International Journal of Lakes and Rivers.
ISSN 0973-4570 Volume 16, Number 1 (2023), pp. 17-33

http://www.ripublication.com/ijlr.htm

Determination of Land Use-Land Cover Changes in the adjoining Panchayats of Sasthamkotta Freshwater Wetland a Ramsar Site in South India

Shibu K[1*], S Ayoob[2] and Muhammed Yousuf S[3]

[1]Assistant Professor, Department of Civil Engineering,
College of Engineering Trivandrum, Thiruvananthapuram 695 016, Kerala, India
[*]Email Id of corresponding author: shibukrishnanp@cet.ac.in
Mobile number of corresponding author: +91 944 60 66302
[2]Pro-Vice Chancellor (Retired), APJ Abdul Kalam Technological University,
Thiruvananthapuram 695 016, Kerala, India
[3]Doctoral Scholar, Department of Civil Engineering,
Indian Institute of Technology Delhi, New Delhi 110 016, India

Abstract

Most of the land use-land cover (LULC) changes that have occurred in the adjoining areas of wetlands have lead to the degradation of water bodies. Wetlands being unique ecosystems, proper land use management of the said area is an essential step towards conserving the same. The present study aims to determine the spatio-temporal changes of LULC in the adjoining three panchayats (namely Sasthamkotta, Mynagapally and West Kallada) of Sasthamkotta freshwater wetland, a Ramsar site in South India. Landsat satellite images for the years 1973, 1990, 2000, 2005, 2015, 2019, 2020 and 2021 were used for determining the LULC changes and the land use classes used in this study were designated as water bodies, barren land, settlement with vegetation, vegetation and built-up area and the same was mapped using Geographical Information System. For the classification of images, the training sample signatures were extracted from each of the imageries corresponding to each land use classes and maximum likelihood algorithm was employed for the supervised classification in ArcGIS software. The LULC maps so generated revealed that there has been reduction in aerial spread of water bodies and large increase in barren land and built-up area in the study area and the same was found to be 17.78%, 240.7% and 184.6% respectively.

Less rainfall and increased water withdrawal for drinking could be attributed for the reduction in the aerial water spread. The barren land increased over

the years as a result of agricultural land getting reclaimed, physical setting of the lake characterised by steep slope towards north east and illegal mining of laterite soil. The built-up area has increased mainly along the northern side of the Sasthamkotta freshwater wetland as the main road network passes through this region. There has been a significant decrease (by 75.8%) in vegetation as new buildings are constructed and agricultural land being reclaimed. During the study period it was found that the LULC class namely settlement with vegetation increased by 117%.
Furthermore, the discharge of effluent from the nearby Bharanikkavu town and Sasthamkotta town to the said wetland, local people using the lake water for their daily necessities, excess nutrient rich water flowing from the Karali marshy land, less bio-degradable acacia leaves (as compared to indigenous species) coupled with pollens of acacia floating on the lake water surface, intense soil erosion in the catchment area and growth of weeds could further degrade this freshwater wetland. All these point towards devising proper land use suitability assessment for proper land-use management of the study area to initiate comprehensive conservation measures.

Keywords: Land use–land cover changes**,** Adjoining Panchayats, Sasthamkotta freshwater wetland, Remote Sensing, Geographical Information System.

Introduction

Human beings have been altering the face of our planet for the last few centuries but with industrial revolution, the land cover of the earth has changed drastically. It is clear that the world is undergoing a shift from predominantly rural based society to an urban based society (Raj et al., 2010). Land use and land cover (LULC) changes are perhaps the most prominent form of global environmental change since they occur at spatial and temporal scales immediately relevant to our daily existence (Oyedotun 2019). The utilisation of land resources by humans has lead to "land use" and the same varies with the purpose it serves, whether it be agriculture, housing schemes, tourism, extraction and processing of raw materials, production of final products and the biophysical characteristics of the land itself.
Thus, the land use changes take place according to the needs of mankind, misuse and overexploitation of land (Harikrishna et al., 2013).
All the ecosystems in this planet are under continuous threat by organic and chemical pollution from agricultural and industrial sectors and the resultant degradation of the natural resources has always been on the rise. In developing countries, due to population pressure and in a bid to extract the maximum output from the available sources, the impact of degradation is worse than rest of the world and adversely affects the land cover of the region.
In India the pattern of LULC change is more complicated and unique compared to rest of the world as population explosion has led to rapid urban expansion (Swapan et al., 2020).Land cover refers to the physical and biological cover over of our planet's

terrestrial surface including our natural as well as our artificial resources (Basant et al., 2013).

The term land use is distinct from the term land cover even though both are commonly used together. The spatial distribution of the different land cover classes on our planet is represented by the term land cover, while land use and its changes require the integration of natural and social scientific methods to determine which anthropogenic activities are occurring in various landscapes, even when the land cover appears to be the same. These changes are mostly driven by anthropogenic activities and more frequently, these changes directly impact both human and the natural environment, causing loss in bio-diversity and contributing to vegetation reduction, soil erosion, ecosystem services alteration and natural resources (Masuma et al., 2018).The changes in LULC due to various physical, climatic and socio-economic factors are directly influencing the socio-economic statusof the local people as well (Ajay et al., 2017).

