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Remote Sensing and GIS Technique Enable to Assess and Predict Landuse Changes in Vellore district, Tamil Nadu, India

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Abstract

Mapping of land use changes using satellite imagery are essential due to its various applications. The present study has been conducted in urban and semi-urban areas of Vellore district, Tamil Nadu, India to analyse the dynamics of land use changes during 1977 - 2015 using multi-temporal satellite images like Land sat 1977 MSS, TM 2009 and SR, OLI/TRS 2015 respectively and were detected by ERDAS IMAGINE 2014.Three land use classification maps (1977, 2009 and 2015) were developed. Analysis shows that urban area has been increased more in 2015 (26.46%) than in 1977 (1.93%) which will further be increased by 37.58% in 2035. Interestingly, it predicts that agricultural land and crop land will be increased by 433.77 km^2 and 113.4 km^2 subsequently in future. It is assumed that the analysed results of the study will help district administration for framing the ground of making Vellore as a smart and sustainable city.

Keywords: Land use lands cover classification, change detection, prediction of change.

INTRODUCTION

Nowadays land use and land cover (LULC) change analysis study becomes a fundamental component in understanding the relationship between human being and natural environment [1].The increasing study of land use and land cover change helps worldwide in managing natural resources [2]. Although LULC have been used at a time but they have distinct meaning and usefulness. Land cover refers to the natural properties of the earth surface e.g. forest cover, water body, barren land etc., while land use refers to the human activities that take place on the land cover e.g. residential area, industrial area or agricultural land [3].With developing technology and increasing population human being become more powerful and become direct cause for environmental change as well as the cause for the change of biodiversity [2]. Important natural resources such as land and water are declining in quantity and quality day by day due to increasing urban demands [4]. With the administrative interest and increasing population of Vellore district, Tamil Nadu, it demands more agricultural land as well as the residential area. In the coming decades, Vellore will face an enormous problem about food scarcity, water, land for agriculture and housing [5]. Proper land use strategy and planning can solve the incoming problems for the area. For the planning purpose, change detection study of the land, rate, and magnitude of the change and future prediction of the change can reveal the clear picture of the area and can include significant help for the city planner and district administration.

The LULC study and relative change detection is very important worldwide to meet the challenges due to the increasing population pressure, unpredicted natural calamities and to provide scientific direction to city planners and district administration. The availability of the multi-temporal data sets are very useful to locate the increasing change [1]. Change detection with the magnitude of change and after ten years future change has been described for the state Ilorin, Kwara [6] using remote sensing data and GIS. Reis (2008) analysed change detection in the north-eastern Turkey, explaining the LULC changes occurred mostly in coastal zone with low slope between 1976 and 2000 [7]. Detection of change with multi-temporal imagery was carried out in Sudan[8]. One of the most populous area, Dhaka city where land use change detection had been studied for better city planning using GIS supported Markov chain modelling [9]. Khan (2012) studied the coastal landuse change and analysed out possibilities of preventing degradation in Bangladesh [10]. Samanta and Pal (2016) studied in Papua New Guinea area recently where the cause of land use changes rapidly for increasing population pressure and industrial development [11]. Change detection had been done with the help of cross tabulation method from where digital change detection has been made possible.

In India, many studies about LULC change detection analysis had been done for several areas. With the help of satellite imagery, population growth and urban development spread on nearby agricultural land, the loss of agricultural land has been detected in the city of Saharanpur [12]. Very populous Allahabad city's land change detection analysis had been analyzed by Singh *et al* (2012) [13]. Mallupattu *et al* (2013) examined the LULC change in Tirupati with the help of RS data and GIS technique [14]. Change detection analysis for monitoring LULC change of Sahibganj district of Jharkhand explains the change in crop system between 2005-2011 where notable changes has been observed in Kharif crops, different categories of agricultural lands and forest cover [15]. Using digital change detection technique, a study in Hawalbagh block in the district of Almora, Uttarakhand, India revealed that vegetation and build up lands were increased while agriculture and water bodies were decreased between 1990 and 2010 [16].

