ASSESSING THE RELATION BETWEEN LAND USE / LAND COVER CHANGES AND ENVIRONMENTAL PARAMETERS FOR CHENNAI CITY, TAMIL NADU : A REMOTE SENSING AND GIS APPROACH

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Abstract

Land use land cover changes in coastal regions are prone to many factors like rapid urbanization and industrialization, tourism, and tideline changes etc. Chennai city, a coastal city of TamilNadu, India has witnessed tremendous changes in land use land cover over the past two decades due to rapid urbanization and industrialization. Remote sensing and GIS technologies can efficiently help in analyzing these changes. In this study, changes in land use land cover patterns of Chennai city from 2005 to 2016 were assessed using IRS P6 LISS III remotely sensed satellite images. Post classification comparison-based change detection method was used to identify the changes in LU/LC. The study shows an increase in compact built-up and industrial areas by 15.36 % and 7.22 % respectively and a decrease in agricultural land, wetlands, and water bodies by 3.66%, 1.73%, and 5.24% respectively over the past decade. The obtained LU/LC changes were correlated with environmental parameters like Land surface temperature (LST), annual average rainfall and average groundwater level to establish a relation. Observations have shown that the temperature in Chennai metropolitan city has increased by 6̊c from 2005 to 2016 and the rainfall has reduced by 100mm from 2005 to 2016. This study demonstrated the relation between LU/LC changes over the past decade and the variations in environmental parameters like increased LST, reduced rainfall and groundwater.

Keywords: Land Use/Land Cover, Post classification change detection, Statistical Analysis, ground truth.

1. Introduction

Due to increase in population, industrialization and with large variation in climate and incidence of natural disaster, natural resources management has become a very complex issue. Study of natural and socio-economic factors that impact an urban environment is important today because of deteriorating environment and human health [Mallupattu et al., 2013] [Jat et al., 2008]. The environmental changes that take place in an urban environment are directly related to the land use/land cover changes of the area. The natural cover present on the earth surface can be termed as 'land cover' while the economic function and human activity associated with a specific piece of land is related to the term land use (Lillesand et al., 2014). The study of land use/land cover changes is important for effective planning and management of land and land related activities. Land use change in general is not only the change in purpose or usage of land (eg; land cover to urban), but can also represent a change in the intensity or management of land [Santhiya et al., 2010] [Verburg et al., 2000].

Land use / Land cover changes in coastal regions can be attributed to many anthropogenic factors like increasing population, tourism activities, development of small- and large scale industries, disposal of municipal wastes and untreated industrial wastes, expansion of harbours and tourism/recreation related activities in the coastal zone, numerous recreational and commercial activities that destroy the quality of coastal waters and pose a serious health hazard to marine biotas and human beings [Santhiya G et al., 2010] [Tran et al., 2002, Beiras et al., 2003; Rama Devi et al., 1996; ;Williams, 1996]. Hence, regular Updation of land use/land cover maps and analysing the changes in LU/LC is important to manage the land.

Traditional methods like regular field visits, Updation of toposheets, surveying etc. are not adequate as these approaches require ample of money and time. Technologies like satellite remote sensing and Geographical Information Systems (GIS) provide a synoptic view of the earth surface at varying resolutions and help in producing appropriate maps at various scales. The temporal acquisitions of satellite data from space borne sensors in conjunction with GIS can aid in studying and monitoring the dynamics of natural resources for environmental management [Berlanga et al., 2002]. Several researchers have focused on LU/LC studies of various districts in Tamilnadu [Senthil et al., 2018; Nagarajan et al., 2001; vijaykumar et al., 2016; Pandian. M et al., 2014] like Kanyakumari, Coimbatore, Thirupattur etc. due to the rapid urbanization taking place in Tamilnadu state. The main objective of this study is to identify and quantify

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the land use/land cover changes in Chennai district, Tamilnadu from 2005 to 2016 using IRS LISS III satellite data and to relate them with environmental parameters.

2. Study area and datasets

The study area is the greater Chennai metropolitan region located on the southeast coast of India and in the northeast corner of Tamil Nadu. The study area is located between longitude 80° 08′ 3.9411″ E and 88° 20′ 2.398″ E and latitude 13° 06′ 26″ N and 13° 14′ 3.924″ N covering an area of about 426 km2 in between 80º8’3.941’’E and 88º20’2.398”E (Figure 1The city has and average elevation of 6 metres (20ft), its highest point being 60m (200ft) and features a tropical wet and dry climate.

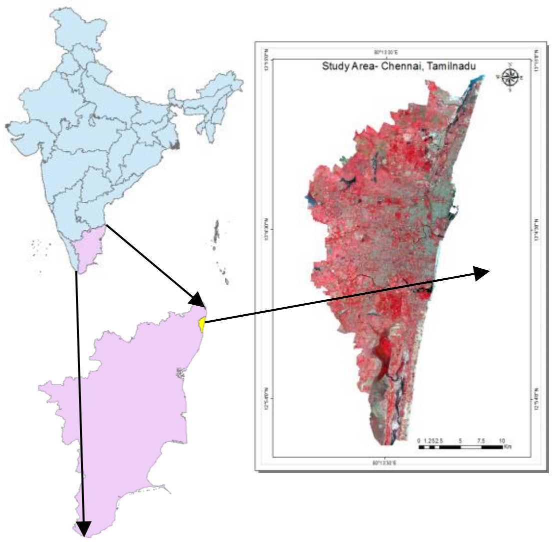

Figure 1: Location of Study Area

The temperature usually ranges between 13.9ºC to 45ºC. Study area lies on the thermal equator and is also coastal, which prevents extreme variation in seasonal temperature. The average annual rainfall is about 1400 mm (55 in) in this district and receives most of its seasonal rainfall from the north-east monsoon winds from mid – September to mid – December. The study area falls includes two rivers namely Adyar River and Cooum River. The Buckingham Canal, 4 km (2.5m) inland is a man-made canal that travels parallel to the coast linking the two rivers. According to 2011 census the total population of the district is 4,681,087 at density of 26,902 per sq.km.

