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Analysis of Land Use and Land Cover Change in Gummidipoondi Using Remote Sensing and GIS Tools

D. Vasudevan[1], A.G. Murugesan[2]
[1]Research Scholar, [2]University Grants Commission Faculty Fellow
[1,2]Sri Paramakalyani Centre of Excellence in Environmental Sciences
[1,2]Manonmaniam Sundaranar University, Tirunelveli,Tamil Nadu, India.

ABSTRACT

The aim of the study was to evaluate the changes in land use and land cover (LULC) in Gummidipoondi and the surrounding areas in Thiruvallur district, Tamilnadu India. Spatio-temporal variation in the land use and land cover were analysed on a decadal basis for the period from 1990 to 2019 using remote sensing and GIS based tools. The Landsat 5 (TM) and Resource-Sat 2 (LISS-III) data was used for the LULC classification in the study area. During the study period from 1990 to 2019, built-up area including industrial, urban and rural land use increased by about 147%. Predominant change was also noticed in the mudflat category where more than 95% of it was lost to various other land uses such as agriculture and marsh area. This observation calls for planning and conservation of sensitive ecosystems in the study area that may be lost due to anthropogenic pressures via pollution and undesirable conversion of LULC. The study revealed no significant changes in the extent of other LULC classes such as agriculture, forests, plantations, land with or without scrub, rivers and waterbodies in the study area.

Key words : LULC, GIS, ArcGIS, Agriculture.

1. INTRODUCTION

Industrialisation has played a major role in uplifting the economic status of the world. However, industrialisation and the associated urbanisation have brought tremendous changes in the natural landscape of regions impacting humans and environment. These changes are known to affect the functioning and balance of natural resources such as water, soil, forests, biodiversity and energy (Vasudevan, D. and A.G Murugesan.,2017)

Analysis of changes in landcover and land use play a key role in planning and management of natural resources (Bhardwaj,A,2015,Cheema and W.G.M. Bastiaanssen.,2010). By definition Land Cover denotes how the land is covered by forests, waterbodies, impervious surfaces, agricultural, and other types of lands while Land Use denotes how humans use the landscape, whether for conservation, development, or mixed uses (Reis, 2008).

Recent advances in geospatial technology including remote sensing and GIS techniques have proven to offer a promising tool for detecting LULC changes. (Estoque & Murayama, 2015, Sinan Jasim Hadi et al., 2014). The technology is being increasingly applied to study the spatio-temporal variations of a region over a required period of time, understand human-environment interactions, monitor environmental degradation and also assess impact of climate change (Tan J et al, (2020), Hussain S et al., (2020), T. N. Carlson and G. A. Sanchez-Azofeifa, (1999)).

Sinan Jasim Hadi et al., (2014) used the geospatial techniques to understand future patterns of change in LULC based on the past observations and suggested remedial measures for preventing water crisis in 2030 for the city of Tikrit, Iraq. Hussain S et al., (2020) demonstrated his observation on LULC changes using remote sensing and GIS data and noted that the built-up area increased by 4.3 % in 2017 as compared to 1977 in Lodhran district, that was reported to undergo environmental challenges due to climate change. Their studies highlighted conversion of bare soil to vegetation and built-up area. Dutta et al. (2019) studied the influence of impervious surface on land surface temperature using remote sensing tools and reported that land use change coupled with rapid urbanisation played a key role in increasing the land surface temperature in the peri urban areas of Delhi. Thus, it can be noted that the geospatial tools have been highly useful in determining and monitoring the changes in Land use and Land Cover with accurate, timely and detailed information (Al-Saady et al., 2015). The analysis of multitemporal satellite imagery will be of immense use for LULC change detection because of its proven capability to correlate between spectral variation of imagery and change in land cover patterns (J. Rogan, D.M. Chen, 2004, Prakasam C 2010).

The main aim of this study was to carry out the land use and land cover analysis of Gummidipoondi, an industrial hub and its surrounding areas. The process involved use of remotely sensed data and image interpretation and classification using GIS tools. The study was carried out to assess the changes in LULC on a decadal basis from 1990 to 2019 across a period of 30 years.