Likely, Jayakumar and Arockiasami (2003) studied the change in the part of Eastern Ghat area of Tamil Nadu using remote sensing and GIS technique, revealing the fact of LU increase in crop category and decrease in scrub category [17]. Cuddalore coast of eastern Tamilnadu is seriously afflicted by the tsunami in 2004 and 2008 respectively. Muthuswamy *et al* (2010) studied about thirty years change detection of that area which revealed that change was due to a rapid growth of built-up land [18]. Deforestation assessment was studied for Erode district of Tamilnadu with change detection analysis between 1990 and 2000 [19]. Shoreline change detection [20] (Salghuna and Bharathvaj,2015) and the impact of change in LULC due to the effect of natural calamity like storm surge and heavy precipitation in the northern parts of Coramandal coast of Tamil Nadu and possible prediction of the risk association was studied recently [21]. Vijaykumar (2015) studied Thirumattur sub-basinof river Cauvery, Tamil Nadu and revealed that built up area were increased with time (1992 – 2010) along with semi-evergreen forest of that area [22].

Vellore a third populous district of Tamil Nadu has been undergoing several changes since time immemorial. Institute for Water Studies, Tharamani (1997) studied change of land use for 18years at Upper Palar river basin and found that 71.7 km^2lands were degraded. Tamil Nadu Agricultural University Research Centre, Vellore had reported that nearly 35,000 ha agricultural land became unfit for cultivation [4] due to wastewater spreading from tannery industries. Land use land cover classification and corresponding analysis of semi-urban Vellore district for ten years (1991-2001) was observed [23]. Land suitability assessment for major crops was studied [4] for Vellore district with the help of GIS. Kumar *et al*.(2012) reported an agricultural change for Vellore city [24]. For Vellore district, vegetation has been monitored with the help of multispectral satellite image based on normalized difference vegetation index (NDVI) [25].

However, land use change detection analysis for more than thirty years (1977-2015) has not yet been done for the Vellore district. Again, Vellore has earned certain specialty since time immemorial because of its historical, geographical, political, health, education and religious importance. In recent time, Vellore has been enlisted to be promoted as a smart city by the Government of India [26]. Therefore, importance of change detection and future LULC change prediction for better development of the area is significantly necessary. The LULC of Vellore city in particular [5] was reported recently. This work focuses on the LULC assessment since 1977 and prediction of LULC in the district of Vellore till 2035.

DATA AND METHODS

A. Study Area

The study area is Vellore district which has total area of6405 km^2 in the state of Tamil Nadu, India (Fig.1). It lies between78° 20'E to79°59'E longitude and 12°15'N to 13°15'N latitude. The maximum portion of the district is covered with reserved forest. The sub-tropical climate and seasonal variation of the temperature are very prominent in the area [23].The area receives rainfall two times a year; first time in July-August from south- west monsoon and the second time in the month of December-January due to north-east monsoon. However, it is a rain shadow area of western ghat range of hills. The district is surrounded by the neighbouring Andhra Pradesh state in the north and north-western part while Thiruvallur district at its north-east, Dharmapuri and Tiruvannamalai district are on the southern part and Kancheepuram district at the eastern part. Rice is the main food crop in the district but other agricultural products are groundnut, sorghum, and sugar cane [4].

Vellore district is now growing with its increasing population. Cities expansion has taken place on agricultural land. Vellore is a significant producer of leather and leather based products. It accounts more than 37% of country's export of leather and leather products and it is reported that leather products worth more than Rs 2000 crores is exported from this district alone [27]. So, agricultural land is devastatingly getting degraded due to tannery effluent waste water [4]. Above all, Bharat Heavy Electricals Limited (BHEL) at Ranipet is a major heavy engineering unit of the state of Tamil Nadu, three industrial parks: SIDCO at Katpadi, SIPCOT at Ranipet, and SIDCO at Arakkonam are important.