2.2. Datasets used

The satellite data used for the study is from IRS – P6 LISS III (Resource-sat 2) of 23.5m spatial resolution, with 4 bands (green, red, infrared and short-wave infrared bands) in VNIR region. The data has a temporal resolution of 24 days with 8-bit radiometric resolution.

The Surface temperature was calculated from Landsat data data using the Landsat 5 TM for 2005 and Landsat OLI data for 2016.

3. Methodology

The methodology adopted for the study has been divided into three parts – Data acquisition and pre-processing, automatic feature extraction and manual interpretation, relating the LULC changes with the environmental factors. The overall methodology flowchart is presented in figure 2.

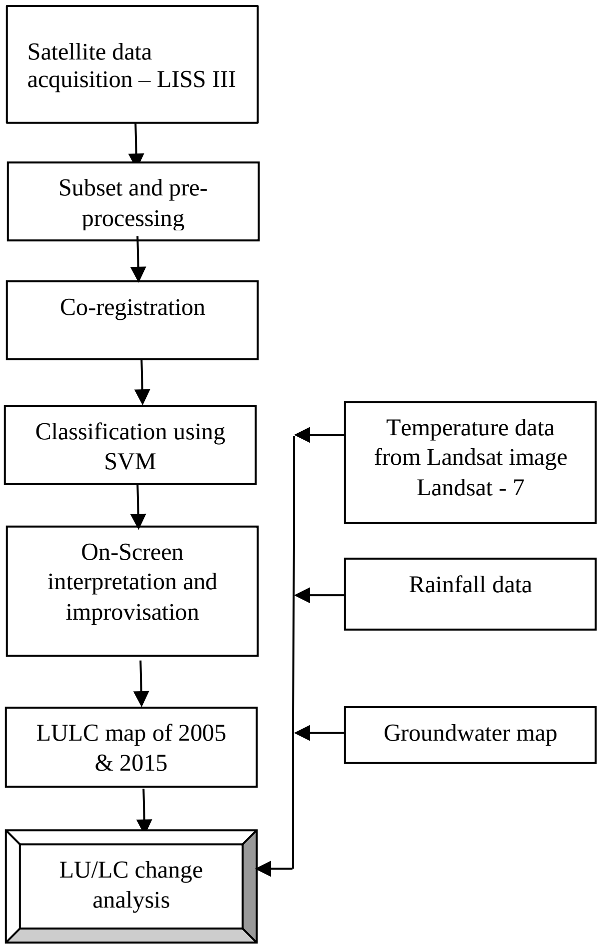

Figure 2. Over view of Methodology

a. Data Preparation: The ortho-rectified and geo-referenced IRS LISS III data acquired for three seasons- Kharif, Rabi and Zaid during 2005 and 2016 was used for delineating and mapping of land use/land cover classes. Change detection techniques work well with atmospherically corrected images as the data is converted to standard reflectance values. Hence, the 2005 and 2016 images were atmospherically corrected using empirical line atmospheric correction method. Later the atmospherically corrected images were co-registered.

b. Classification and Image Interpretation : The atmospherically corrected images were classified using Support Vetor Machine classifier with RBF kernel . Classification was performed on the rabi image for 2005 and 2016. Six major LU/LC classes were considered for SVM classification. Later the obtained classes were vectorised and used for onscreen interpretation.

Image interpretation of three season's data was based upon on-screen up interpretation using image interpretation keys. Standard image enhancement procedures and extraction of interpretation keys was followed prior to actual start of visual image interpretation of the satellite data. Besides a quick reference from interpretation keys, use of field knowledge acquired from field visits provided extra help in demarcating and delineating the land use classes. Classification of rabi season data was carried out first and resultant vector was overlaid on the Khari season satellite imagery to incorporate the features better delineable in Kharif data.

A Total of 36 land use / land cover classes were studied for the year 2005 and 2016 under the major six classes of land use/land cover classification - given in **table 1.**A brief description of Major land use/ land cover of the study area is given below.

Major Class	Definition	Sub classes
Built Up Land	They constitute area of human habitation developed due to non-agricultural use and consists of buildings, transport and communication , utilities in association with water, vegetation and vacant lands.	1. Compact Built up (Continuous) 2. Sparse Built up (Discontinuous) 3. Vegetation/Open area 4. Rural 5. Industrial areas. 6. Mining areas – Active 7. Ash cooling ponds 8. Quarry
Agricultural Land	They are lands primarily used for farming and for production of food, fibre and other commercial and horticulture crops. It includes land under crops (irrigated or non-irrigated fallow, plantations etc.).	1. Kharif Crop, 2. Rabi crop 3. Zaid crop 4. Cropped in two seasons 5. Cropped in three seasons 6. Fallow land 7. Agriculture plantation 8. Aqua culture
Forest	The term forest is used to refer to land with a tree canopy cover of more than 10 percent and area of more than 0.05ha.These are areas which constitute predominantly of trees and other associated vegetation types capable of producing timber and other forest produce.	1. Deciduous-Dense/Close, 2. Scrub Forest, 3. Swamp/Mangroves-Dense/Closed, 4. Swamp/Mangroves-Open 5. Tree Clad Area-Dense/Closed 6. Tree Clad Area-Open.
Wasteland	Wasteland refers to degraded land which can be brought under vegetative cover with reasonable effort and which is currently underutilized and land which is deteriorating for lack of appropriate water and soil management or on account of natural causes. These lands can result from inherent/imposed disabilities such as location, environment, chemical and physical properties of the soil or financial or management constraints.	1. Salt Affected Land 2. Scrub land-Dense 3. Scrub land-Open 4. Sandy area-Coastal.
Wetland	Refers to submerged or water-saturated lands, natural	1. Natural (Ox-box lake cut-off meander, waterlogged etc.)