2. STUDY AREA

Gummidipoondi is an industrial town located in the Chennai Metropolitan area of Tiruvallur District in the state of Tamilnadu, India (Figure.1).

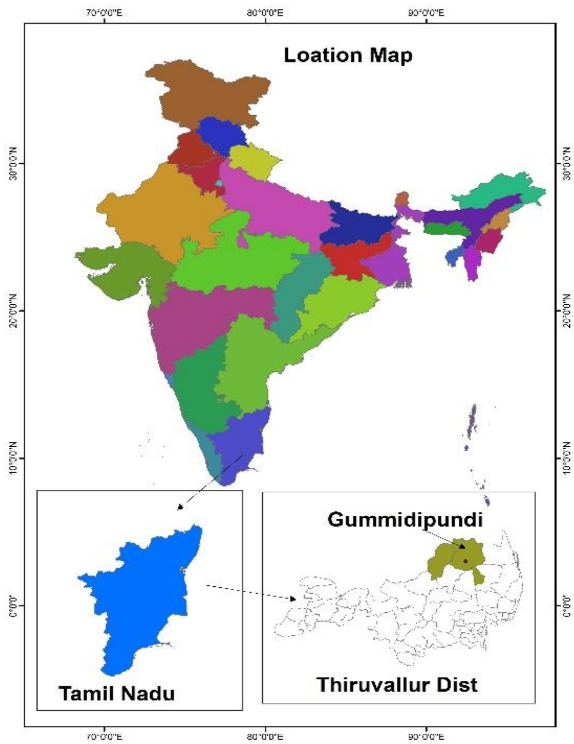

Figure. 1. Location of Gummidipoondi

Its geographical coordinates are 13°24'0" North,80°9'0" East. The study area comprises 10 km radius of the Gummidipoondi industrial estate covering 32364.656 ha. The terrain of the study area is mostly flat and dreary with an average elevation of about 17 metre above mean sea level. Average summer temperature of the district is 37.9°C and the average winter temperature is about 18.5 °C. Hot climate is during April - May and humid climate is during the remaining part of the year except December-February when it is slightly cold (Thiruvallur District Profile, TN ENVIS, 2015). Gummidipoondi is popularly known for its *industrial area that is spread over 1400 acres* and is a manufacturing hub for auto components, engineering products, leather, garments, rubber products, bicycles, electronic goods, marine products, cosmetics, petrochemical products etc.

3.0. MATERIALS AND METHODS

3.1 Materials

Landsat 5 (TM) data was used for mapping and analysis of the years 1990 and 2000, and Resourcesat – 2 (LISS III) sourced from NRSC was used for the years 2010 and 2019 for LULC mapping and change analysis. Table 1. presents the details of the satellite data used in this study. The map of study area was sourced from the Survey of India Toposheet with 1:50,000 scale. The digital image processing was performed using ERDAS software. Ground truth validation of the LULC maps were carried out using Google Earth Pro for the years 1990, 2000, 2010 and through field survey for 2019. The Ground truthing was performed using Garmin E-traxs GPS.

Table.1. Details of the satellite data used

SL No	Year	Satellite	Sensor	Spectral Bands	Month of Year	Path/ Row
1	2020	Resourcesat-2	LISS – III	4	Oct 2019	102/64
2	2010	Resourcesat-2	LISS – III	4	Oct 2009	102/64
3	2000	Landsat 5	TM	7	Oct 2000	153/51
4	1990	Landsat 5	TM	7	Aug 1990	142/51

3.2. METHODOLOGY

3.2.1. Pre-processing of data

The satellite data was radiometrically and geometrically corrected with respect to survey of India topo sheet. To carry out the geo-referencing, ground control points (GCPs) were identified on the maps and raw satellite data. The coefficients for two co-ordinate transformation equations were computed based on polynomial regression between GCPs on map and satellite data. Alternate GCPs were generated till the Root Mean Square (RMS) error was less than 0.5 pixel and then both the images were co-registered. The image used for the classification was extracted from satellite imagery.