To determine the quantitative and qualitative changes in LULC of a region the spatial data on LULC is a pre-requisite. LULC changes, in addition to altering the physical dimension of the spatial extent of the land use and land cover classes, also influence many of the secondary processes which has lead to environmental degradation of our planet as a whole. The primary impact of LULC changes is the reduction of vegetation cover. The loss of vegetation cover in turn, leads to harmful environmental impacts namely biodiversity loss, change in climate, deterioration of existing natural ecosystems with a reduction in their quality, changes in hydrological regimes, and the list is endless. The secondary impact of LULC changes initiates a cascade of negative impacts on the environment and this in a cyclic process will further influence the forthcoming LULC changes. At the same time, it is to be noted that urban expansion and LULC changes will continue with time and space, and it is necessary to protect the land resources by taking imperative planning models with appropriate spatial data (Sandipta et al., 2020).

The scientific study and analysis of LULC change involves a quantitative estimation of LULC at a particular location and time. Application of remotely sensed data has made possible to study the changes in land cover in less time at low cost and with better accuracy (Rawat et al., 2013). Remote Sensing (RS) and Geographical Information System (GIS) techniques have been widely used nowadays to understand the changes in LULC and to document the spatio-temporal changes of an area as a part of environmental conservation (Hanqiu et al., 2006).RS is a technology used to monitor and evaluate the LULC changes, which typically vary from global to regional scale (Kaliraj et al., 2017). RS techniques have been found highly effective for timely accurate detection of regional and global deviation in LULC phenomena. The periodic alteration in land topographies, owing to natural or anthropogenic activities is defined as LULC transformation (Geena et al., 2018). Also the GIS technology provides a flexible environment for collecting, storing, displaying, and analysing digital data necessary for LULC change detection (Butt et al., 2015). GIS provides a digital representation of the LULC which is an important tool in the spatial analysis (Fang et al., 2021). During recent years a lot of advances have taken place in the field of remote sensing which has enabled the scientific community to capture repeated observations of the earth's surface in spatial and temporal scale. The multi-spectral satellite images provide satisfactory spectral resolution which in turn offers a reliable means to diagnose LULC changes. The integration of RS and GIS technologies proves to be an efficient method for mapping and analysis of urban land use changes as well (Li et al., 2010).

The triggering factors for landscape changes may be physical, biophysical, industrial, technological, institutional or economical. Deforestation and conversion of waterlogged wetlands into built up areas directly affects the ground water recharging capacity and natural water system flow regimes. The spatio-temporal changes especially in the land use of a wetland's catchment area have a direct influence on its hydrological realm as well. Now-a-days due to demographic pressure, LULC changes, rapid industrialisation and climate change, surface water quality deterioration has become a serious concern worldwide. As evident from the recent studies, the LULC change is one of the five major drivers of wetland degradation in Asia. Wetlands are unique ecosystems which play a pivotal role in climate adaptation and mitigation as the same is the home to 40% of the world's species and 12% of all animal species, wetland cover around 6% of the world's land area (Seema et al., 2018). Of late, the progressive deterioration of freshwater wetlands around the globe is an issue of grave concern. Even though freshwater habitats occupy less than 1% of the earth's surface, they support approximately 10 % of all known living species (David et al., 2010). Since the land use pattern of the adjoining area of freshwater wetlands play an important role in wetland conservation, the same demands high priority. It is estimated that approximately 35% of anthropogenic CO_2 emission resulted directly from land use. Thus, the relationship between climate change and land use change is very significant (Adam et al., 2019). The main driving force responsible for altering intensity and the frequency of hydrological process within a catchment area are LULC changes (Dionissis et al., 2020). Research on land use and land cover provides a base for exploration, the need for protecting freshwater wetlands. Past studies put focus on exploring LULC changes and their implication on climatic variables as well (Mohammad et al., 2019). Thus the need of the hour is constant quantitative as well as qualitative monitoring of water bodies thereby restoring the existing fresh water resource which is the prime most step towards sustainability of water quality management. Along with water quality parameters and sediment regime, spatial changes in LULC could be used in assessing the overall environmental burden of fresh water systems. Complex interaction between behavioral and structural factors associated with social relation, demand, infrastructural and technological capacity lead to land use changes affecting not only demand and function of the environment but also nature of the environment. Remote sensing technology is widely used by scientists in wetland research to determine LULC changes and hydrological processes in wetlands (Saleh et al., 2020).The well documented research in this direction driven by the need to predict the LULC changes and pollution is a standing testimony of the global concern over the issues (Pillai, 1981) (Prakasam, 1991) (Kokkal et al., 2007) (Sheela, 2012).

Intensive agronomic practices, population pressure, poverty and absence of comprehensive land-use practices have led to accelerated land use alteration

(Abreham et al., 2020). The State of Kerala, lying in the south western part of India, is well known for its unique pattern of development called urban rural continuum which is characterized by high level of growth in the socio-economic sector. Rapid urbanisation particularly in the adjoining areas of water bodies in Kerala has resulted in the deterioration of water bodies in terms of quantity and quality. In recent years, flash flooding in the monsoon season and severe drought in the summer season is being reported from the State of Kerala. Hence it is essential to study the impact of LULC changes in the said area.

This study focuses on determining the LULC changes in the adjoining three panchayats (namely Sasthamkotta, Mynagapally and West Kallada) of Sasthamkotta freshwater wetland, a Ramsar site in the Southern part of India both spatially and temporally using remote sensing-based techniques.