	or manmade, inland or costal, permanent or temporary, static or dynamic which necessarily have a land-water interface.	2. Coastal Wetlands -Lagoon creeks, mud flats etc. 3. Saltpans.
Water Bodies	Water bodies comprise areas with surface water, either in the form of ponds, lakes and reservoirs of flowing as streams, rivers etc.	1. River-Perennial 2. River-Non Perennial 3. Canal/drain 4. Lake/Ponds-Permanent 5. Lake/Permanent-Seasonal 6. Reservoir/Tank-Permanent 7. Reservoir/Tank-Seasonal.

Table 1. List of major classes and their subclasses

c. Ground truth collection and verification: Once the pre-field interpretation is completed, fields visits for verification and correction of doubtful areas were carried out. Field details were directly noted on the maps for post-ground truth corrections and modifications for compilation in the laboratory. All the parameters collected were used for checking the quality of mapping as well as accuracy estimation and corrections to be incorporated into the post-interpretation process. During ground truth collection at the specified points plotted, a detail of the land use site that was verified is recorded in Ground data.

d. Post field corrections and accuracy assessment: The resultant maps obtained after visual interpretation were validated using the ground data. The points collected during field visits are used for quantitative assessment of overall accuracy of the map. After finalization of the layers, area calculation is done to obtain area statistics. Change analysis is also carried out and change area and percentage were calculated.

e. Relating the LU/LC changes to environmental parameters

Three parameters namely temperature, rainfall and groundwater levels were related to the LU/LC changes observed in the study area. Seasonal rainfall data along with ground water depth from mean sea level were used. The field data was collected for ground water depth (from mean sea level) at 25 different location within the study area. The data was collected every month from 2005 to 2016. Average yearly ground water depth map for the years 2005, and 2016 was prepared in GIS. The obtained ground water level maps were related with the rainfall information. Landsat data for 2005,and 2016 were used to analyse the trends of temperature in Chennai district. Thermal bands from Landsat 8 OLI sensor (for 2016), and Landsat 5 TM sensor(2005) were used to analyse the land surface temperature. The Landsat images were downloaded for October month from USGS earth explorer site. The methodology for temperature calculation was adapted from Reddy, S. N., & Manikiam, B., 2017. The thermal bands were first converted to radiance and then converted to surface temperature using K1 and K2 constants. The obtained temperature image is converted into Celsius by subtracting a value of 272.15 from the image.

4. Results and Discussions

4.1. Land use/land cover Classification of 2005

For land use/land cover analysis of 2005 year, IRS LISS III image of covering an area of 426 sq.km was initially classified into six major classes namely built up, agricultural land, forest, wastelands, wetlands and water bodies**.** The classified LU/LC map with six classes is shown in figure 5. This map was further classified into subclass map with 36 classes, presented in figure 3. Observations have shown that a major part of the study area is covered by built up land. Chennai district is a flat coastal area. In the year 2005, the total area of 316.55 sq.km area is covered by built up and 49.47 sq.km area is occupied by agriculture and follow lands and 34.86 sq.km by water bodies.

The rest of the classes like wastelands, Wetlands and Forest cover less than 2 percent of the total area. In 2005, a major part of the study area is covered with built up land whereas agriculture is dominantly seen in the northern part of the district. Table 2 gives the area and change statistics of various major LU/LC classes and Table 3 represents the area & change statistics of various LU/LC sub classes for the years 2005 and 2016.

The major class – built up was further classified into eight major classes, built up - compact (continuous), sparse (Discontinuous), vegetated/open area, rural, industrial area, ash/cooling pond/effluent and other waste, mining-active and mining-quarry. The study area is dominantly covered with compact built up area- 74.31 % followed by 15.64 % of sparse built up (Discontinuous) area, 8.38 % of vegetated/open area and 5.13 % of industrial area coverage. The rest of the built up classes covered less than 1 % of the area. 49.47 sq.km of the total study area is occupied by agricultural land. 3.43% of the total area is covered by Cropped in 2 season's area and 2.70 % is covered by agricultural plantation area. The forest class was less than 2 % area(1.25%), covered by deciduous - dense, scrub forest, and swamp / mangroves-open, tree clad area-dense and open. 31 sq.km of the total area is covered by forest area. Under the major forest class six sub classes were studied for the year 2005. Swamp/Mangroves-Dense/Close area covered a total of 3.60 sq.km of the total forest area of 5.31 sq.km. Wastelands occupied an area of 8.10 sq.km in Chennai district in the year 2005. 0.02 % covered by salt affected land, 0.90 % Scrub land-dense, 0.73 % by scrub land-open and coastal sandy area was 0.25 %.

Wetlands occupied an area of 11.70 sq.km i.e., 2.75%. Natural (Ox-box lake, cut-off meander, waterlogged etc.) occupied an area of 0.02 %, coastal-lagoon, creeks, mud flats etc. covered an area of 2.70 % and 0.02 % of area is covered by saltpans. 34.86 sq.km is classified under water bodies in the year 2005. Seven sub-classes were studied, namely perennial river, non-perennial river, canal / drain, lake ponds-permanent, seasonal lakes/ponds, reservoir /tank-permanent and reservoir /tank-seasonal. 15.10 sq.km of the total area is covered by perennial river and seasonal reservoir/tank is of 11.43 sq.km and 4.40 sq.km is covered by non-perennial river.

