonymous The Hindu 2016, Figure 1.2: Puli Srinivasa Prasad 2018).

Chapter 2

LITERATURE REVIEW

1983, Spatial and Temporal Changes in Louisiana's Barataria Basin Marshes, 1945-1980, Charles E. Sasser ,Malcolm D. Dozier,James G. Gosselink

Coastal wetlands are valuable ecosytems that support productive fisheries, fur-bearing muskrat and nutria, and waterfowl. They also take the brunt of coastal storms, protecting inland areas, and have been shown to be effective in purification of polluted waters containing high concentrations of nutrients and heavy metals.The objective of this study was to document the condition of the southwestern portion of Barataria Basin in 1945, prior to most oil and gas exploration and extraction, and at three later periods (1956, 1969, and 1980). To this end, a computerized spatial data base was developed to determine the amount, rate, and location of wetland change over time. In addition, the sequence and spatial patterns of water body development (indicative of marsh deterioration) were monitored to begin to determine the phases and causal mechanisms of marsh loss.

August,1999, Spatial Variation among Lakes within Landscapes: Ecological Organization along Lake Chains, Patricia A. Soranno, Katherine E. Webster, Joan L. Riera.

Spatial variation within and among lakes has been recognized as playing an important role in structuring lake ecosystems at a variety of scales. The natural boundary of the lake shoreline has long focused the attention of limnologists on the lake as the unit of study (Forbes 1887). Understanding spatial patterns within individual lakes occupied early limnologists since they first lowered thermometers and water samplers into deep stratified lakes(Forel 1892; Birge and Juday 1911). The observed vertical gradients in light, temperature, oxygen, and nutrients were viewed as major drivers of ecological process.

However, to make predictions about how landscape position influences lake solute concentrations, we can examine patterns and infer likely mechanisms based on the following assumptions: (a) loading increases as the watershed to lake area ratio (WS:LK) increases; (b) transport and retention within a lake depends on water residence time (WRT); and (c) patterns for individual variables depend on retention strength and reactivity.

Janaury, 2007, Faunal Diversity of Nallamalai hill ranges of Eastern Ghats, Andhra Pradesh, India, K.Thulsi Rao and I.Siva Rama Krishna

Nallamalais, one of the five biodiversity hot spot regions of the country, harbours rich diversity of flora and fauna. It lies in a biodiversity rich zone of the Eastern Ghats and less studied from faunistic survey point of view. The state of Andhra Pradesh in East Central peninsular India is typical of the extensive Deccan bio-geographic zone. The forest vegetation of the state is largely of dry deciduous, thorn type and seasonally arid. The Eastern Ghats add a mossaic of biological diversity and provide centers of endemism for flora and fauna.Nallamalais are constituted in three very important Protected Areas having rich and highly endangered species. They are 1. Rajiv Gandhi Wildlife Sanctuary (Nagarjunasagar Srisialam Tiger Reserve) 2. Gundla Brahmeswara Wildlife Sanctuary (GBM) 3. Rollapadu Wildlife Sanctuary for conservation of GIB and its associated species.

The faunal inventory has been carried out for both invertebrates and vertebrates. Inventorisation of these species has been carried out by various established methodologies. The field visits have been conducted periodically in all three seasons and habitat wise. By following the standard methods, Avian fauna has been documented by direct sighting and their vocalizations. Mammalian diversity is estimated by direct sighting and indirect evidence (including footprints and droppings). Reptiles, amphibians and other faunal components were documented by direct sightings and collections. The status of each species is recorded and compared with red data book. All the survey results have been well analyzed to take necessary steps for formulating conservation strategies. Voucher specimens collected were deposited in ERM Labs for identification and further studies.

Over 50 species of mammals, 200 species of birds, 54 species of reptiles, 18 amphibians, 55 fishes, 89 species of butterflies, 57 species of moths, 45 species of Coleopteran, 30 species of Odonata and numerous other forms of insects are inventoried from this area and prepared a checklist.

June, 2011,Delineation of reservoirs using remote sensing and their storage estimate: an example of the Yellow River basin, China, Lishan Ran and X. X. Lu.

The Yellow River, originating on the eastern edge of Qinghai-Tibet Plateau and flowing for a total length of 5464 km, is the second longest river in China. It drains a large basin of about 752 000 km2 which exhibits a wide range of climatic and geological features. Spatially, the mean annual precipitation is highly variable across the river basin, varying from 700 mm in the southeast to 250 mm in the northwest.

The infrared, visible red and near-infrared bands provided in the Landsat images were used to distinguish between land and water and map the extent of open water surface. In the near-infrared and mid-infrared wavelength regions, water, when not turbulent, increasingly absorbs energy making it appear darker in the satellite images while vegetation appears as bright spots or stripes. This is dependent upon water depth and wavelength. For the visible spectrum's, generally, water bodies do not reflect much depending on the extent of turbidity. For example, clearer water tends to have less reflectance than turbid water. In this study, the combination of bands 7, 4 and 3 was used to separate water bodies from surrounding surface features. Specifically, band 3 (0.63–0.69 µm in wavelength) senses in a strong chlorophyll absorption region and strong reflectance region for most soils; band 4 (0.76–0.90 µm in wavelength) operates in the best spectral region to distinguish water bodies as water is a strong near infrared light absorber; band 7 (2.08–2.35 µm in wavelength) can also separate land and water sharply as it has strong water absorption region and strong reflectance region for soil and rock.