Materials and methods

Sasthamkotta freshwater wetland lies between $9^0$1'N to $9^0$4'N latitude and $76^0$36'30" E to $76^0$39'E longitude and is located in Kunnathur taluk of Kollam district (in the State of Kerala) in the south western part of India. The catchment area of Sasthamkotta freshwater wetland (the largest freshwater lake in Kerala) spreads out in three Panchayats namely, Sasthamkotta, Mynagapally and West Kallada. Physiographically the lake is located in the midland region (elevation between 7.5m and 75m above Mean Sea Level) and the highest elevation of the lake catchment area is 33m above Mean Sea Level in the northern part of the lake. The study area experiences a tropical humid climate (relative humidity 78%) with mean annual air temperature varying between 26.7ºC and 29.2ºC and an annual average rainfall of 2398mm due to south west and north east monsoon rainfall. Sasthamkotta freshwater wetland is surrounded on three sides by small residual hills and by an artificial bund in the south eastern part which was constructed in the year 1956 which separates the lake from the surrounding low lying land. Forest cover which existed in early forties has almost disappeared and currently cash crops are being grown in the hilly region causing changes in the hydrological cycle of the area. Water has been extracted from Sasthamkotta lake since 1956 for drinking purpose and the same caters to the drinking needs of more than 10 lakh people in Kollam district (Salin &Sreedevi, 2013). The contour of the lake is irregular with an inverted F shape which extends into the lake as pockets at several places. This freshwater wetland supports about twenty seven species of freshwater fishes (including pearl spot and catfish) and two genera of prawns (Prakasam & Joseph, 2000). The south western tip of Sasthamkotta lake has turned lush grassland over the years and the same is utilised by local farmers for cultivation and grazing their livestock. Hence there is a need for protecting and conserving the said lake ecosystem. **Fig. 1** shows the location map of the study area (adjoining panchayats of Sasthamkotta freshwater wetland system namely Sasthamkotta, Mynagapally and West Kallada) and the same was digitized from the Survey of India Topographic sheet 58C12 1967, using ArcGIS software.

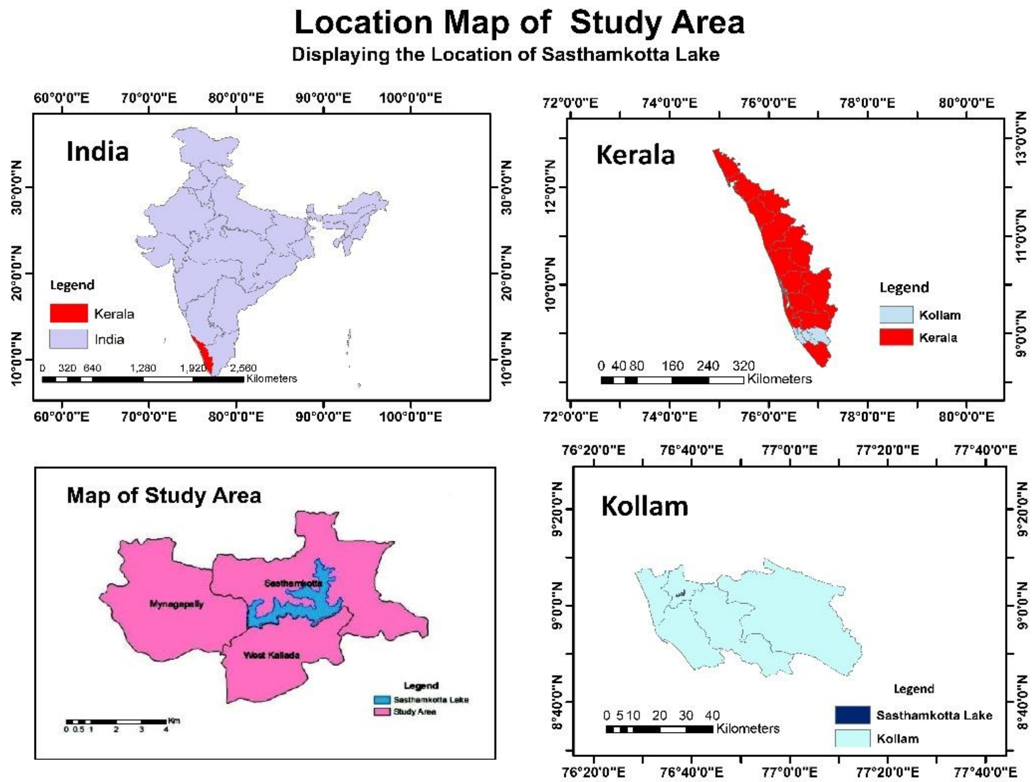

Fig. 1 Map of the study area

Satellite images for the years 1973, 1990, 2000, 2005, 2015, 2019, 2020 and 2021 consisting of multi-spectral data acquired by Landsat satellite provided by the United States Geological Survey (USGS) Earth Explorer were downloaded from the USGS website and the same was used for visual image interpretation and detecting LULC changes in the study area. Satellite images namely Landsat Thematic Mapper (Landsat TM), Landsat Enhanced Thematic Mapper Plus (Landsat ETM+) and Landsat 8 Operational Land Imager (Landsat 8 OLI) were used in this study and the details of the said satellite images are given in **Table 1.** The lack of clouds over the study area was an important factor in the selection of satellite images so as to increase the accuracy of the classification work.