4.2. Land use/Land cover Classification for 2016

Observations of land use/land cover map of 2016 have shown that a major part of the study area is covered by built up land. The classified LU/LC map with six classes is shown in figure 4. This map was further classified into subclass map with 36 classes, presented in figure 5. Out of the entire 426 sq.kms of area, 361.33 sq.km was occupied by built up, followed by 22.32 sq.km by water bodies and 15.61 sq.km by agricultural land. 14.21 sq.km area was covered by wasteland, wetlands occupied an area of 7.38 sq.km and 5.51 sq.km was covered by forest. The built up area is increasing because of the increase in population. Around 33.86 sq.kms of agricultural land was lost due to urbanization during the past decade. Built up and wastelands have increased by 10.51% and 1.43% from 2005 to 2016. Agricultural land and water bodies reduced by 7.95% and 2.94% respectively.

Under the built up sub classes, 58.21 % of the total area is covered by compact built up, 12.35 % is covered by industrial area, 5.78 % is includes sparse built up classes. Vegetated / Open Area and Rural area covered 3.74 % and 3.62 % of the total study area. The remaining three sub-class covered less than 2 % of the of the study area shown in **Table 3**. Statistics show that there is 9.86% of sparse built up and 4.64% of vegetated/open area was converted to compact built up during 2005 to 2016. Similarly, the statistics of various agriculture classes, forest, wastelands and wetlands are shown in table 3.

It was observed that the reservoirs/tanks – seasonal have reduced by 5.74 sq.km and perennial rivers have reduced by 11.21sq.kms. During the year 2005, the total Agricultural area covered was 11.61 % and during 2016 the total agricultural area has drastically reduced to was 3.66 %. Nearly 33.86 sq.km of agricultural land is converted to built up area. 11.70 sq.km area covered by wetlands in the year 2005, has reduced to 7.38 sq.km. This reduction in wetlands and agricultural lands can be attributed to the intensity of urbanization or anthropogenic activities in Chennai district. Similarly, the area of water bodies – tanks, rivers/canals etc have reduced by 12.53 sq.km which may be due to seasonal changes or drying up of rivers. Ground investigations have revealed that water bodies were dumped with piles of materials and were later on converted to concrete structures. Built up area showcased a drastic increase by 44.78 sq.km. In 2005, the total area under built up was 316.55 sq.km and during the year 2016 , the total area covered by built up was 361.33 sq.km. This increase was due to establishment of various Institute, Industries and development in the process of urbanization due to the increase in population. The area of wastelands has almost doubled during the decade from 6.10 sq.km in 2005 to 14.21 sq.km in 2016. This may be attributed to the development of scrubs on wetlands, dumping yards etc.

Change analysis was carried out by subtracting the area of 2005 from 2016 area statistics. The change area and percentage change is presented in table 2. Figure 5 shows the change area statistics in graphical format. Figure 6 and Figure 7 represent the area percentage of various major LU/LC classes in 2005 and 2016 respectively.