September, 2011, Spatial and temporal changes of lake wetlands in Jianghan Plain after the implementing of 'thirty-six-word policy', Wang Chengcheng, Wang Hongzhi and Xarapat Ablat

After the cataclysm of the Yangtze River in 1998, the State Council put forward the "thirty-six-word policy" for harnessing large rivers and lakes. Jianghan Plain is one of the main areas to get harnessed according to the policy. Based on the CAS land use databases of 1995, 2000, 2005 and 2010, the spatial changes information of lakes in Jianghan Plain were captured and analyzed under the ARCGIS platform or by indexes of landscape ecology. The results show that: From 1995 to 2010, the area of lake wetlands has been grown constantly; Transitions from farmland and unused land to lake were dominant for the increase of lake area, while so were the transitions reversely; Lake wetlands were divided into two categories (lake and pond) to be analyzed according to the area of every lake wetland patch, lakes mainly increased in the area while ponds mainly increased in the number of patches. Ponds are not as curved as lakes in shape and more dispersed than lakes; Lakes became less curved and concentrated with the augment of the area of lake wetlands. The shape of pond wetlands changed little and its distribution became a little concentrated with the increasing number of pond wetlands. During the three five-year analyzed, the increase of wetlands of Jianghan Plain was notable during the period of from 2000 to 2005, though the area of wetlands increased during all the three periods.

July, 2016, Change Detection of Manzala Lake Using Remote Sensing and Geographic Information System,H.Hossen and A.Negm

The maximum likelihood supervised classification is applied to subsets of the Landsat TM, ETM+ and OLI/TIRS images acquired on 1984, 1998 and 2015, respectively to monitor changes in Manzala Lake. Manzala Lake is the largest natural lake in Egypt, it is located between longitudes 31°45' and 32°22' E and latitudes 31°00' and 31°35' N. Six classes are detected including sea water, lake water (water bodies), floating vegetation, Islands, sand bar and urban, and agriculture. ERDAS IMAGINE and ArcGIS software are used in this study for processing of the images and managing the database of each image. The results showed that the water bodies of the lake decreased by 57.06% (47,419.1 ha), while floating vegetation and islands area increased mostly by the same amount during the period from 1984 to 2015. This increase in floating vegetation is due to the discharge of agriculture wastes and municipal wastes in the lake without adequate treatment. The sea water has minor changes during the period of study. The agriculture area increased by 28.57%(19,285.6 ha), while the sand bar and urban area decreased mostly by the same amount during the period from 1984 to 2015. The future prediction was conducted using the annual rate of change over the next 15 years.

July, 2016, Change detection in the water bodies of Burullus Lake, Northern Nile Delta, Egypt, using RS/GIS, H.Hossen and A.Negm

the Burullus Lake was selected as a case study. It is the second largest of the Egyptian northern coastal lakes along the Mediterranean coast. It has economic and environmental impacts on the nearby society of Kafr El-Sheikh, Egypt. ERDAS IMAGINE and ArcGIS software are used in this study for processing of the images and managing the database of each image. Different classification techniques are tested, the results showed that the maximum likelihood supervised classification technique was more accurate to monitor changes in the water bodies of the Lake. The method is applied to subsets of the Landsat TM, ETM+ and OLI/TIRS images acquired on 1984, 1990, 1998, 2003 and 2015, respectively. Five classes are detected including sea water, lake water, floating vegetation, sand bar and urban, and agriculture land. The results showed that the water bodies of the lake decreased by 44.97% (14,503.68 ha), while floating vegetation area increased mostly by the same amount during the period from 1984 to 2015. This increase in floating vegetation is mainly due to discharging of agriculture wastes and municipal wastes in the lake without adequate treatment. The sea water has minor changes during the period of study. The agriculture area increased by 45.52% (10,529.02 ha), while the sand bar and urban area decreased mostly by the same amount during the period from 1984 to 2015. Statistical models were developed using statistical tools. The models indicated that the water bodies of the lake will be reduced by 58.95% (19,013.42 ha) in 2030. The results of the present study shall help the decision-makers to take the necessary measures to reduce the environmental risk and maintain the lake in order to sustain the lake water area against further reduction.

August, 2016, Mapping the spatial changes in Lake Volta using multitemporal remote sensing approach, Benjamin Ghansah,Yaw M. Asare,Eric T. Tchaoand Eric K. Forkuo

Lake Volta is the world's largest man-made lake by surface area, and the fourth largest by water volume. Located completely within Ghana, it has a surface area of about 8502 km2 (3283 square miles).Spatial extent mapping of the lake using Landsat TM 1990, ETM + 2000 and ETM + 2007 images indicated the lake experienced both increased and decreased surface area changes during the study period. The lake's surface area varied by about 197 km2 between 1990 and 2007, with the water level fluctuating between $\pm 7m$.
Spatial changes in lake areas are significant occurrences requiring monitoring. The causes of these changes include both anthropogenic causes and natural phenomenon. Extreme temperature, heavy rainfall and global warming are some climatic forces responsible for variations in lake surface areas. Deforestation, over-abstraction of water and facade establishment are some of the human activities causing changes in water body areas. Geological formation has also been found to be a cause in some cases.Climate change is thought to be one of the main causes of the observed spatial changes in the surface area of Lake Volta.

June, 2018, Planning and estimation of water grid in sub basin of Gundlakamma River, Andhra Pradesh, India: A model study, Sai Krishna Kesanapalli,Rajasekhara Reddy Konda,Sundara Kumar Pitta

States like Andhra Pradesh, Telangana, Tamil Nadu and Maharashtra in India are witnessing the frequent failure of crops due to acute shortage of water for agriculture resulting debit trap of farmers in turn migration to urban areas in search of livelihood or suicides.. In order to address such critical social, agricultural and rural employment issues, it is necessary to evolve a comprehensive water network model for meeting the water requirements of growing population in water scarce areas.

The study area forms part of Gundlakamma river basin, covers an area of 1846 km^2 and falls in Survey of India topo sheets 57 M/2, 57 M/3, 57 M/6, 57 M/7, 57 I/14, 57 I/15. Geographically this area lies between the latitude 15°11´ - 15°48´N and longitude 78°42´ - 79°22´ E and located in the eastern coastal plain of Indian sub-continent with an average elevation of about 91m above the sea level. The Gundlakamma River passes through the east central portion of prakasam district, Andhra Pradesh. The average annual rainfall of the study area is around 895mm and receives rainfall during south west as well as north east monsoon. The Cumbum Lake also known as Gundlakamma Lake, which irrigates about 11,000 acres of land in prakasam district. It is the major source for drinking purpose as well as for irrigation needs.

December, 2019, Spatio-temporal changes in surface water quality and sediment phosphorus content of a large reservoir in Turkey, Memet Varol.