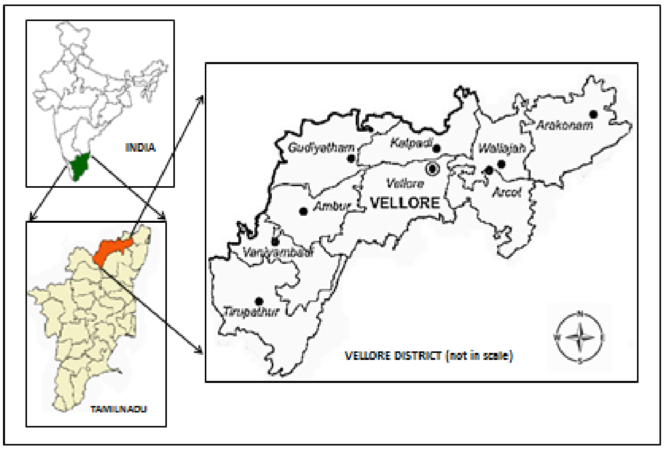

Figure 1: Location of study area (not in scale)

Besides, three major hubs: the centuries-old Christian Medical College and Hospital have been attracting patient all over India while reputed engineering institute Vellore Institute of Technology has been attracting students and the Golden temple has been for pilgrims. These have created anthropogenic pressure in the district. The state Tamil Nadu lies under drought-prone zone in India [27]declared by Tamil Nadu government and Vellore district is situated in northern part of the state (Fig.1).Vellore district with it's totally dry sandy main river "Palar" encroached by thorny scrublandthroughout the area has proven the fact that it is a dry region.

METHODOLOGY

GIS and Remote sensings are the powerful tool to determine accurately and timely information of land use and land cover change [28]. Secondary data (Table-I Data source is described below) were used with nineteen collected toposheets which have covered the study area (surveyed 1977-78), geo-referenced, mosaic was carried out then district boundary was extracted for the base map and was used for reference purpose. Landsat images of 1977, 2009, and 2015 were collected for analysis. Those images were radiometrically corrected for atmospheric correction then were classified in nine classes with supervised classification with the help of ERDAS IMAGINE software. Training samples of nine different classes were taken with the reference of Survey of India toposheets, Google Earth and ground truth for the better classification [29]. Accuracy assessment for three images was done with 300 random samples. The land use land cover maps for the study area were prepared following three steps, namely i) Laboratory work, ii) Field observation and verification, and iii) Post field laboratory work respectively.

Table I: Details of data sources used in the study

Data type	Source	Year	Number/ Specifications
1.Toposheet(scale1:50,000)	Survey of India, Chennai, India	1977-78	57K/12,16
			57L/06,07,08,09,10,11,12,14,15
			57O/08,12,16
			57P/1,2,5,6,9
2.Satellite imagery			Resolution
a) LANDSAT MSS	USGS	1977	60 m (Resampled by 30 m)
b) LANDSAT 7 TM	GLCF	2009	30 m
c) LANDSAT 8 SR OLI/TRS	USGS	2015	30 m
3. Vellore district map	Vellore Municipal Corporation	2014	Scale: 1cm=7.5 km

[a] USGS, US Geological Survey, USA; GLCF, Global Land Cover Facility, Maryland, USA

In the laboratory work, layer stacking of the bands of satellite data, mosaicking, sub-setting of the study area are included. The field observation included identification of features and collection of ground truths. Post field laboratory work is embraced with land use classification, verification of the classification, smoothing of the image by removing pepper and salt effect, and finally by creating the thematic maps. Statistics generation were done according to cell size (Table III) of corresponding classes. Different classifications were prepared as described below:

Land use land covers classification for 1977

For the year 1977, landsat2 multispectral scanner was used with a spatial resolution of 60 meters. Original pixel size for MSS was 79*50 meter which was resampled by 60 meter using production system (Landsat USGS. gov). Four bands (Bands 4, 5, 6, 7) were downloaded from USGS earth explorer with spectral resolution between 0.5 and 1.1 micrometer. Two scenes with four bands each were downloaded for the study area covered properly. The scenes had path 153 and row 51 and path 154 and row 51 respectively. After layer stacking the bands, two scenes were prepared, and then were mosaicked those and subset the study area.

In this study supervised classification has adopted with nine separate classes (Fig. 2). Before classification, the satellite image resembled from 60m to 30m for bringing it to the same resolution with another imagery. Unsupervised classification, especially for this year (1977) was done for proper identification of the spectral content, personal experience and later with the reference of toposheets which were surveyed in the year 1977-78. Nine different classes (Table II) were identified. Accuracy assessment was not done for the year1977.