3.2.2. Land use/ Land cover Classification

Land use land cover analysis was carried out using ERDAS imagine Software using unsupervised classification techniques which groups cases together based on their relative spectral similarity. (Foody GM, 2002, Thangaperumal.S et al 2020). Training sites with unique spectral signatures for each land use class were first selected and developed. These training sites along with the image of different combinations of bandwidths were used to create spectral signatures from the specified areas, which in turn was used to classify all the pixels into different classes. Digital image processing was carried out to delineate various land use land cover categories in 10 Kms radius study area in Gummidipoondi that comprised urban, industrialised, rural, crop land, fallow land, plantations, land with or without scrub, rivers, lakes and ponds, mud-flats, marsh and salt affected area by giving necessary training sets that were identified based on tone, texture, size, shape pattern and location information. The interpretation of various land use land cover classes was followed based on classification by National Remote Sensing Centre (NRSC 2012). Necessary care was taken to identify proper land use class, where there is conflict between signatures of various classes. The interpreted map was verified on Google earth and ground truthing was carried out by field visits using GPS before the land use / land cover map was finalised.

4. RESULTS AND DISCUSSIONS

4.1. Trends in LULC change from 1990 to 2019

The study involved analysis and measurement of LULC changes in the 10 km radius of the Gummidipoondi industrial estate over a period of 30 years. Decadal analysis was carried out for the years 1990, 2000, 2010 and 2019 that focussed on the transition pattern of a green field area to an industrial and urbanised zone. The map showing the LULC changes and the progression of industrial and urban area is presented in Figure.2.