The Keban Dam Reservoir, located on the Euphrates River, is the second largest reservoir of Turkey. Water quality of this reservoir is of great importance because it is widely used for recreation, aquaculture production, fishing, and irrigation. In this study, discriminant analysis, principal component analysis (PCA), factor analysis (FA) and cluster analysis (CA) were conducted to evaluate the seasonal and spatial variations in surface water quality of the reservoir.In this study, sediment and surface water samples were taken seasonally from 11 different sampling stations (S1-S11) in the reservoir from November 2014 (autumn) to August 2015 (summer). Nineteen water quality parameters were chosen for measurement during and after sampling. Dissolved oxygen (DO), temperature (WT), pH, electrical conductivity (EC) were measured in situ by a portable multimeter.

Febraury, 2020, Geomorphology, Land Use/Land Cover and Sedimentary Environments of the Chilika Basin,Rajiv Sinha, R. Chandrasekaran, and Neeraj Awasthi.

The Chilika is one of the largest brackish water lagoons in Asia and is well known for its biologic diversity. Designated as one of the Ramsar sites in 1981, Chilika was under serious threat in the late 1990s due to severe physical and ecological degradation. Some of the severe problems included large-scale siltation and reduction in the water level as well as salinity, threatening some of the rare species of fauna in this region.

This study aims to map different landforms and LULC in the Chilika basin to evaluate spatial variability and temporal dynamics of geomorphic and anthropogenic processes during the last 35 years. Remote sensing and GIS are important tools to understand the global, regional, and local scale processes that affect the earth, and therefore, have a wide range of applications in the field of geology, agriculture environment and integrated ecological assessment.

The lagoon area increased from 865.42 km2 to 932.62 during 1980–1988 and decreased to 909.28 during 1988–2000 and then increased to 876.10 km2 between 2000 and 2015. On the other hand, both island area, as well as sand bars, decreased during the period 1980–2000. The period 2000–2015, however, shows a slightly different trend. During this period, the island area kept on declining, but sand bars increased drastically from 4.78 km2 to 11.33 km2 . It appears that the elevations of the islands are only slightly higher than the lagoon resulting in their submergence as the water level increases. While some of the sand bars were also submerged during the pre-intervention period, a drastic increase in their area in the post-intervention period suggests a much higher sediment flux through the new opening in September 2000.

Chapter 3

Methodology

3.1 Work flow

The entire work process can be divided in to the following steps:-

1. A toposheet is taken and the boundary of the lake is digitised.
2. A buffer of 5KM is created around the lake boundary and it is used as the area of interest.
3. . The Satellite images of the time periods '2001','2003','2010','2016','2022' are collected.
4. The subsets of the area of interest are clipped from all the satellite images in false color composite(FCC).
5. The satellite images are classified by using the supervised classification.
6. Finally the conclusions are drawn from the results.

3.2 Data Collection

3.2.1 Toposheet

A toposheet with the study area is to be taken as a reference. The required toposheet is selected and downloaded from the 'Survey Of India'(SOI). The toposheet of the scale 1:50000 with the study area is collected .