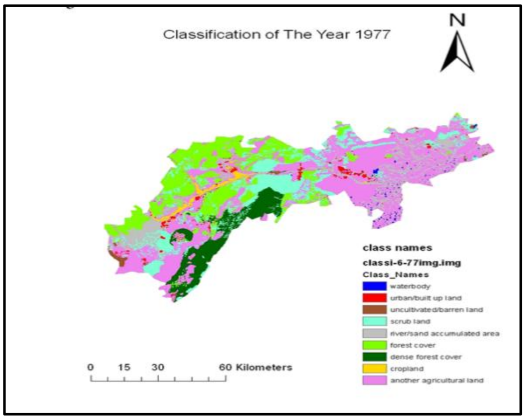

Figure 2: Classification of the year 1977

Table II: Land classification scheme

Land use classes	Descriptions
1.Water body	Ponds, Tanks, Lakes are under the water body
2.Cropland	Mainly paddy is common in Vellore
3.Another agricultural land	Sugarcane, Groundnut, millet, Fruits and Vegetable garden are under another agricultural land
4.Dense forest cover	Northern, South-Western part mountainous region -dense forest cover with mixed jungle and South-Eastern part also has a dense mixed jungle
5.Forest cover	Forest cover with sparse vegetation
6.Urban/built-up land	Settlements, commercial area, industrial area etc.
7.River/sand accumulated area	River dry-bed full of sand and sand accumulated area
8.Scrubland	Thorny bush area dense or light
9.Uncultivated/barren land	Rocky, rocky knobs, rocky outcrops without vegetation cover

Land use land covers classification for 2009 :

For the year 2009, Landsat5 TM data from which bands number 1, 2, 3, 4, 5, 6 and 7 were downloaded with spectral resolution difference between 0.45 and 2.35 micrometer. Two scenes with 7 bands each were downloaded mosaicked the scenes then subset the study area. Alike 1977 image classification, nine classes were identified (Table II) and supervised classification was created with the help of ERDAS IMAGINE. Google earth, satellite image, toposheets, personal experience could help for proper identifying the signatures required for the classification (Fig. 3).The overall accuracy of the classification is 80% (taking 300 random samples from reference).

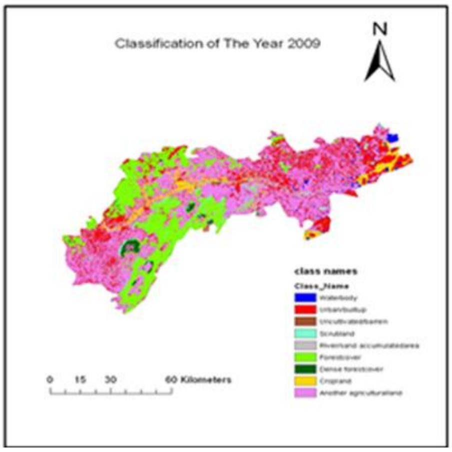

Figure 3: Classification of the year 2009

Land use land covers classification for 2015

Landsat8Surface Reflectance Operational Land Imager (OLI) and Thermal Infrared sensor (TIRS) which is advanced in technology, data were downloaded from USGS Earth Explorer data provider. All visible bands and near infrared, SWIR1, SWIR2 (short wave infrared bands which have an atmospheric correction algorithm) Bands, a total of 7 bands were included for the study. Spectral resolution difference between SWIR Bands is 1.57 to 2.29micrometer.Two scene with each 7 bands were layer stacked to produce two images, and then were mosaicked followed by subset the study area. Image resolution was 30 meter. Supervised classification (Table II) was with nine classes (Fig. 4). Overall accuracy is 90% (taking 300 random samples from reference).