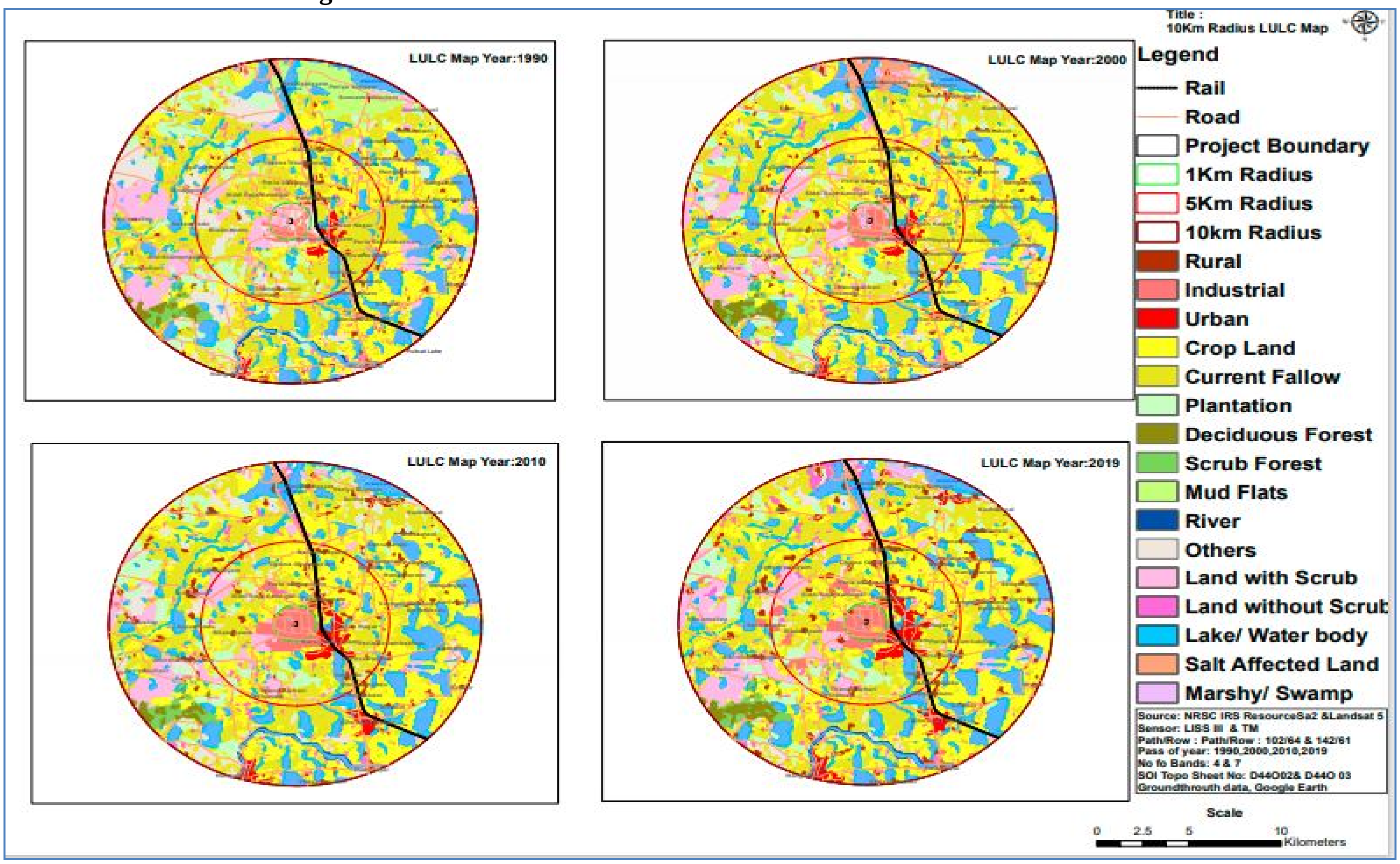

Figure. 2. Pattern of LU/LC in the 10 km radius of Gummidipoondi between 1990 and 2019.

The landcover in the study area comprising 32,364 ha was classified into various LULC classes as described in section 2.2.2. From the recent LULC maps of 2019, it can be seen the nearly half the extent of the study area i.e., about 47% falls under agricultural land that comprises crop land and current fallow land, making it the predominant land use in the study area. The crop land comprising 22% of the study area represents single and double crop land use. The forest cover in the study area is 2% comprising deciduous and scrub forests. And about 11.69% of the land is waste land without any revenue benefits (land with/without scrub). Other land cover classes like rivers, waterbodies, mud flats, salt affected, marshy land occupies 20.05% of the study area.

Table.2 shows the area covered under each LULC class for the different years studied i.e., 1990, 2000, 2010 and 2019. The extent of areas under the LULC map of 1990 were used as the base values of LULC to compare the changes in the subsequent decades. The table presents absolute and percent change in the required time period (1990–2000, 2000–2010 and 2010–2019) on a decadal basis and LULC changes with respect to the base year 1990.

4.1.1. LULC changes in Urban, Industrial and Rural Areas

Urban areas referred to in the study are centres of human population and consist of compact or continuous built up area. Industrial area constitutes those areas that are primarily involved in manufacturing activities. These areas add up to built-up areas generally characterised by impervious surfaces (NRSC,2012).

Table.2. presents the changes in LULC in the study area on a decadal basis. It shows a clear trend of increasing urbanisation with the urban extent increasing about 5 times from 252 ha to about 1319 ha over a period of 3 decades from 1990 to 2019 respectively. The industrial area during the same time has tripled in extent in comparison to the year 1990. Overall, it can be observed from Figure 2. that the built-up area is extending from the centre of the study area in the Gummidipoondi industrial estate radially outwards. Significant economic growth as contributed by industrial growth and higher demand for living space due to the population increase have found to be the major drivers for increase of built-up space in the study area. (Al-Saady 2015). Similar observation was reported by Vijayalakshmi Rajendran et al., (2014) who reported that the urban extent in the Chennai Metropolitan Area increased from 16% in 1989 to 34% in 2000 which again rose in 2012 to 44 %.