Toposheet no : D44B2

Year of Survey : 1978-79

source : Survey Of India

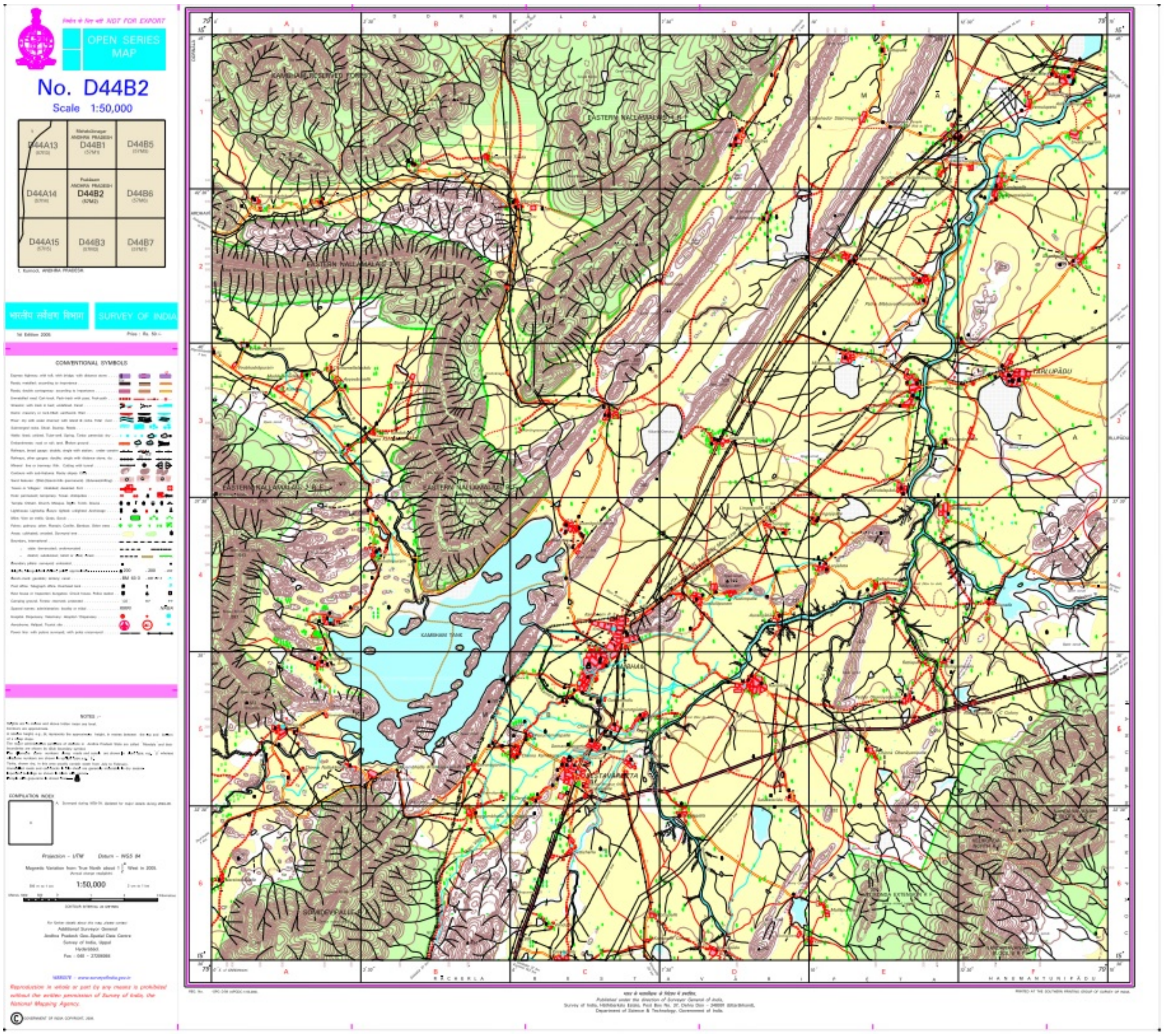

Figure 3.1: Toposheet

The toposheet is georeferenced to the geometrical co-ordinate system, so that the toposheet represents a real world feature. The toposheet is registered to the projection system, UTM, WGS-84, Zone 44, using ERDAS Imagine 2014(Raju et al.2018). The boundary of the lake is digitized in the toposheet and a buffer of 5KM is created for the boundary of the lake. The obtained buffer area is considered as the area of interest(AOI) and the changes happened within that area are detected.

Figure 3.2: Area of Interest

3.2.2 Satellite data

The satellite images of years '2001', '2003', '2010', '2016' and '2022' respectively are downloaded from United States Geological Survey (http://earthexplorer.usgs.gov/). The satellite images for the years 2001, 2003 and 2010 are taken from the LANDSAT-5 Thematic Mapper(TM), for the years 2016 and 2022 images are taken from LANDSAT-8 Operational Land Imager and Thermal Infrared Sensor(OLI/TIRS) and LANDSAT-9 Operational Land Imager-2 and Thermal Infrared Sensor-2(OLI-2/TIRS-2) respectively, all the datasets used are shown in Table3.1 along with the acquisition date of the imagery. All these satellite images are registered at the same projection system, UTM, WGS-84, Zone 44.

Satellite	Path	Row	Acquisition date
Landsat5 TM	143	049	Jan,2001
Landsat5 TM	143	049	Dec,2003
Landsat5 TM	143	049	Jan,2010
Landsat8 OLI/TIRS	143	049	Nov,2016
Landsat9 OLI-2/TIRS-2	143	049	Feb,2022

Table 3.1: Tabulation of all the satellite data

3.3 Processing

All the satellite images downloaded are imported in ERDAS Imagine 2014 and the sub-setting of all the satellite images is performed by extracting the study area using the Geo-referenced area of interest(AOI). False Color Composite (FCC) of the subset images is utilized to detect the changes in the lake and its surroundings(Raju et al.2018). False color composite consists of three spectral band layers,Visible Green,Visible Red and Near-Infrared respectively. In the Landsat5 Thematic Mapper(TM), the layers 2,3 and 4 are stacked. Whereas in the Landsat8 (OLI/TIRS) and Landsat9 (OLI-2/TIRS-2) the layers 3,4 and 5 are stacked. The difference in layers is mainly due to the presence of an additional band 'Aerosol' in the Landsat8 (OLI/TIRS) and Landsat9 (OLI-2/TIRS-2) in its first spectral band layer and then followed by visible blue, visible green,etc(Kristi Sayler, 2022). In Landsat5 Thematic Mapper(TM) the visible blue is the first one and then followed by visible green, visible red,etc.

The classification of image helps to know about the quantitative details of different classes present in the image. There are two types of classifications, Supervised classification and Unsupervised classification(Mohd Hasmadi et al. 2009). The major difference between supervised and unsupervised classification is, in the supervised classification the labeled data of classes for the classification is used, whereas in unsupervised classification no data about the classes to be classified is present. Supervised classification is the most widely used technique for the quantitative analysis of a remotely sensed data images, in this classes in the image can be classified based on our requirements(Hossen et al. 2016a).

3.3.1 Stacking and Clipping

To get the better results in the supervised classification, keep all the required band data of the satellite images and stack them into a single image. For the purpose of Change detection it is a common practice to use the False Colour Composite (FCC). False Color Composite can be achieved by stacking the Green, Red and Near Infra-red layers of a Satellite image. For the LANDSAT-5(TM) images 2, 3, 4 layers are stacked and for the LANDSAT-8(OLI/TIRS) and LANDSAT9(OLI/TIRS) images 3, 4, 5 layers are stacked.

After stacking the images, clip the study area from the satellite images using the area of