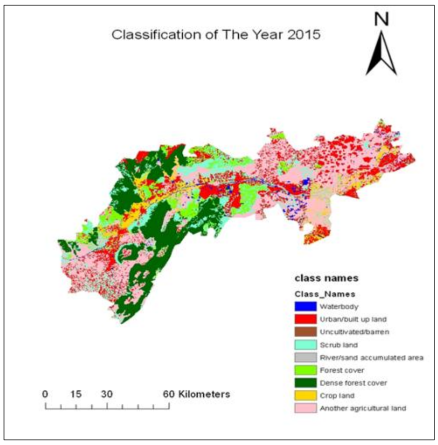

Figure 4: Classification of the year 2015

Different processes are available for change detection analysis and have been meticulously reviewed elsewhere [30]. Image differencing is the most common and easy way to detect the change of certain area. Here spatially registered two images were subtracted pixel by pixel in image differencing method. Threshold boundary 10% was selected between change and stable pixels. One change map (Fig. 8) has been derived from the previous year 1977, classified image and latter year 2015, classified image with the help of that image differencing method. Increased and decreased area or positive and negative value of the image depicts that the region whose radiation value is changed. Where radiation value is '0' there is no change in area. In the change map, the area which part are increased more than the threshold change 10% in the area has shown by green colour and which part is decreased by more than the threshold change 10% in the area is shown by red colour and the unchanged area is shown by black colour. Another increased and decreased area which is changed below 10% is described by different colours. Increased area means the area of positive change those are urban or built-up areas are increased by area, dense forest cover areas, croplands are increased by area, whereas other agricultural lands, forest cover areas, scrublands are decreased than before. The Urban or built-up area is increased in which extent is shown in the Fig.7. Linear regression has been used for predicting the change after twenty years that is for the year 2035 (Table IV). With limited data it is difficult to properly predict the future assessment. But it can produce a rough sketch of land use for future. A flow chart has been depicted for the procedures adopted in this study (Fig. 5).

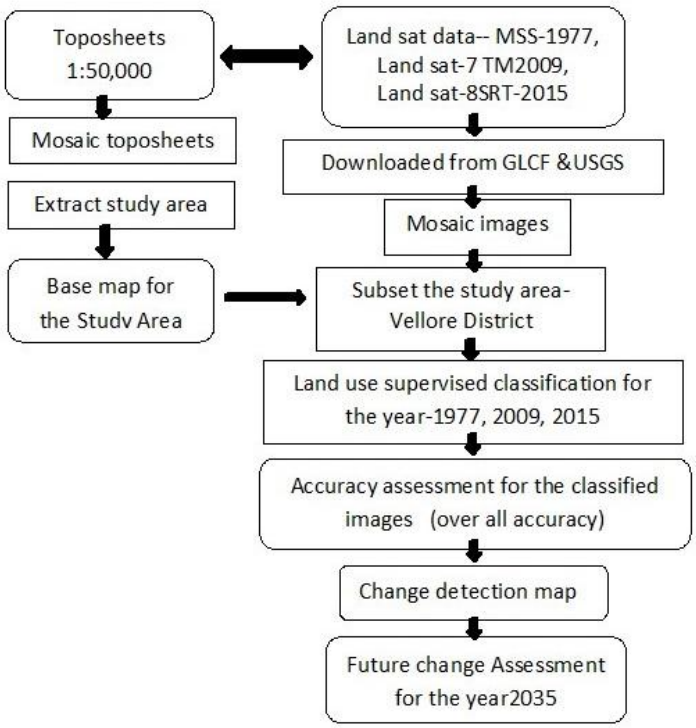

Figure 5: Flowchart showing procedures adopted in the study

Table IV: LULC area (km^2) during 1977, 2009, 2015 and percent change prediction during 2015

Year	Land use classes								
	*UCL	WB	CL	DF	AL	SL	SA	FC	UR
1977	60	34.84	62.08	426.56	2701	965	913	1121	121.52
2009	22.19	31.34	241	108	3183	61.64	129.96	1338.87	1289
2015	2.26	112.32	237.5	964.68	2237.73	534	126.01	371.5	1819
2035	-20.62	105.429	351.439	712.876	2598.52	-67.478	-371.573	565.643	2530.76
2035 (area change in %)	_	1.65%	5.48%	11.13%	40.57%	_	_	8.83%	39.51%

*UCL-Uncultivated barren land; WB-Water body; CL-Crop land; DF-Dense forest; AL-Another agricultural land; SL-Scrub land; SA-River's and accumulated area; FC-Forest cover; UR-Urban built up land

RESULTS AND DISCUSSION

The present study has analysed the LULC change in Vellore district between 1977 and 2015 with a prediction till the year 2035. Changes have been evaluated from the statistics (Table I) developed from three classified maps (Fig. 2, Fig. 3, Fig. 4). Detectable changes were observed, analysed and magnitude of changes depicted in Table III.