The shapefile of the study area consisting of three Panchayats were delineated from Google earth pro. Later digitisation using ArcMap Software was carried out and the area of the corresponding polygons were computed. Thereafter, the downloaded satellite images for each required bands were mosaicked and necessary corrections were applied on the mosaicked images and stacking of all bands was carried out so as to obtain the composite multispectral images corresponding to each year. The composite images were then clipped using the study area and the said satellite images were classified using supervised classification. Various type of land use types were identified using visual interpretation and spatial pattern recognition and the land use change analysis was carried out on the classified images. The image classification was done in ArcGIS 10.3 using Landsat images by maximum likelihood classification. Maximum Likelihood Classifier (MLC) technique is an algorithm based classification method that depends on a combination of ground samples and personal experience with the study area and is strictly used in the field observed training samples of the real ground surface (Islam et al., 2017). The various land use classes used in this study were designated as water bodies, barren land, settlement with vegetation, vegetation and built-up area respectively.

Table 1 List of satellite imagery used in the study

Satellite and Sensor	Date of Acquisition	Path and Row	Spatial Resolution (m)
Landsat MSS	February, 1973	154/54	60
Landsat TM	February, 1990	144/54	30
Landsat ETM +	February, 2000	144/54	30
Landsat ETM +	February, 2005	144/54	30
Landsat OLI	January, 2015	144/54	30
Landsat OLI	February, 2019	154/54	30
Landsat OLI	February, 2020	154/54	30
Landsat OLI	March, 2021	154/54	30

For the classification of images, the training sample signatures were extracted from each of the imageries corresponding to each land use classes (from 1973 to 2021). GPS field surveyed data from the site was used for pre-field verification and training set creation and maximum likelihood algorithm was employed on the images for the supervised classification in ArcGIS software. MLC is the most widely adopted parametric classification algorithm and the same is used for the LULC classification of acquired imagery data taking into account the spectral characteristics of the satellite images and existing knowledge of land use of the study area. Thereafter the land use map of the study area for the said land use classes was prepared using ArcGIS10.3 and finally the changes in LULC over the years were determined.

Table 2 Delineated classes based on supervised classification

Class Name	Description
Water Bodies	River, lakes, canals, ponds and reservoirs
Barren land	Exposed soil, sand and rocky strata
Settlement with vegetation	Areas covered by planted vegetation/trees around settlements
Vegetation	Areas covered by trees, natural plants and Agricultural areas
Built-up area	Areas designated as residential, commercial, industrial zone, roads and transportation

Spatio-temporal LULC change information can be used for effective management and conservation of ecologically sensitive areas worldwide (Juan et al., 2021). The study area was selected for the image classification and the delineated classes were designated as water body, built-up area, settlement with vegetation, vegetation, and barren land respectively and the same is given in **Table 2.** Then the mapping and labeling of LULC features were done and thereafter the LULC change detection analysis was carried out. Finally, estimation of the transformed area from one class to another was calculated.

Results and discussion

LULC maps of the adjoining three panchayats (namely Sasthamkotta, Mynagapally and West Kallada) of Sasthamkotta freshwater wetland for the years 1973, 1990, 2000, 2005, 2015, 2019, 2020 and 2021 were prepared using the above methodology and the same are shown in **Fig. 2, 3, 4, 5, 6, 7, 8** and **9** respectively. In the LULC maps prepared for the study area, blue colour represents water bodies, yellow represents barren land, pink: settlement with vegetation, green: vegetation and red: built up area. The total area of the study area was found to be 64km^2.

LULC statistics of the adjoining three panchayats of Sasthamkotta freshwater wetland during the study period are given in **Table 3**. A detailed study of the said LULC statistics reveals that the area under various categories of LULC in the study area has changed significantly. Incorporation of built-up areas in the vegetated areas and reclamation of water body for agriculture is well reflected in the said land-use change statistics. From the year 1990, there has been a steady decline in the aerial water spread of water bodies in the study area. Water has been extracted from Sasthamkotta freshwater wetland for drinking purpose since 1956 with an intake capacity (water treatment plant constructed in the year 1956, run by Kerala Water Authority) of 22 million litres of water per day (MLD), which was enhanced later in the year 1991 to 37.5MLD. In addition to the said water withdrawal, another water treatment plant with a capacity of 11.5MLD was set up in the year 2008. Thereafter in the year 2015 an additional water treatment plant with a capacity of 9MLD started functioning.

As on today, water is pumped from Sasthamkotta lake at a withdrawal rate of about 58MLD for the said purpose. Less rainfall, water depleting acacia trees planted along the periphery of the said lake (during social forestry programmes) and increased rate of water withdrawal are the major causes for the reduction in the aerial water spread of Sasthamkotta freshwater wetland. During the field visit, it was observed that the south western tip of the lake corresponding to the Anjalimoodu region, south eastern portion of the lake corresponding to the bund that separates the lake from the surrounding paddy fields, Ambalakkadavu region and Bharanikkavu-Ookkanmukku region of Sasthamkotta lake has turned lush grassland and the same is utilised by local farmers for cultivation (namely plantain and tapioca) and for grazing their livestock.