Table.2. Decadal trends in LULC change in Gummidipoondi

Sl. No	Land Use/ Land Cover Classes	Area under different LULC classes								% LULC changes on decadal intervals			% LULC changes from base year 1990 to 2019		
		1990		2000		2010		2020		1990-2000	2000-2010	2010-2019	1990-2000	1990-2010	1990-2019
		Area in Ha	%	Area in Ha	%	Area in Ha	%	Area in Ha	%	%	%	%	%	%	%
1	Urban	252.02	0.78	360.48	1.11	571.77	1.77	1318.65	4.07	43.04	58.61	130.62	43.04	126.88	423.24
2	Industrial	281.05	0.87	427.42	1.32	786.69	2.43	867.31	2.68	52.08	84.06	10.25	52.08	179.91	208.60
3	Rural	679.03	2.10	868.14	2.68	1130.24	3.49	803.00	2.48	27.85	30.19	-28.95	27.85	66.45	18.26
4	Crop Land	6848.37	21.16	9184.53	28.38	8728.21	26.97	7197.74	22.24	34.11	-4.97	-17.53	34.11	27.45	5.10
5	Current Fallow	8935.97	27.61	8205.31	25.35	7977.40	24.65	8112.48	25.07	-8.18	-2.78	1.69	-8.18	-10.73	-9.22
6	Plantation	2084.29	6.44	1621.37	5.01	1946.77	6.02	1633.15	5.05	-22.21	20.07	-16.11	-22.21	-6.60	-21.64
7	Deciduous Forest	252.02	0.78	345.16	1.07	261.69	0.81	337.83	1.04	36.96	-24.18	29.09	36.96	3.84	34.05
8	Scrub Forest	243.95	0.75	212.10	0.66	295.16	0.91	250.36	0.77	-13.06	39.16	-15.18	-13.06	20.99	2.63
9	Mud flats/ intertidal land	1426.61	4.41	144.76	0.45	204.03	0.63	57.92	0.18	-89.85	40.95	-71.61	-89.85	-85.70	-95.94
10	River	198.32	0.61	205.65	0.64	208.47	0.64	223.53	0.69	3.69	1.37	7.23	3.69	5.12	12.71
11	Others	3001.88	9.28	2100.80	6.49	2146.77	6.63	1572.50	4.86	-30.02	2.19	-26.75	-30.02	-28.49	-47.62
12	Land with Scrub	2613.54	8.08	1950.40	6.03	1585.66	4.90	1838.35	5.68	-25.37	-18.70	15.94	-25.37	-39.33	-29.66
13	Land without Scrub	1315.74	4.07	1654.43	5.11	1750.40	5.41	1945.70	6.01	25.74	5.80	11.16	25.74	33.04	47.88
14	Water Body	4169.30	12.88	4648.78	14.36	4652.41	14.38	5890.09	18.20	11.50	0.08	26.60	11.50	11.59	41.27
15	Marshy/ Swamp	61.80	0.19	414.11	1.28	60.26	0.19	143.84	0.44	570.08	-85.45	138.70	570.08	-2.50	132.75
16	Salt Affected Land	0.80	0.00	20.97	0.06	58.47	0.18	172.22	0.53	2520.80	178.85	194.55	2520.80	7207.99	21425.78
	Total Area	32364.68	100.00	32364.40	100.00	32364.40	100.0	32364.66	100.0						

Rural areas on the other hand comprise habitations comparatively lesser than urban settlements and are found as clusters or scattered built up area. Majority of the population in rural settlements have agriculture as their primary occupation. The current analysis showed no particular trend of increase or decrease in the rural extent, which initially appeared to increase by 28% and 30% in the first two decades of study period and later decreased by 30% in the last decade. The sudden drop in the rural extent during 2010 to 2019 can be attributed to a sharp spurt in the urban area by about 130% during the same time.

Overall built up expanse combining urban, rural and industrial areas showed about 147% increase from 1990 to 2019. This observation clearly indicates increasing trend of urbanisation in Gummidipoondi necessitating proper environmental planning, conservation and sustainability measures for conservation of natural resources.

4.1.1. LULC changes in Agricultural Land

Cultivated lands comprise prepared and improved lands for agricultural purposes to grow crops for food production purposes. As noted earlier, agricultural land comprising crop land and current fallow land occupy the major land use category constituting nearly half the extent of the study area. Leaving the land uncropped for certain period or for the entire growing season to improve the soil fertility for crop production in the following year is known as fallowing (Havlin et al. 1995).