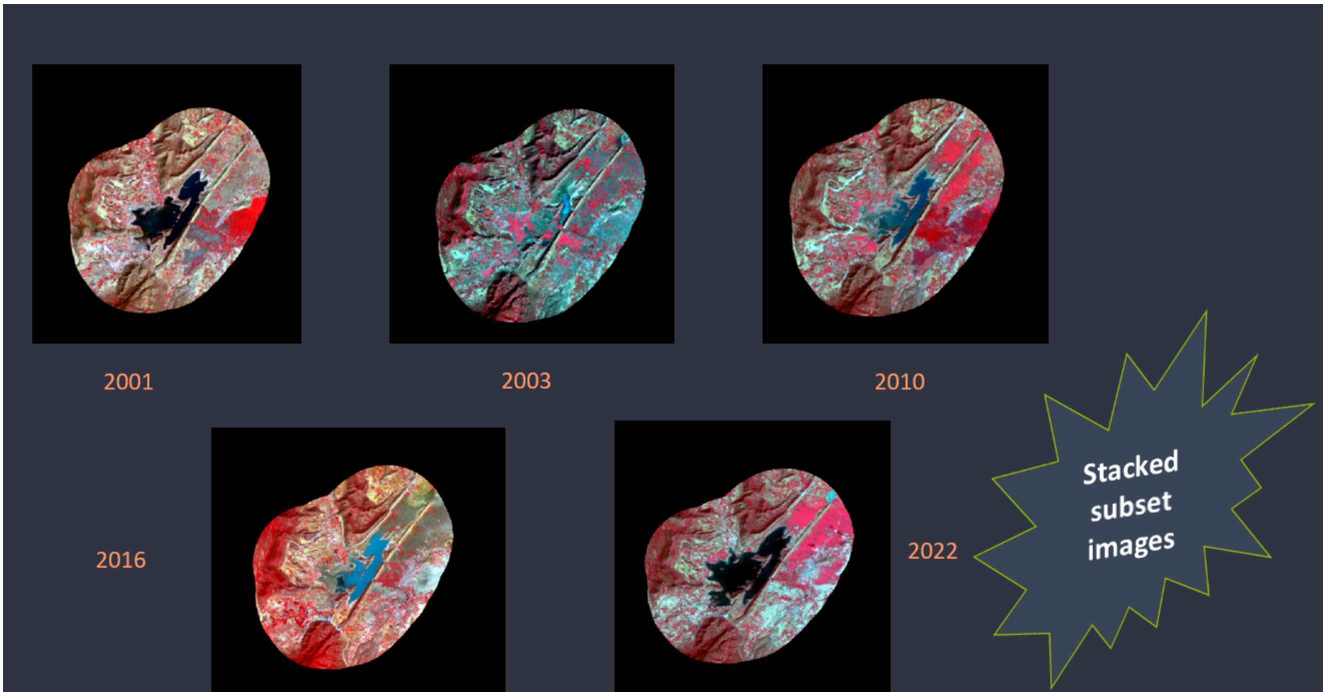

Figure 3.3: Stacked subset satellite images

interest, created earlier extract the study area. This process can be done simply by using the subset tool in ERDAS.

3.4 Supervised Classification

The classification of image helps to know about the quantitative details of different classes present in the image.There are two types of classifications;

1. Supervised Classification.
2. Unsupervised Classification.

The major difference between supervised and unsupervised classification is, in the supervised classification the labeled data of classes for the classification is used, whereas in unsupervised classification no data about the classes to be classified is present. Supervised classification is the most widely used technique for the quantitative analysis of a remotely sensed data images. In this classification the image can be classified based on our requirements. In this study, all the subset images are classified in to the five classes ;

- Water body
- Cultivated land
- Forest cover
- Settlement areas
- Others

Note:- Rest of the features in the images, such as fallow lands, rocks and cliffs, open scrubs, marshy land and barren lands etc., are kept under the 'Others' class.
The images are classified using the 'maximum likelihood classification'(MLC) algorithm. This method assigns all unclassified pixels to the class with the highest probability, hence it is preferred most widely all over the world(Hossen et al. 2016b). After completion of the classification, to get all the classes more accurately, re-coding is done to correct the classes in the images.

Chapter 4

Results and Discussions

4.1 Classification results

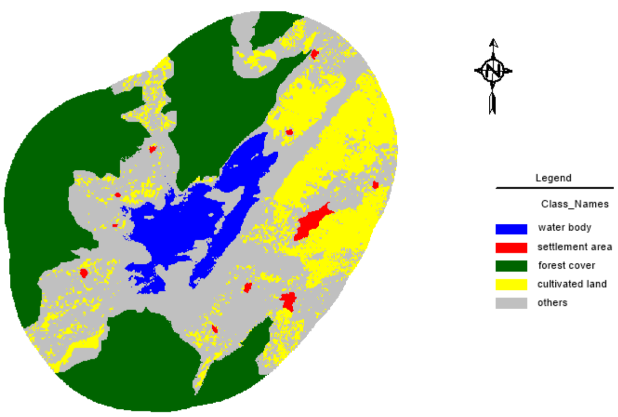

Figure 4.1: The Classified Image of 2001

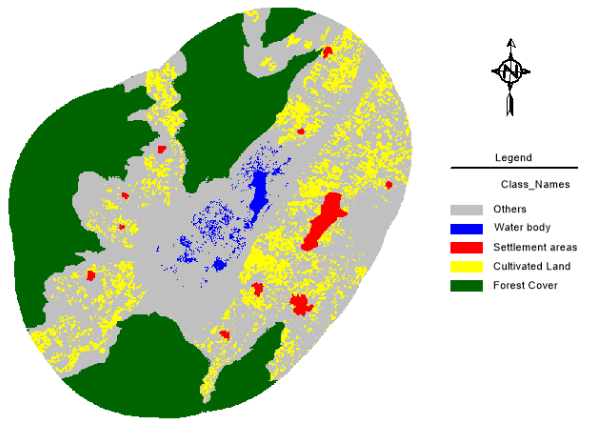

Figure 4.2: The Classified Image of 2003

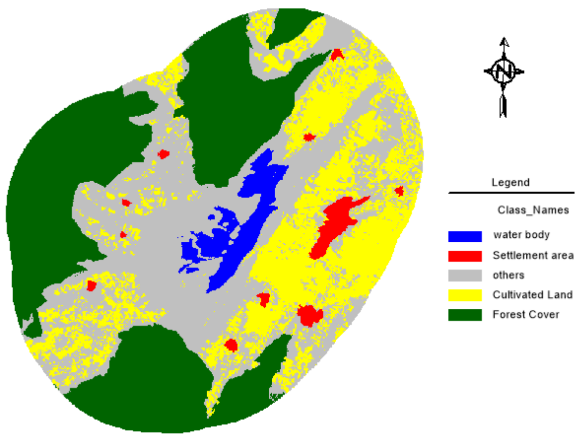

Figure 4.3: The Classified Image of 2010

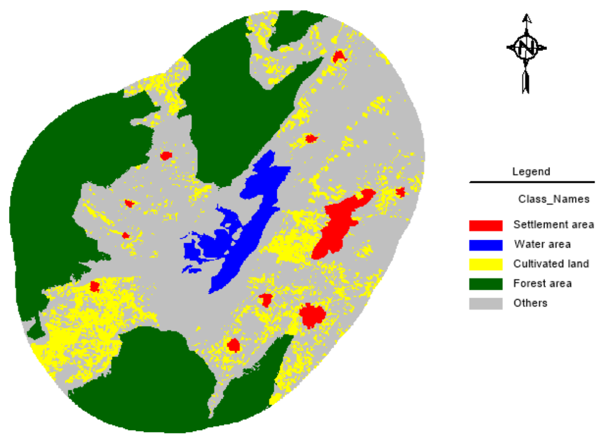

Figure 4.4: The Classified Image of 2016

The classified images of the years 2001, 2003, 2010, 2016, 2022 are obtained as in the figures 4.1 - 4.5 respectively. The classified images reveals that considerable changes are happened within the study area. Area of the each class in all the five years is tabulated as in Table 4.1 and the variation of all the classes is shown in the Figure 4.6.