Figure 2: Land use land cover map of 1973

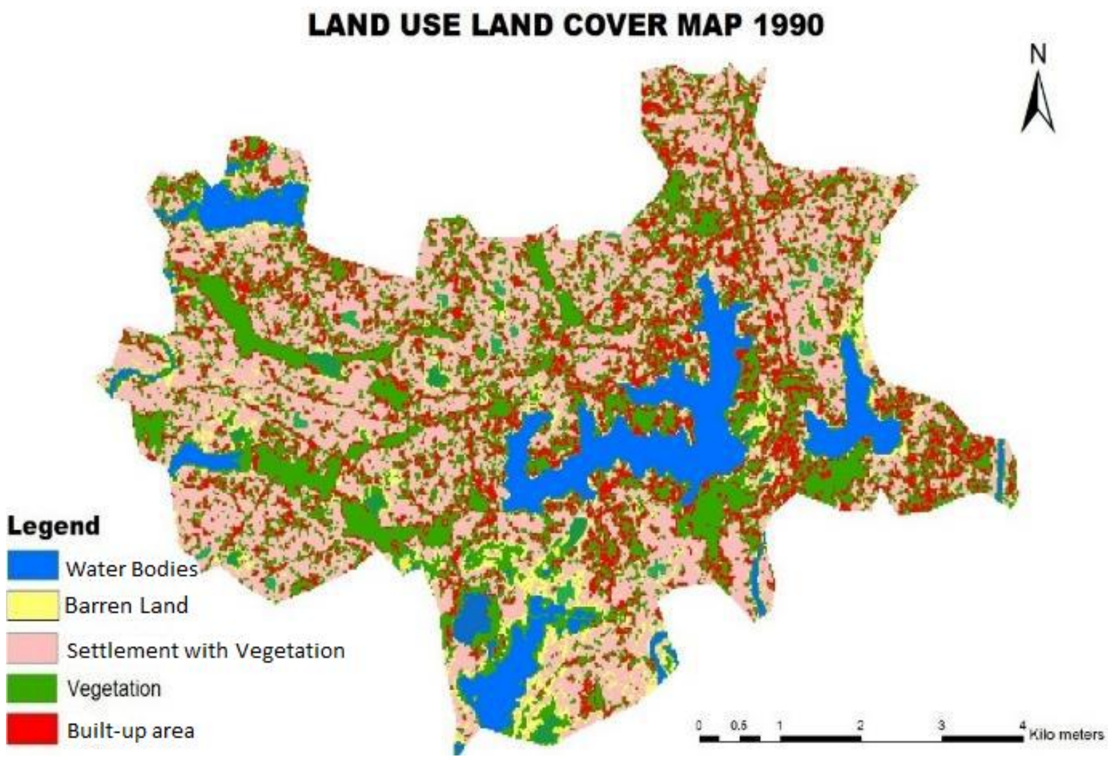

Figure 3: Land use land cover map of 1990

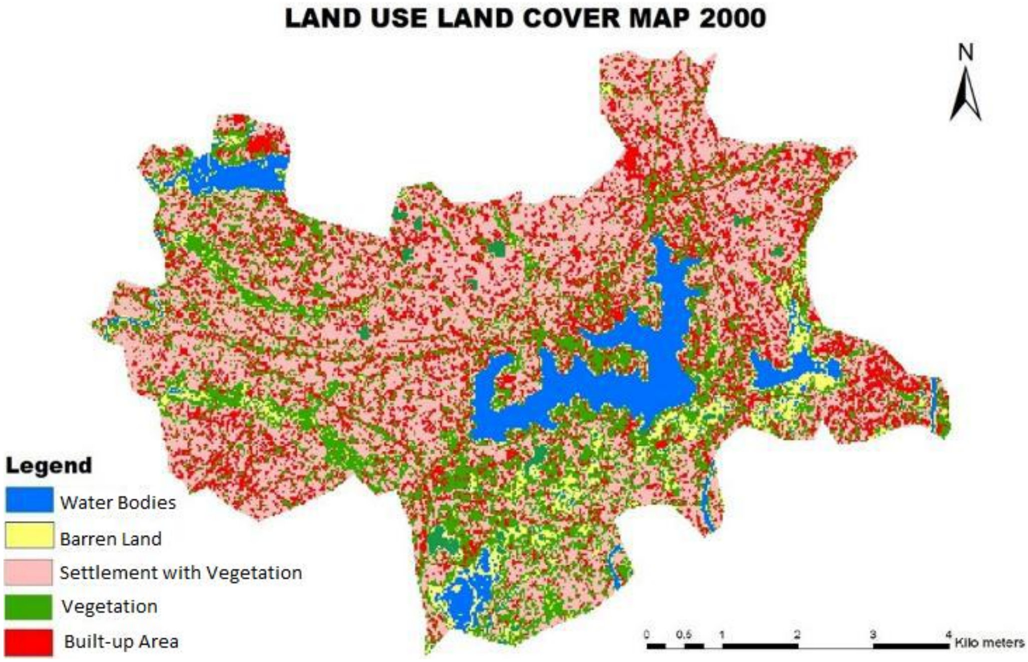

Figure 4: Land use land cover map of 2000

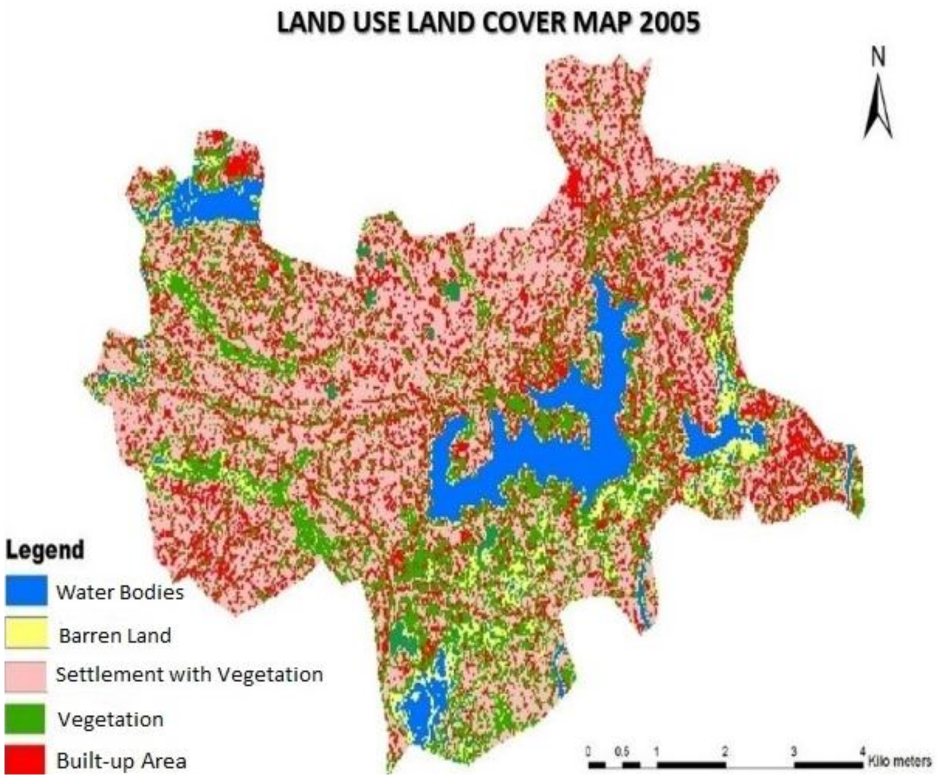

Figure 5: Land use land cover map of 2005

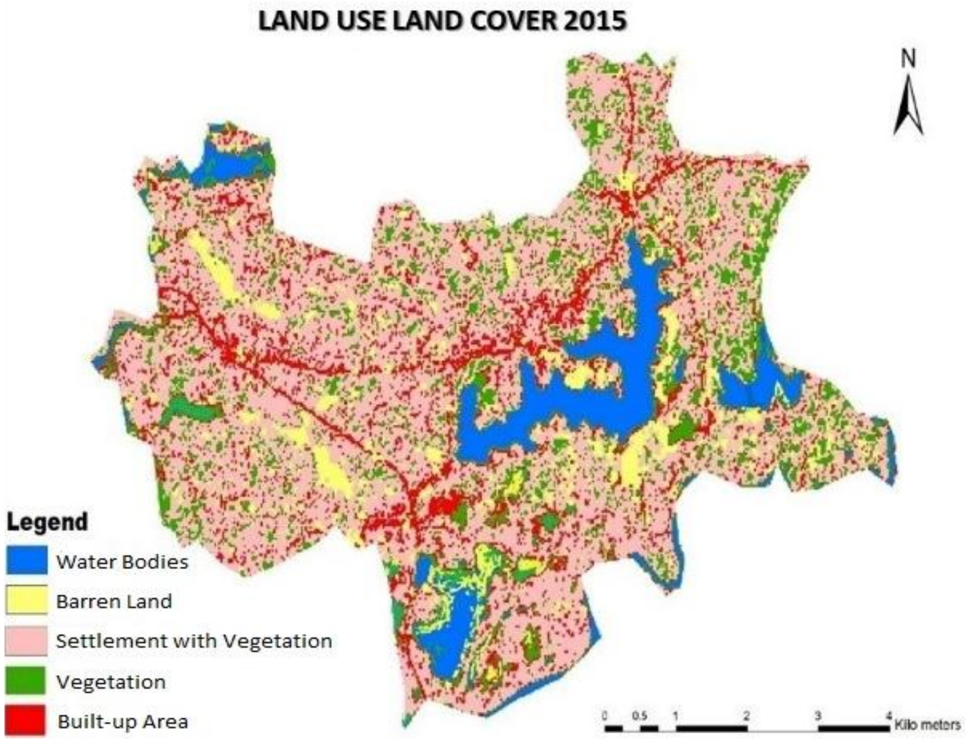

Figure 6: Land use land cover map of 2015

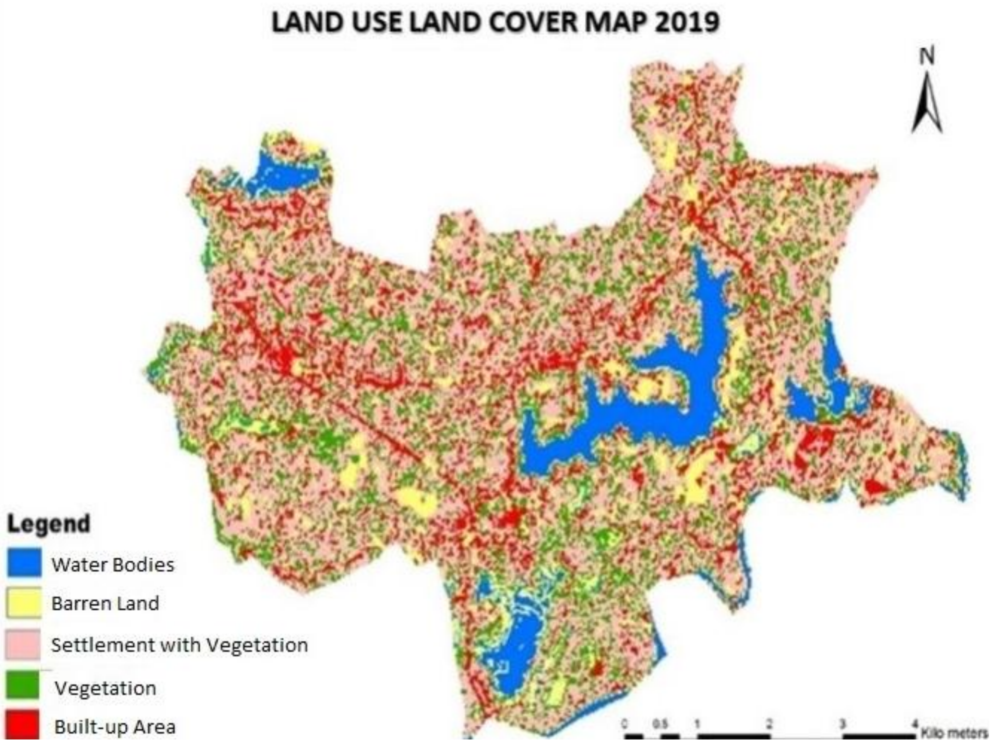

Figure 7: Land use land cover map of 2019