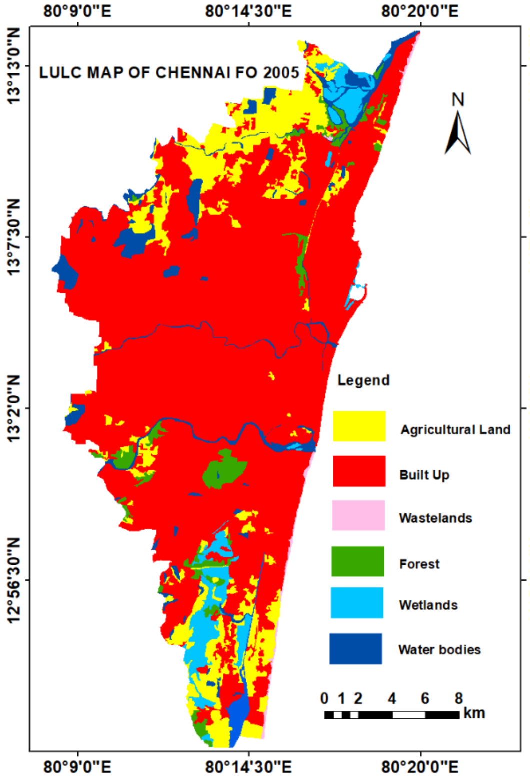

Figure 3a. LU/LC map for major classes – 2005

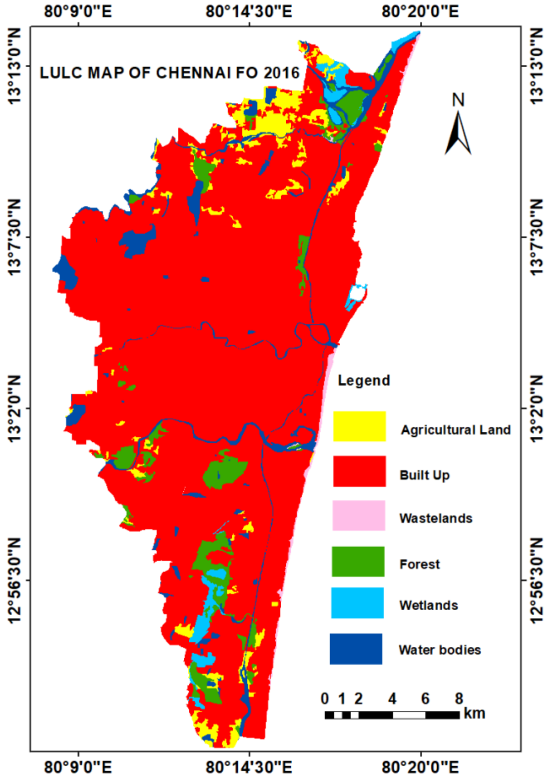

Figure 3b. LU/LC map for sub-classes - 2005

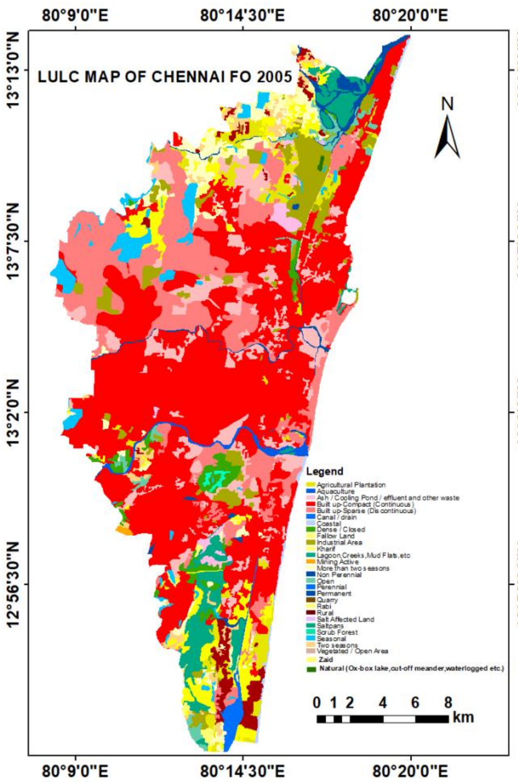

Figure 4a. LU/LC map of major classes – 2016

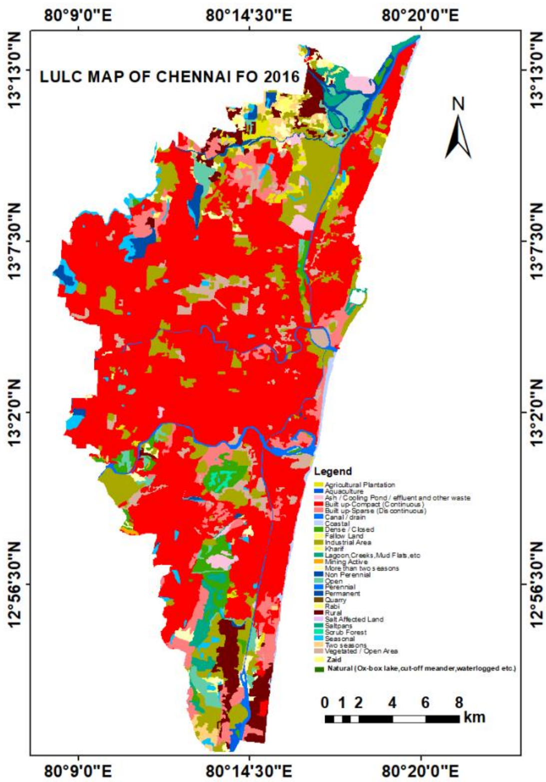

Figure 4b. LU/LC map of sub classes - 2016

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Table 2. Comparison of Major Land Use/Land Cover Statistics Changes from 2005-2016

Sl. No	Land use/land cover	Area in sq.km.		Area in %		Changes (2016-2005)	
		2005	2016	2005	2016	Area in sq.km.	Area in %
1	Built up	316.55	361.33	74.31	84.82	44.78	10.51
2	Agricultural Land	49.47	15.61	11.61	3.66	-33.86	-7.95
3	Forest	5.31	5.15	1.25	1.21	-0.16	-0.04
4	Wastelands	8.10	14.21	1.90	3.34	6.10	1.43
5	Wetlands	11.70	7.38	2.75	1.73	-4.32	-1.01
6	Water bodies	34.86	22.32	8.18	5.24	-12.53	-2.94

Figure 5. Chart showing change in area from 2005-16 in sq.kms

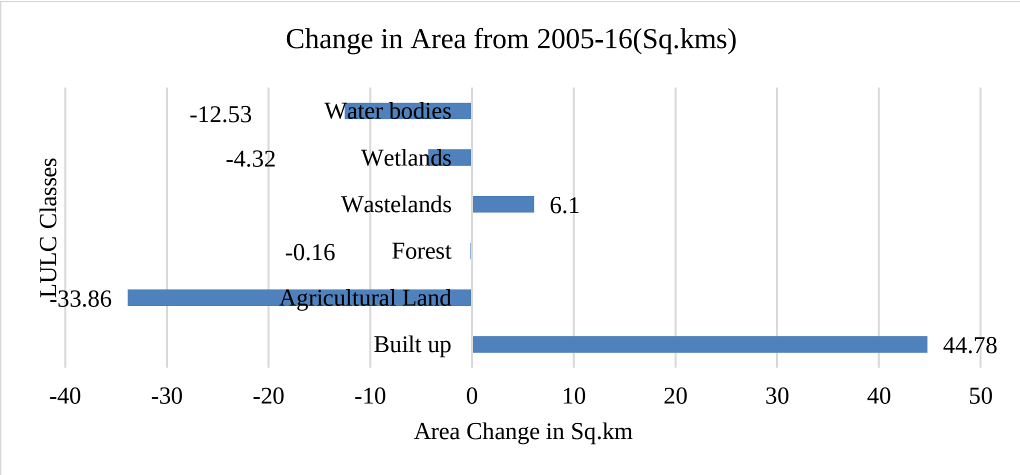

Table 3. Comparison of Land Use/Land Cover Statistics Changes of various sub-class within the major class from 2005 & 2016