Table III shows relative changes calculated from the classified landuse maps with an analysis that uncultivated or barren land has decreased tremendously and gradually by 0.93% in the year 1977, 0.34% in 2009 and 0.03% in the year 2015 respectively (Table III). Area of cropland has been increased from 0.96% in 1977 to 3.34% in 2015 because of excess population pressure, demand of food crops and good rain. But another agricultural land that means beside food crops (Table II), sugar cane, millets, bajra, fruits, and vegetables, area has also been increased by 42.17% to 49.7% from1977 to 2009 but the area decreased by 34.94% in 2015 due to the area is utilized for food crop cultivation. In 2015 area is decreased from uncultivated barren, scrubland, forest cover area, sand accumulated area (Table III). In 1977 urban and the built-up area was 121.52 km^2 where it was increased by 1419 km^2in 2015(Table III). Summary of changes are depicted in Fig.5.

Table III: Quantitative evaluation of landuse change during 1977, 2009 and 2015

Land use classes	Year 1977		Year 2009		Year 2015		Year 1977-2015		Annual rate of change (area)	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Change of area (km^2)	Change area (%)	1977-2009	2009-2015
1.Water body	34.84	0.54	31.34	0.49	112.32	1.75	77.48	0.05	0.109375	-13.4967
2. Crop land	62.08	0.96	241.0	3.76	237.5	3.7	175.42	-2.8	-5.59125	0.583333
3. Another agricultural land	2701	42.17	3183	49.7	2237	34.94	-463.27	-7.53	-15.0625	157.545
4. Dense forest cover	426.56	6.66	108	1.68	964.68	15.09	538.12	4.98	9.955	-142.78
5. Forest cover	1121	17.5	1338.87	20.9	371.5	5.8	-749.5	-3.4	-6.80844	161.2283
6. Urban /built-up land	121.52	1.93	1289	20.12	1419	22.15	1297.48	-18.19	-36.4838	-21.6667
7. River and sand accumulated area	913	14.25	129.96	2.05	126.01	1.96	-786.99	12.2	24.47	0.658333
8. Scrub land	965	15.06	61.64	0.96	934	14.58	-31	14.1	28.23	145.393
9. Uncultivated/ barren land	60	0.93	22.19	0.34	2.26	0.03	-57.74	0.59	1.181563	3.321667
Total	6405	100	6405	100	6405	100				