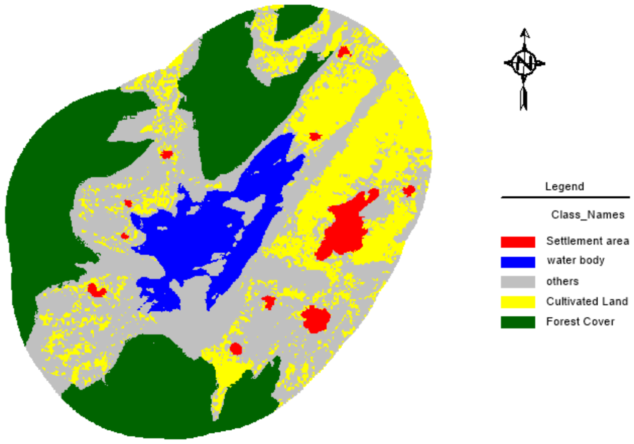

Figure 4.5: The Classified Image of 2022

In the year 2001 the lake area is 16.95 sq.Km (7.77% of the study area), in 2003 it is 3.084 sq.Km(1.41% of the study area),a drastic reduction is seen in the capacity of the lake, in 2010, 7.778 sq.Km (4.94% of the study area), in 2016, 7.847 sq.Km (4.97% of the study area) and in the year 2022, 19.17 sq.Km(8.79% of the study area), the lake has regained its capacity. And it is observed along with the time, the settlement area has the constant growth, from 2016 to 2022, there is more than 90% increase in the growth of settlement area with in the study area. Majority of the study area is covered with the forest, and there are very slight variations in the area of the forest cover in all the five years. Forest area is declining very moderately along the time. The forest area decreased 2.89% from 2001 to 2016.

Class	Area in 2001(sq.Km)	Area in 2003(sq.Km)	Area in 2010(sq.Km)	Area in 2016(sq.Km)	Area in 2022(sq.Km)
Water Body	16.95	3.084	10.778	10.847	19.17
Cultivated Land	38.96	28.16	32.77	25.31	35.23
Settlement Area	2.908	3.286	3.740	3.904	7.735
Forest Cover	76.26	75.42	74.17	74.12	74.06
Others area	83.09	108.2	96.71	103.99	81.98

Table 4.1: Area occupied by each class in each year in sq.km

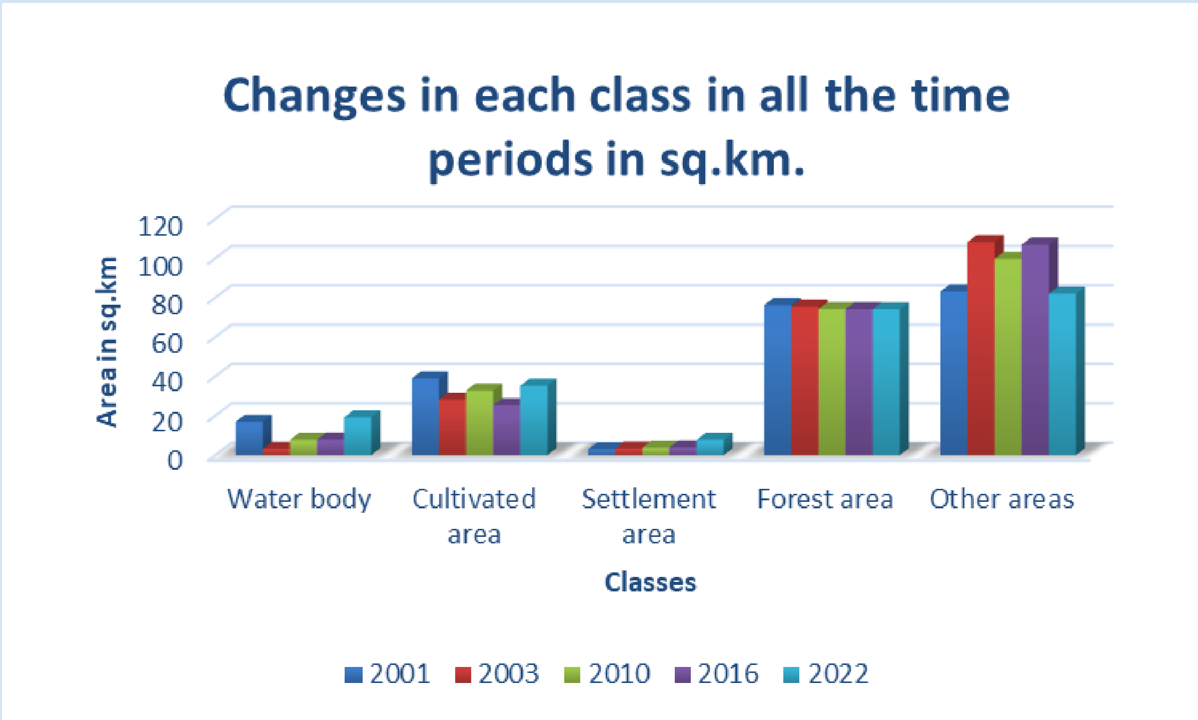

Figure 4.6: Area occupied by each class in five years

4.2 Accuracy assessment

Accuracy assessment is a part of satellite image classification, image classification is incomplete with out accuracy assessment(Raju et al. 2018). Accuracy is the degree of confidence and can be defined as the degree of convergence between the results and the truth. For accuracy assessment to images classification, there are two methods, error matrix and Kappa coefficient(Foody 2002).