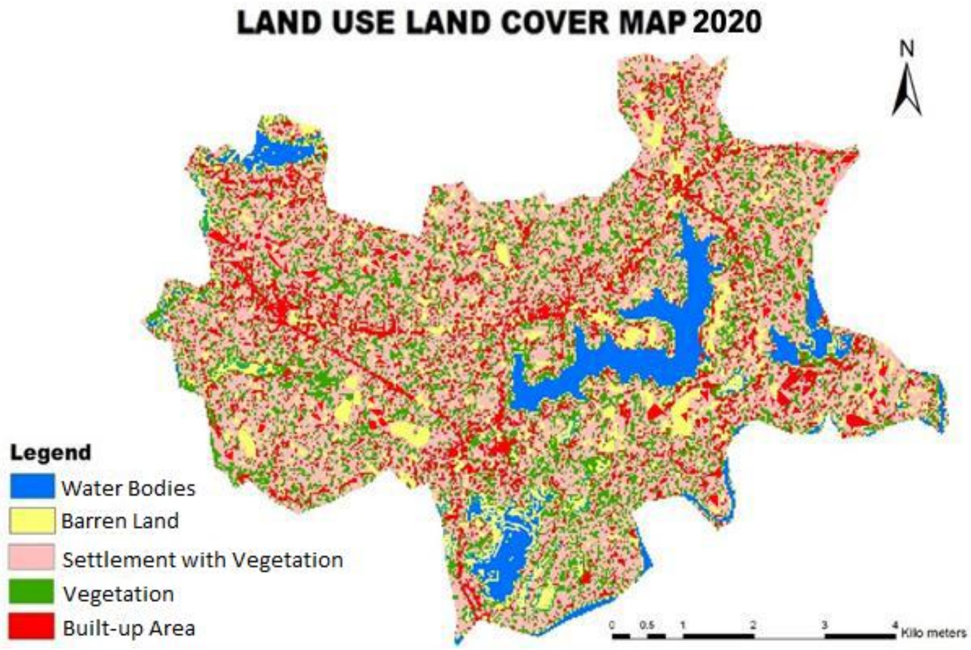

Figure 8: Land use land cover map of 2020

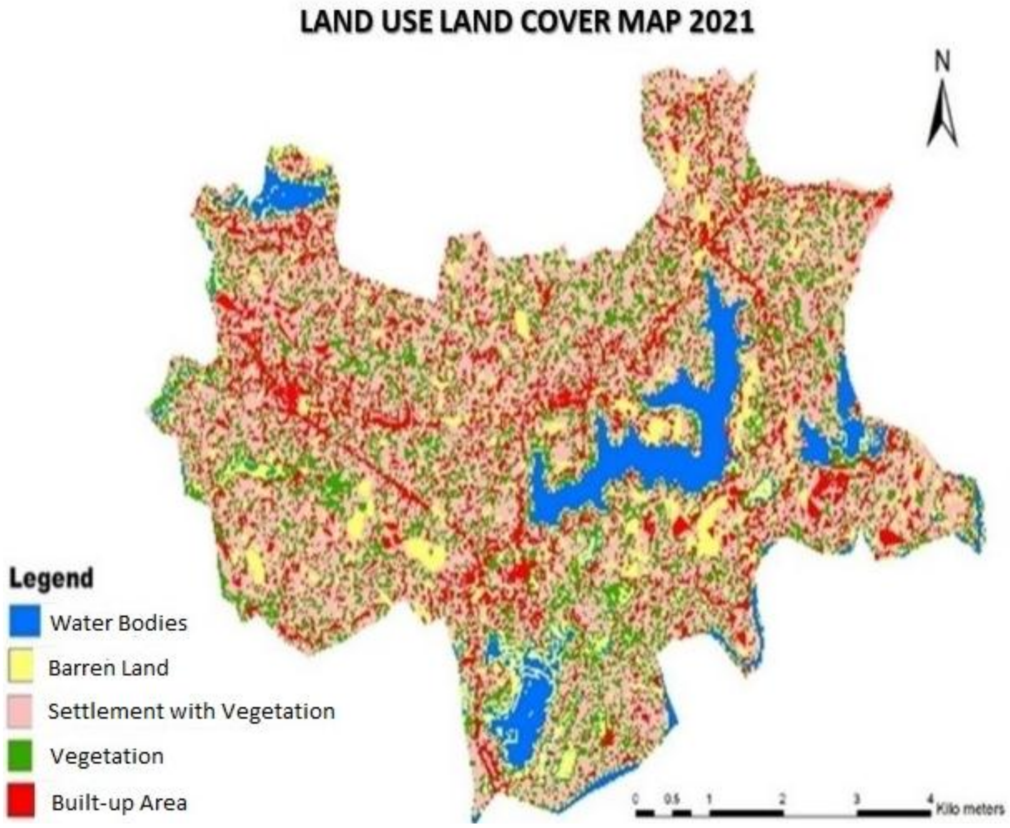

Figure 9: Land use land cover map of 2021

During the past 48 years there has been a significant decrease (by 75.8%) in vegetative cover and this could be attributed to the thickly populated catchment area of Sasthamkotta lake because of rapid urbanization (Incorporation of built-up areas into the vegetated areas) during the study period. Large tracts of Sasthamkotta lake's catchment area where water has receded during the summer (namely, Anjalimoodu region, south eastern portion of the lake corresponding to the bund that separates the lake from the surrounding paddy fields, Ambalakkadavu region and Bharanikkavu-Ookkanmukku region of Sasthamkotta lake) have been cleared and the local people are undertaking plantain and tapioca cultivation.