SL.No	Land use/land cover	Area sq.km.		Area in %		Changes (2016-2005)	
		2005	2016	2005	2016	Area in sq.km.	Area in %
1	Built up-Compact (Continuous)	182.51	247.96	42.84	58.21	65.45	15.36
2	Built up-Sparse (Discontinuous)	66.63	24.62	15.64	5.78	-42.01	-9.86
3	Built up-Vegetated / Open Area	35.68	15.92	8.38	3.74	-19.76	-4.64
4	Built up-Rural	6.53	15.41	1.53	3.62	8.89	2.09
5	Built up-Industrial area	21.85	52.62	5.13	12.35	30.77	7.22
6	Built up-Ash / Cooling Pond / effluent and other waste	3.12	4.64	0.73	1.09	1.51	0.36
7	Built up-Mining-Active	0.20	0.13	0.05	0.03	-0.07	-0.02
8	Built up-Mining-Quarry	0.03	0.03	0.01	0.01	0.00	0.00
9	Agricultural Land-Kharif	7.58	0.10	1.78	0.02	-7.48	-1.76
10	Agricultural Land-Rabi	7.61	1.20	1.79	0.28	-6.41	-1.51
11	Agricultural Land-Zaid	0.75	0.06	0.18	0.01	-0.69	-0.16

12	Agricultural Land-Cropped in 2 seasons	14.63	4.63	3.43	1.09	-9.99	-2.35
13	Agricultural Land-Cropped in more than 2 seasons	6.74	5.62	1.58	1.32	-1.12	-0.26
14	Agricultural Land-Fallow land	0.61	0.13	0.14	0.03	-0.48	-0.11
15	Agricultural Land-Agriculture Plantation	11.52	3.83	2.70	0.90	-7.69	-1.80
16	Agricultural Land-Aquaculture	0.03	0.03	0.01	0.01	0.00	0.00
17	Forest Deciduous-Dense / Closed	0.98	1.03	0.23	0.24	0.05	0.01
18	Forest-Scrub Forest	0.03	0.08	0.01	0.02	0.05	0.01
19	Forest-Swamp / Mangroves-Dense / Closed	3.60	3.41	0.85	0.80	-0.19	-0.05
20	Forest-Swamp / Mangroves-Open	0.08	0.02	0.02	0.01	-0.06	-0.01
21	Forest-Tree Clad Area-Dense / Closed	0.40	0.42	0.09	0.10	0.02	0.00
22	Forest-Tree Clad Area-Open	0.22	0.18	0.05	0.04	-0.04	-0.01
23	Wastelands-Salt Affected Land	0.09	0.06	0.02	0.02	-0.02	-0.01
24	Wastelands-Scrub land-Dense / Closed	3.85	3.09	0.90	0.73	-0.76	-0.18
25	Wastelands-Scrub land-Open	3.09	9.21	0.73	2.16	6.12	1.44
26	Wastelands-Sandy area-Coastal	1.07	1.84	0.25	0.43	0.77	0.18
27	Wetlands-Inland-Natural (Ox-box lake, cut-off meander, waterlogged etc.)	0.10	0.05	0.02	0.01	-0.05	-0.01
28	Wetlands-Coastal-Lagoon, creeks, mud flats etc.	11.50	7.21	2.70	1.69	-4.29	-1.01
29	Wetlands-Coastal-Saltpans	0.10	0.12	0.02	0.03	0.02	0.01
30	Water bodies-River-Perennial	15.10	3.89	3.54	0.91	-11.21	-2.63
31	Water bodies-River-Non Perennial	4.40	5.03	1.03	1.18	0.63	0.15
32	Water bodies-Canal / drain	2.52	2.96	0.59	0.70	0.45	0.11
33	Water bodies-Lake / Ponds-Permanent	0.03	0.02	0.01	0.01	-0.01	0.00
34	Water bodies-Lake / Permanent-Seasonal	0.25	0.89	0.06	0.21	0.64	0.15
35	Water bodies-Reservoir / Tank-Permanent	1.14	3.83	0.27	0.90	2.69	0.63
36	Water bodies-Reservoir / Tank—Seasonal	11.43	5.69	2.68	1.34	-5.74	-1.35

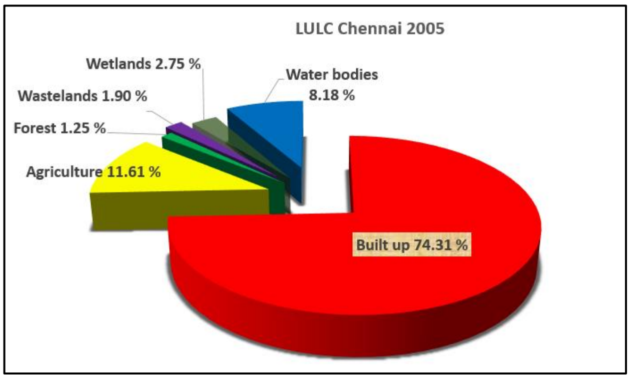

Figure.6. LU/LC of Chennai District in 2005

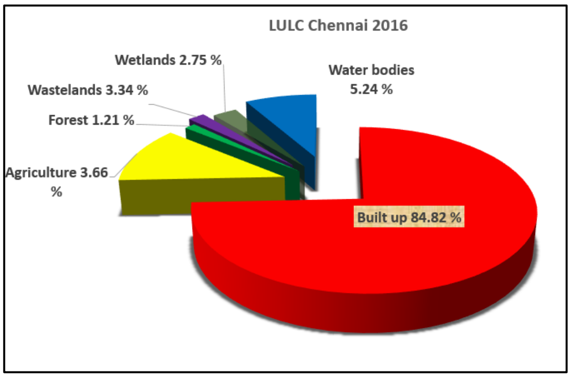

Figure.7.LU/LC of Chennai District in 2016

Table 4 gives the accuracies of LU/LC maps for 2005 and 2016 maps. Accuracy assessment was performed using 8 control points and 6 check points for each class. The sub class map was validated using 5 control points and 2 check points. The major class LU/LC map of 2005 has an accuracy of 91.08% and the LU/LC major class map of 2016 has an accuracy of 90.89%. The sub-class maps have recorded a slightly less overall accuracy of 87.56% for 2005 map and 87.88% for 2016 map.