The extent of agricultural land in 1990 and 2019 was about 48.77 % and 47.31 % respectively. The major crops grown in the study area are paddy, sugarcane and groundnut. It is very interesting to note that despite the increasing built up space in the study area, there has been no significant reduction or notable changes in the agricultural land extent. The minimal change in the agricultural land area (<10 %) could be due to the rich water availability and strong dependence of people on agriculture as a primary occupation. This observation also corroborates with the fact that 45% of workforce in the district still followed agriculture as their main occupation as per the handbook of the Tiruvallur District 2020. Similar observation on the extent of agricultural land was observed by Vijayalakshmi and Toshiyuki, 2014 in the Southern regions of Chennai who reported a 7 % decrease in cropland during the period 1989 to 2012.

4.1.2. LULC changes in Plantations

The areas under plantations are those areas with horticulture or other plantations that has commercial values. In the study area, the tree plantations are mostly belonged casuarina, coconut trees, eucalyptus and teak. The extent of plantation currently stands at 5.0 % which was about 6.4 % three decades ago. This is about one-fifth of decrease in the plantation area. Such a steady decrease of plantation can serve as early warning with respect to decreasing plantation highlighting the need for devising appropriate remedial strategies to prevent further declining trend.

4.1.3. LULC changes in Forests

The forest cover comprises both the deciduous forests that refers to perennial plants that are leafless for a certain period of the year and also scrub forests where the vegetative (Crown) density is less than 20% of the canopy cover (Ford Robertson,1971). The total forest cover in the study area increased from 496 ha to 588 ha from 1990 to 2019 respectively with associated percentage increase of 37% in the land area. Though a dip in the area extent was observed with the deciduous forests during the period 2000 to 2010 and in scrub forest area during the period 2010 to 2019, the overall values stood positive in case of the forest lands in the study area. While similar studies on LULC analysis on urban areas point out decline of forest areas (Maina. J et al, 2020), the results of the present study indicate a promising trend and appreciable measures of forest protection adopted in the study area.

4.1. 5 LULC changes in Mudflats/ Intertidal Zones

Mudflats also known as tidal flats, are coastal wetlands that form intertidal areas where sediments have been deposited by tides or rivers. In the study area, mudflats are found in the north eastern part adjacent to the Pulicat lake, which is the second largest brackish water lagoon in India. This area is known to offer a rich biodiversity habitat also acting as natural feeding ground for flamingos, pelicans and a variety of waders and other birds (A. Nagarjuna, et al., 2010). The study showed that over 95 % of the mudflat falling in the study area have decreased in 2019 in comparison to its extent in 1990. The reason may be attributed to the increase of marshy/ swampy land along the coastal lagoon and also conversion of mudflats to built-up and agricultural land uses as can be seen in Figure. 2. A similar observation on conversion of mudflats to swamp areas was also reported by Ismail Mondal et al., 2015. The trend observed in loss of mudflats to anthropogenic pressures are of serious concerns due to their impact on local biodiversity and ecosytems (A. Nagarjuna, et al., 2010, Santhiya, G.2010 et al).

4.1.6 **LULC changes in Rivers**

Rivers are flowing water courses on the land along definite channels. It includes streams, river and its tributaries which may be perennial or non-perennial. From the LULC imagery (Figure.2) and the LULC conversion analysis (Table.2), it can be noticed that there is a slight increase in the river area amounting to about 25 ha from 1990 to in 2019. This translates to an increase in percentage of about 0.61 to 0.69 in the years from 1990 to 2019 respectively, and does not constitute a significant change.

4.1.5 **LULC changes in Others Category**

The LULC falling under the others category are treated as miscellaneous because of their nature of occurrence, physical appearance and other characteristics. The area under the others category constituted about 3001 ha (9.2%) in 1990 which decreased by nearly half of its extent to about 1457 ha (4.85%) in 2019. From Figure 2, it can be observed that much of this category of land was found in the eastern most part of the study area in 1990. However, in the subsequent decades the ‘others’ land category had transformed into ‘plantation category’ leading to its decrease in areal extent. In some patches of the study area, it was also observed that the others category had transitioned to built up area, land with or without scrub category. Similar observations were noted by Duraisamy Vijayasekaran et al., (2018) who reported gaining up of built-up areas over wasteland comprising miscellaneous land characteristics.