New buildings constructed as part of urbanization is well reflected in the land-use change statistics which has resulted in the decrease of vegetation that has occurred in the study area. It can be computed from **Fig. 2, 3, 4, 5, 6, 7, 8** and **9** that the barren land and built-up area has significantly increased during the study period and the same are 240.7% and 184.6% respectively. The increase in barren land in the study area could be attributed to agricultural land getting reclaimed for other purposes (due to economic loss in cultivation), the physical setting of the lake characterised by steep slope towards north east in Sasthamkotta lake's catchment area and very sparse vegetation on its banks and illegal mining of laterite soil by destroying hillocks (in the north eastern portion of Sasthamkotta lake). This illegal mining of lateritic soil has resulted in disappearance of several small hills which has lead to intense soil erosion and deposition of mud into the said wetland system.

It was observed that the increase in built-up area was close to two times during the study period. This increase in built-up area may be due to urbanization as the population growth rate of Kerala is expanding at a rate of 14% per decade and the number of households in the State is growing at an average annual rate of 19.35%. It is also seen that the built-up area has increased along the northern side of the Sasthamkotta freshwater wetland as the main road network in the study area passes through this region. As per the Government of India Census 2011, the number of households (Census houses) in Kollam district has increased to 6,63,276 compared to that of 5,92,237 in the year 2001 and this increasing trend is reflected in the LULC category settlement with vegetation as the same displayed an increase by117% during the study period (Government of India Census 2011). The breakdown of joint families giving way to the growing culture of nuclear family and high population density in Kerala coupled with high foreign remittance to the State has increased the demand for housing in the State.

This has resulted in rapid land conversion (Marshy lands and wetlands, which recharge groundwater and help in retaining soil moisture, have been today commonly reclaimed for constructing houses and setting up coconut and other plantations) which has lead to profuse changes in the State's landscape. After reclamation, the land is being sold at a higher price. It is also observed in the study area that the natural vegetation and conventional agricultural land are giving way to cash crops (namely rubber plantations which are being grown in the hilly region).The profit gained by cultivating rubber plantations could be attributed for the reduction in conventional agricultural practices in the study area. The said activities are taking place without the consent from the authorities concerned, and hence the LULC category namely barren land and built-up area has shown remarkable increase in the year 2021 compared to that of 1973.

Table 3: Area of various land use land cover categories (km^2) during 1973 and 2021

Category	**1973**	**1990**	**2000**	**2005**	**2015**	**2019**	**2020**	**2021**
Water body	9.17	10.53	.42	8.23	8.13	7.96	7.86	7.54
Barren land	1.77	2. 16	2.43	3.02	5.06	5.93	5.94	6.03
Settlement with vegetation	15.3	20.08	23.74	26.39	28.69	31.97	32.75	33.20

Conclusions

LULC monitoring and the associated change analysis is a prerequisite in preparing any conservation plan for our natural resources. This study, quantitatively demonstrates the pattern of LULC dynamics in the adjoining three panchayats (namely Sasthamkotta,
Mynagapally and West Kallada) of Sasthamkotta freshwater wetland using RS and GIS techniques from the year 1973 to 2021. During the study period, it was found that the LULC pattern showed a marked difference in areal extension of different LULC categories. The LULC classes namely barren land, built-up area and settlement with vegetation displayed an increasing trend and the same were quantified in terms of percentage as 240.7, 184.6 and 117 respectively. The LULC maps so generated revealed that there has been reduction in both vegetation (by 75.8%) and aerial spread of water bodies (17.78%) in the study area. Less rainfall, water depleting acacia trees planted along the periphery of the lake, increased rate of water withdrawal for drinking, agricultural land getting reclaimed for other purposes, the physical setting of the lake characterised by steep slope towards north east in Sasthamkotta lake's catchment area, very sparse vegetation on its banks, illegal mining of laterite soil by destroying hillocks and new buildings constructed as part of urbanization could be attributed to the said changes in the LULC dynamics. Furthermore, the discharge of effluent from the nearby Bharanikkavu town and Sasthamkotta town to the said wetland, local people using the lake water for their daily necessities, excess nutrient rich water flowing from the Karali marshy land, less bio-degradable acacia leaves (as compared to indigenous species) coupled with pollens of acacia floating on the lake water surface, intense soil erosion in the catchment area and growth of weeds could further degrade this freshwater wetland which point towards devising proper management action plan for the lake's conservation. To comprehend the said scenario, subsequent assessment with respect to landscape monitoring, human activities and close monitoring on climate parameters namely temperature, rainfall, relative humidity and evaporation are required. It is further suggested that detailed study on the same is to be carried out both at the micro as well as at the macro scale which will help policy makers to understand the environmental change dynamics so that appropriate policies could be framed for maintaining the ecological balance of Sasthamkotta freshwater wetland system.

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