Year	Overall Accuracy	Kappa Coefficient
2001	84%	0.7942
2003	88%	0.8166
2010	92%	0.8638
2016	88%	0.8067
2022	88%	0.8223

Table 4.2: Overall accuracy and Kappa coefficients.

The Error matrix , also called as the confusion matrix accumulates pixels of agreements and disagreements by matching the position and the class of each ground truth pixel with the representing location and class in the classification image(Jiang et al. 2014). The Kappa is a multi-discrete variables method used to assess the accuracy of classification maps, it is computed from the error matrix and implemented over the classification based on the data reference(Jensen 1996). The overall accuracy and the Kappa coefficients for the classification using maximum likelihood method are shown in the Table 3.2. The matrices reflect the overall accuracy and the Kappa coefficient value for each year. Accuracy value greater than 70% is considered to be acceptable and the Kappa value ranging from 0.40 to 0.85 represents the good correspondence (Congalton, 1991). Hence, the obtained accuracy results are acceptable.

4.3 Spatio-temporal changes

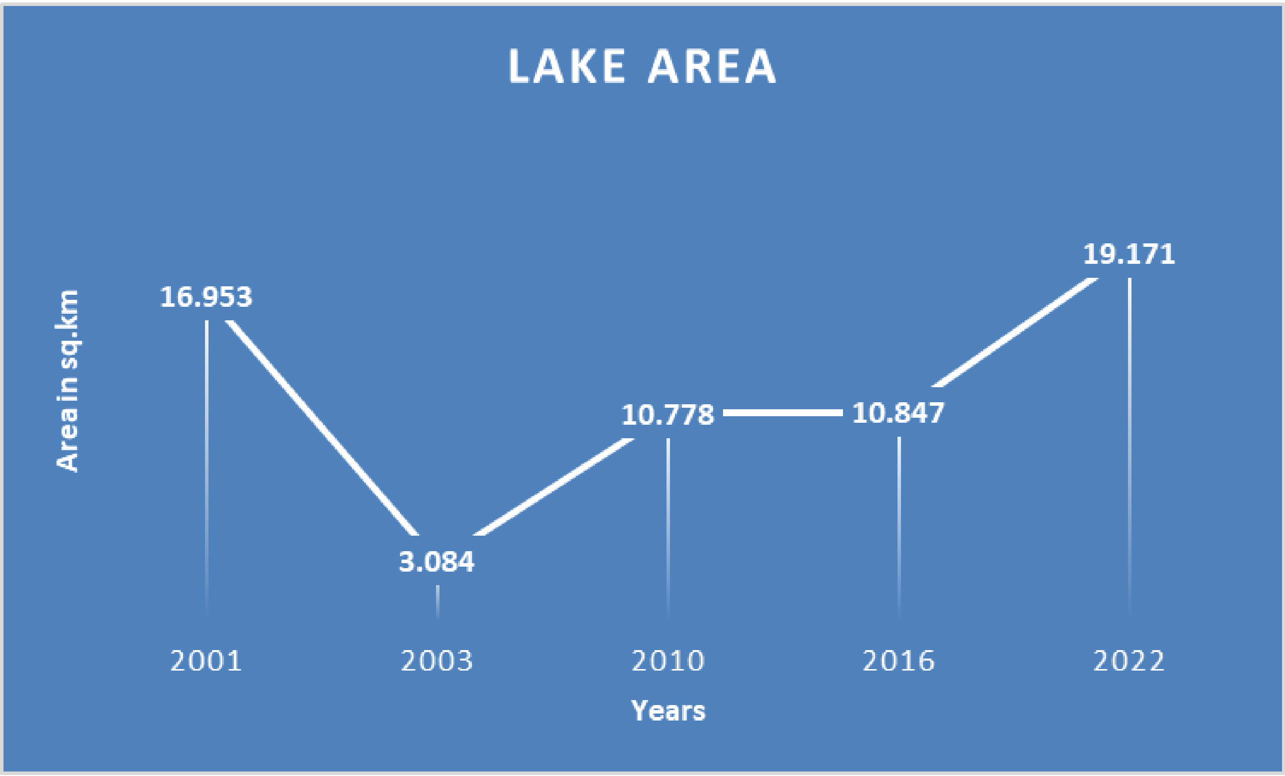

Figure 4.7: Area(sq.Km) of lake in each year

Using the remote sensing techniques and Geospatial analysis the lake area in five different time periods, 2001, 2003, 2010, 2016 and 2022 is determined. The variations in the surface area of the lake are plotted as shown in Figure 4.7. From the topographical data extracted, the surface area of lake is seen as 20.71 sq.Km. The lake area is decreased when compared with the area in the topographical data. There is a drastic fall in the surface area of the lake from 2001 to 2003, with in the span of just two years the lake area reduced by 81%(from 16.95 sq.Km to 3.084 sq.Km). This steep change in the lake surface area is because of the climatic conditions in that time periods. The intermediate year, 2002 seen a worst drought within the monsoon season having a return period of 200 years(Vimal et al. 2022). This lead for the depletion of water in the lake and thus the surface area of lake reduced largely. From 2003 to 2010 in the span of 7 years the lake recovered from its poor state, nearly 71.38% of the lake area increased from 2003. After 2002, the rainfall especially in the monsoon has never been such low, annual rainfall level in the monsoon season is above 400mm in these 7 years (Pulak Guhathakurta et al. 2020). The variation in the lake surface area in between the years 2010 and 2016 isn't much, just 0.88% increase in surface area of the lake. In the year of 2020, more than 25% excess of rainfall is witnessed in the state anual rainfall, in the entire Prakasam district 19.4% excess rainfall is seen, and the streams which the lake is dependent are originated from the Kurnool district which has an excess rainfall of 55% (Anonymous, 2020b). Hence, the inflow in to the tank started increasing. After 2020, another decent monsoon season in 2021 with 7.3% deviation of rainfall (Anonymous, 2021). These excess rainfalls helped the lake to increase its area over 59% as compared with 2016.