Table 4. Overall accuracy of land use/land cover maps for major and sub class maps in 2005 and 2016

Year	Classes	Overall accuracy
2005	Major class map – 8 classes	91.08%
2005	Sub class map – 36 classes	87.56%
2016	Major class map – 8 classes	90.89%
2016	Sub class map – 36 classes	87.88%

4.3. Rainfall Variation from 2005 to 2016

Monthly rainfall data collected from at different rain-guage stations was averaged according to seasons (table 5.). Rainfall from April to July was considered as pre-monsoon, August to November was considered as monsoon, December to March was considered as post – monsoon. A detailed trend analysis of rainfall data from 2002 to 2016 was carried out in three intervals – 2005, 2010 and 2016. Trend indicated that highest yearly average rainfall was recorded in the years 2005 and 2016 while the year 2010 recorded a relatively less rainfall. From figure 8, it can be observed that the year 2005 recorded highest rainfall upto 982.93mm at Egmore, while the same location encountered the lowest rainfall in the year 2010. The rainfall conditions have again improved by 2016.

Table 5. Season-wise rainfall data of different rain-guage stations for 2005, 2010, 2016.

Seasonal Average Rainfall at Red hills			
YEAR	Pre-Monsoon	Monsoon	Post Monsoon
2005	269	1430	510
2010	583	823.6	243
2016	277	1571.8	464.8
Seasonal Average Rainfall at Tharamani			
YEAR	Pre-Monsoon	Monsoon	Post Monsoon
2005	235.20	1463.00	459.00
2010	411.80	681.40	301.50
2016	299.90	1229.80	446.20
Seasonal Average Rainfall at Nungambakkam			
YEAR	Pre-Monsoon	Monsoon	Post Monsoon
2005	295.70	1838.20	428.20
2010	415.90	840.10	292.60
2016	246.40	1390.70	456.70
Seasonal Average Rainfall at Mylapore			
YEAR	Pre-Monsoon	Monsoon	Post Monsoon
2005	328.50	1738.80	483.00
2010	376.00	724.60	290.20
2016	278.60	1410.00	490.60
Seasonal Average Rainfall at Egmore			
YEAR	Pre-Monsoon	Monsoon	Post Monsoon
2005	409.50	1971.30	568.00
2010	527.00	559.00	264.00
2016	219.00	1549.00	600.20

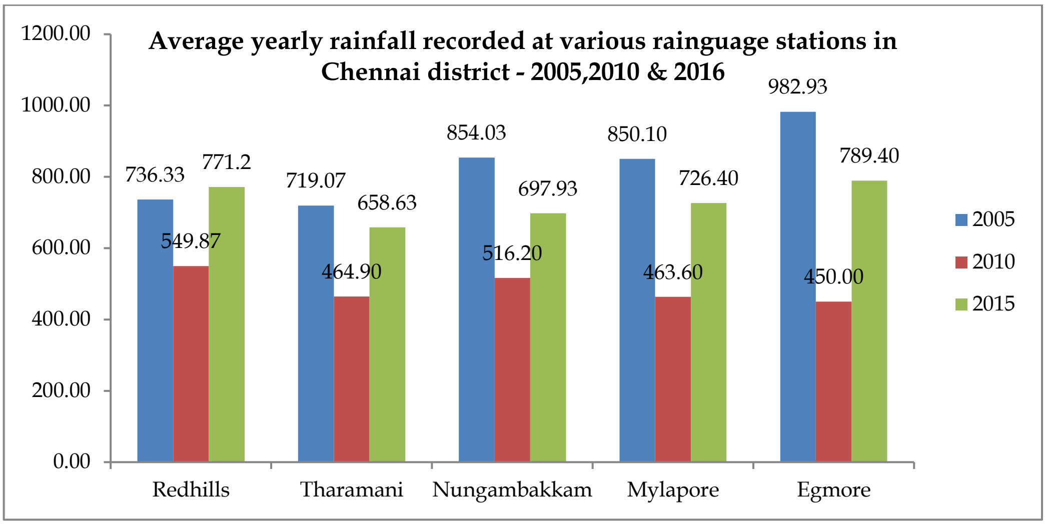

Figure 8. Average yearly rainfall in 2005, 2010 and 2016.

4.4. Groundwater level observations

Ground water level (from mean sea level) data was obtained from secondary sources from the year 2005 to 2016. The obtained data was analysed at two intervals – 2005, 2016. Monthly data available for these years was averaged to obtain the average ground water map. Field data was collected for 25 well points spreading all over the study area. The groundwater level in the study area was ranging from -2.8 to 39.06 meters above the mean sea level. In order to analyse the data, the entire range was divided into five intervals like –3.0 to 0.0m, >0 to 5.0m, >5 to 10.0m, >10 to 15.0m and >15.0 to 40.0m. The ground water level maps for 2005 and 2016 are presented in figure 9. It was observed that, in the year 2016, the ground water depths close to the coast area mostly ranged between 0.0 to 5.0m. And, observations in the land region showed that the ground water depth has ranged from 11 – 40m.