4.1.6 **LULC changes in Land with or without scrub**

This category of land with or without the presence of scrub is found in elevated topography such as uplands or high grounds and excludes hilly and mountainous terrain (NRSC, 2012). From the trend observed in Table. 2, it could be observed that land area with scrub showed a decrease of about 29.66 %. This could be due to the conversion of land with scrub for agricultural purposes, as can be observed in Figure. 2. As for the land without scrub, there seems to be an increase of about 47.88 % indicating conversion to other land uses. However, the combined land with or without scrub in the study area showed a negligible decrease of about 3.70% during the observation period from 1990 to 2019.

4.1.7 LULC changes in Water Body

The water category comprises water bodies, streams, canals, and other linear water bodies, lakes, reservoirs, bays and estuaries (Anderson et al. 1976). The total extent of the waterbodies in the study are observed to have increased from 4169.30 ha to 5890.90 ha translating to a percentage increase from 12.88% to 18.62 % in 1990 and 2019 respectively. The percentage increase during various decades are 11.50 %, 0.08% and 26.60 % during the periods 1990 to 2000, 2000 to 2010 and 2010 to 2019, indicating that the increasing trend was highest in the last decade. The reason could be due to increasing trend of built-up area resulting in higher run-offs and filling up of low-lying areas or water bodies, as reported earlier by Garg V et al., 2019 during their studies on Pennar river basin in Southern India. In the current study, the increase in the extent of water bodies of about 1721 ha could also be a result of increased water conservation measures such as rainwater harvesting, creation of new water bodies and waterbody restoration efforts carried out in the Chennai Metropolitan Area by the Water Resource Division of the State Public Works Department.

4.1.8. LULC changes in Marsh/ Swamp

Marsh land are those that remain inundated in water permanently or periodically and are characterized by vegetation including grasses and weeds. The extent of marsh land in the study area increased from 61.80 ha to 143.84 ha amounting to an increase of 132.75 % from 1990 to 2019 respectively. This development was observed along the Northeast boundary of Pulicat lake where the original water spread area in 1990 without vegetation seem to have converted into a marshland with growth of grasses and weeds (Figure 2). The underlying reason could be the pollution and eutrophication in the Pulicat lake, caused by anthropogenic activities such as discharging domestic waste and agricultural run-off triggering the growth of weeds and marshes in the originally water spread area.

4.1.9 LULC changes in Salt affected Land

The salt-affected land is characterised as the land that has adverse effects on the growth of most plants due to presence of excess soluble or high exchangeable sodium (NRSC,2012). In our study area, the salt affected land are found in and around the Pulicat lake which has seen a stark increase during the period 1990 to 2000. These are characteristic of coastal saline soils that may have been deposited due to inundation or ingress by seawater. The percentage of salt affected area to the total study area during the year 1990 was almost nil which increased to about 0.53 % during 2019. In a scenario of increasing salt affected areas along the coastal areas or coastal estuaries, Ajay Kumar Bhadwal et al., suggested adopting suitable land use strategies, such as the adoption of rice-based and grass-based cropping systems, to control the development of sodicity in soils. Their research studies indicated the probability of lesser exchangeable sodium potential with increased vegetative cover/primary productivity.

5. CONCLUSION

Remote Sensing and GIS tools were used to perform LULC trend analysis and decadal change detection in and around Gummidipoondi. The study helped in gaining insights on the expanding industrialisation and urbanisation in the study area. The results revealed a significant increase in the built-up area of over 147% during the study period from 1990 to 2019. Another predominant change that was of concern was around the Pulicat lake, situated along the coastal line of Chennai. The spatio-temporal analysis revealed that mudflats along the Pulicat lake boundaries decreased by 96% during the study period. It was also noted that a portion of the lake was transformed to marsh area, which could be attributed to anthropogenic influence such as discharge of wastewater and run-off from agricultural lands leading to eutrophication and weed growth. No major change was observed in landuse classes such as forest, plantation, land with or without scrub, rivers and waterbodies in the study area.

The geospatial tools have proven to be a highly effective tool in the analysis of spatio-temporal variation, thereby helping to understand the progression of economy and environment that impact the social factors in a region. The results of such analysis can go a long way in assisting spatial planning for development and identification of conservation areas of importance for a sustainable economy and ecosystem.

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