An observation can be made on the cultivated land and the lake area, as in fig 4.8. The

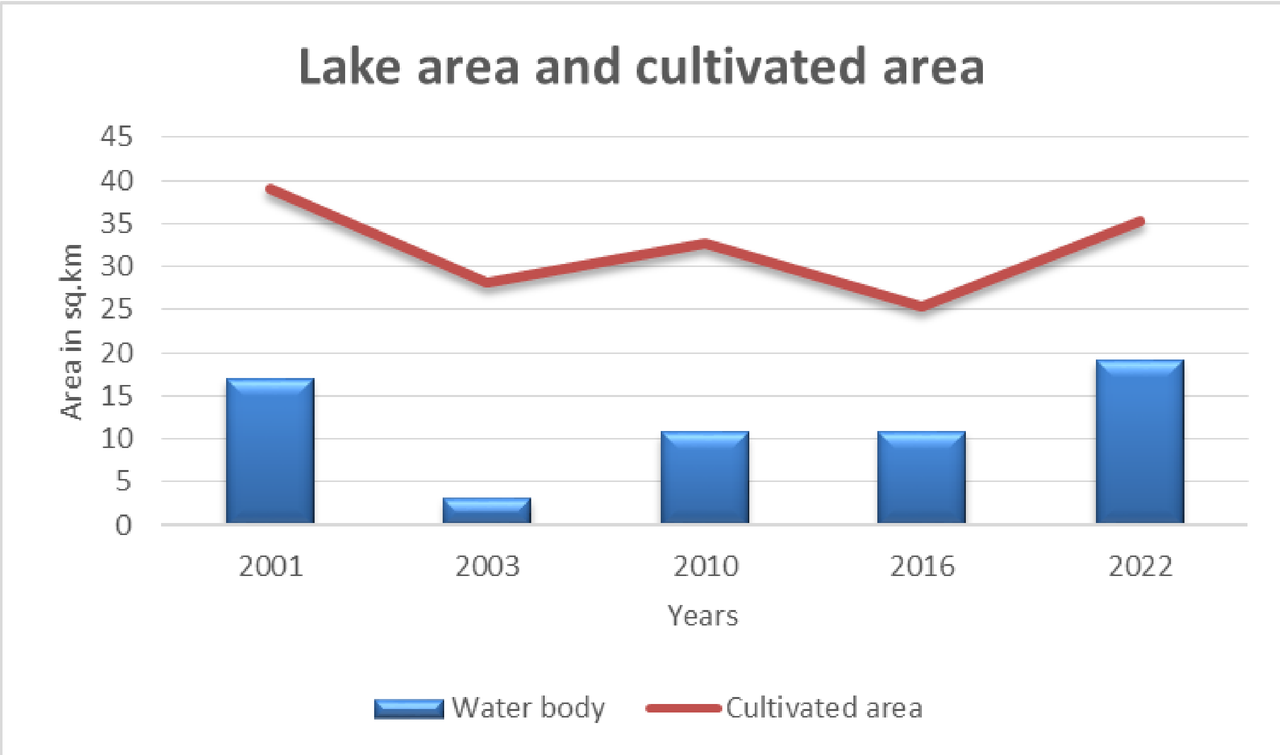

Figure 4.8: Variation in cultivation with lake area(sq.Km)

cultivation in the study area is widely dependent on the water supplied from the lake. So, whenever the lake capacity reduced the entire cultivation is effected, for the regions in our study area, it is also said that totally 19 villages depends on the lake directly, for agriculture as well as domestic purposes(Anonymous 2020a).

Chapter 5

Conclusions

This study focused on the temporal changes of the Cumbum lake, India, using remote sensing techniques and Geographic Information Systems. Geospatial technology provides an efficient way in understanding of spatial and temporal changes with supervised classification approach. Supervised classification using Maximum likelihood classification algorithm is applied to the subsets of the satellite images acquired on 2001, 2003, 2010, 2016, 2022, respectively to identify the changes in the Cumbum lake and surroundings.

- The overall accuracy of the classification for the 2001, 2003, 2010, 2016 and 2022 years is 84%, 88%, 92%, 88%, 88%, respectively.
- From the classified images the lake area in 2001, 2003, 2010, 2016, 2022 is 16.95 sq.Km, 3.084 sq.Km, 10.778 sq.Km, 10.847 sq.Km, 19.17 sq.Km, respectively.
- This lake depends on two seasonal water streams which depends on rainfall for their flow, when there is no considerable amount of rainfall in the region the lake water starts reducing continuously. That is why the lake area reduced drastically from 2001 to 2003 (from 16.95 sq.Km to 3.084 sq.Km). Later on the moderate rainfalls made the lake to regain its structure, these rainfalls were not enough to fill the lake completely.
- The surface area of the lake reached up to 10.847 sq.Km by 2016, due to the heavy rainfalls in 2020-2021 southwest monsoon, after two decades, the lake attained almost of its complete structure in 2022, having area of 19.17 sq.Km.
- It is also observed that cultivated lands are more when the lake area is more, because this lake is the only major water resource present in that area.

- The change in capacity of the lake is mainly due to the climatic conditions at that particular time period. There is no encroachment or any kind of movement of other classes towards the lake. The growth in settlement is observed but it is not towards the lake.

- Even though the lake is dependent mostly on the rainfalls, the water stored in it can be utilized for many years. Even, if the rainfalls are moderate the lake can be kept with average capacity.

Based on all the results, it is recommended to take appropriate measures to maintain the same structure of lake, this can be achieved in short term, by fixing the leakages of the lake. While the long term measures are providing artificial inflows along with the Gundlakamma and Jampaleru streams in to lake to maintain the lake with full capacity and clearing the sedimented soils in the lake area improves the the capacity and purity of the lake water. It is also seen the settlement area is increasing more rapidly, so certain measures are to be taken, so that any kinds of wastes are not to be released in to the lake and also so proper distribution of the lake water is to be done according to the growth of the population.

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