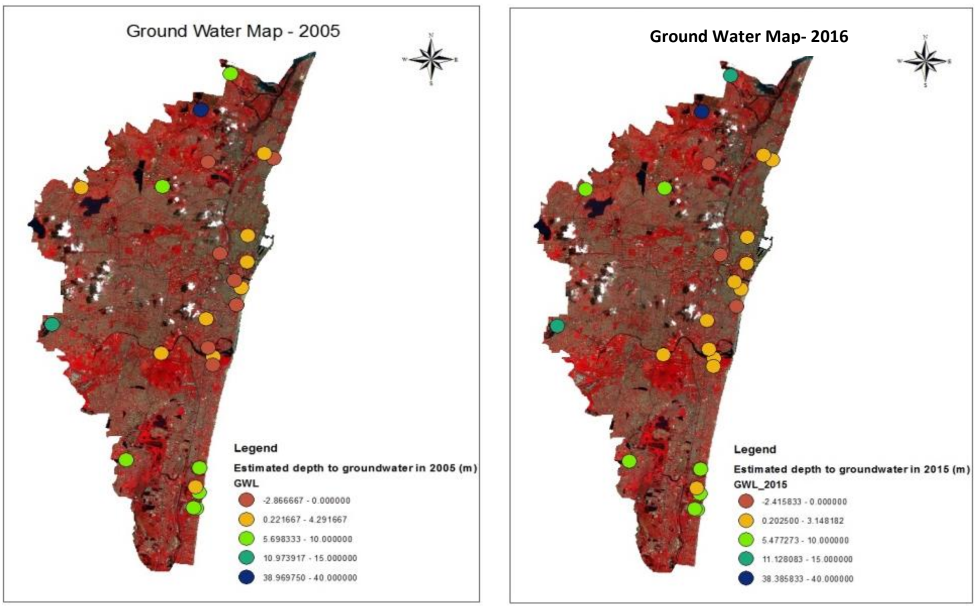

Figure 9. Ground water level from MSL in 2005 and 2016.

Observations from Figure 9 have shown that , in 2005 the points along the coast had low groundwater depth level . In 2016, the surface water bodies have disappeared leading to increase in the ground water depth level. The points in the northern region were noticed to have depleting groundwater levels changing from 5-10m range to 10-15m range and 0.2-3.0m range to 5.4 to 10.0m range.

4.5. Analysis of land Surface Temperature

Land surface temperature was calculated from 2005 and 2016 using thermal band data from Landsat OLI and Landsat 5 TM sensors. Observations of temperature data from 2005 to 2016 at three intervals have shown that, the overall temperatures have increased from 2005 to 2016. The maximum temperature in October month in 2005 was 35.06˚c and minimum temperature was 23.37˚c. In the year 2016, the maximum temperatures have raised by 6˚c i.e., from 35.06˚c in 2005 to 41.28˚c in 2016. The minimum temperature in 2016 were recorded as 23.08˚c. The raise in temperatures in 2016 can be related to the increased urbanization and compactness of Chennai city. Synoptic observation of Land use/land cover maps, rainfall information, Land surface temperature and ground water level maps of Chennai district have shown that, the temperatures have relatively increased by 6˚c from 2005 to 2016 which can be related to reduction in ground water levels, relatively lower rainfall, and increased urbanization. The conversion of approximately 7% of agriculture area to urban area has led to increase in temperatures.

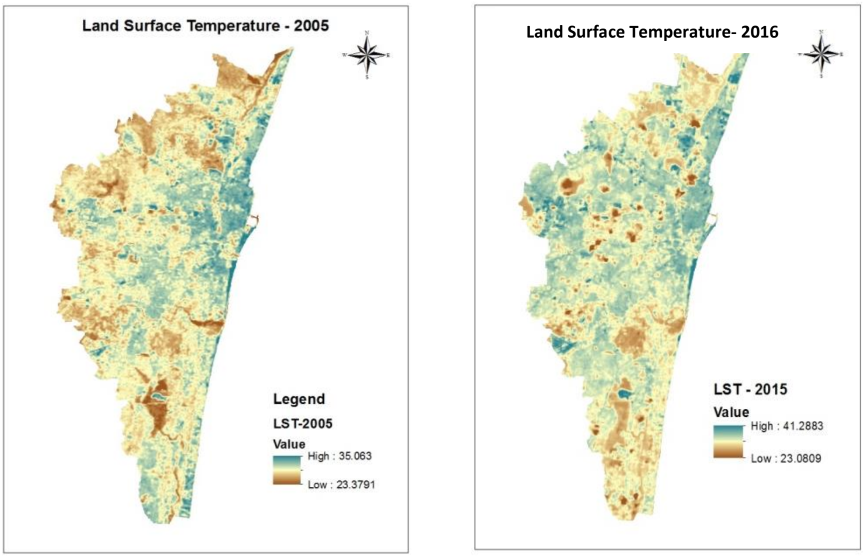

Figure 10. Land surface temperature for the year 2005 and 2016 - October month

5. Conclusions

The study was carried out in Chennai district of Tamilnadu state. The study clearly demonstrated that satellite remote sensing coupled with GIS can be a powerful tool for mapping and evaluation of land use/land cover changes of a given area. IRS LISS III satellite data of 2005 and 2016 were used to analyse the LU/LC coverage and their changes in the study area. Significant changes were observed in croplands, wet lands, water bodies, built up and wastelands. The features crop land, wetland and water bodies indicated a decreasing trend whereas the features namely built up and waste lands have indicated an increasing trend between 2005 and 2016. Increase in population and urbanisation have led to drying up of lakes and ponds as well as conversion of 33.86 sq.km of agricultural land into built up area.

These changes in LU/LC were analysed using Land surface temperature, ground water level and rainfall data of Chennai district where a clear relation was found between increasing built up, increasing temperatures, and decreasing rainfall. The reasons for these changes may be attributed to increased population and urbanization, industrial activities, changing patterns of agricultural activity etc. Chennai being a coastal city needs a close monitoring of these changing LU/LC patterns, as excess urbanization and industrialization can affect the coastal waters and its biota.

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