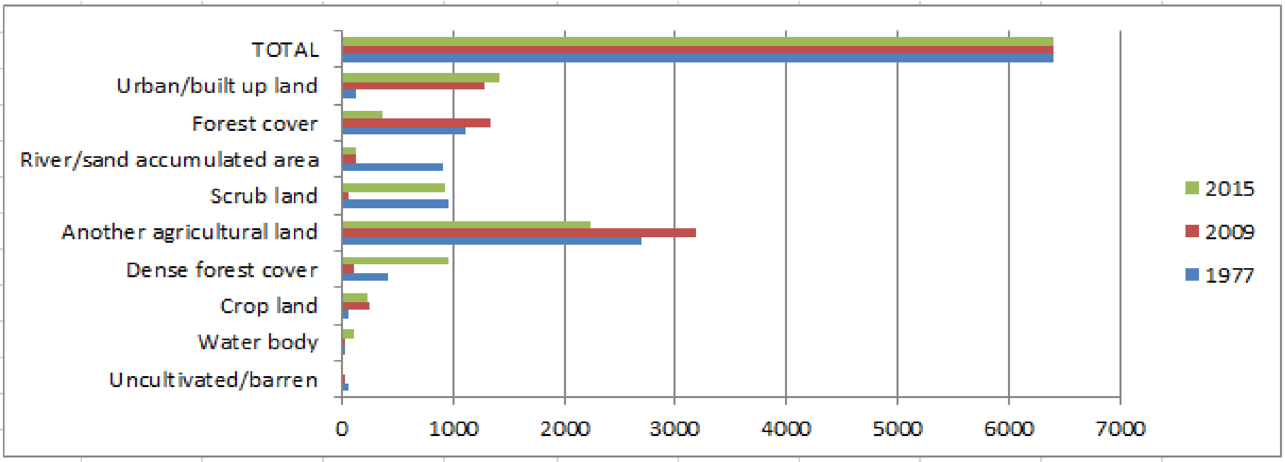

Figure 6: Different landuse change, rate and magnitude (sq.km) during 1977, 2009, 2015

Dense forest cover area is increased from 1977 to 2015 from 6.66% to 15.09% due to rainfall condition which is increased from the past while open forest cover area is decreased in 2015 by 5.8%. It was 17.5% in 1977. Due to increasing rainfall, a portion of forest cover area converted to the dense forest area. In between 7 years (2009 to 2015) annual rate of change is more rapid than change in previous 32 years, between 1977 and 2009 (Table III). Different landuse change, rate and magnitude (sq.km) during 1977, 2009, 2015 has been depicted in Fig 6.

Vellore district is gaining its importance gradually with the announcement from Government of India (GOI) for enlisting the Vellore city in the panel of smart city [26]. This has facilitated the population growth in the study area during recent time which has direct impact on rapid urbanization [31]. As per the Census report of GOI, the Vellore district (district code-040) has total population strength of 3,928,106 with 2,234,049 in rural and 1,694,057 in urban areas. The decadal population growth is 12.96% including 2.98% in rural areas and 29.52% in urban settlements between 2001 and 2011. The percentage share of total population by residence was 62.38 (rural) and 37.62 (urban) in 2001 while according to 2011 census, it shifted to 56.87 (rural) and 43.13 (urban) respectively in Vellore district. These records clearly show the momentous increasing trends of population by residence in urban areas during last 10 years [32]. As it is observed in this study, the south-eastern portion has been increased by area (Fig. 8) more than 10%; forest cover is changed by dense forest cover, urban and built-up area. Some part of south-west, the middle part of the district, and some part of the north, where the area has been decreased by more than 10%. Interestingly, the forest cover, sand accumulated area are converted by urban or built up area and scrub land. Some part which is shown in black colour (Fig. 8) is the area which remains totally unchanged. Excessive change has been marked is urban or built-up land by 26.46% in 2015 which was only 1.93% in the year 1977 (Fig. 7). After 20 years in 2035 all land cover classes will be increased but scrub land, barren land, and sand accumulated area will not be there due to land transformation (Table IV).

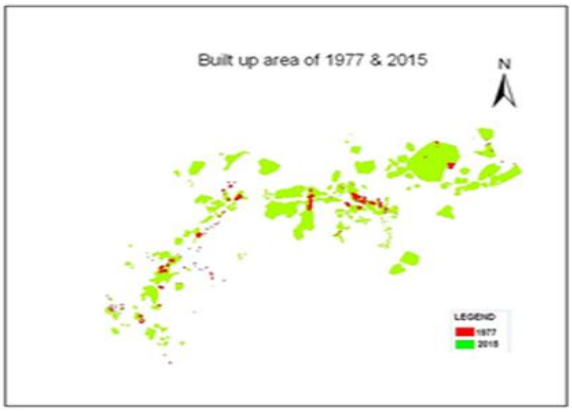

Figure 7: Built up area of 1977 and 2015

Analyses of few studies in and around Vellore district showed landuse changes occurred either by anthropogenic activities, degradation of upper Palar basin or by successive pollutants migration due to continuous discharge of effluents from more than 650 tanneries [33] decrease in agricultural lands and continuous increase of built up areas; or by damaging the agricultural land for cultivation by the wastewater spreading of leather industries[4], or by change from rural to urban areas in towns and municipalities [23, 24] respectively. Mariappan *et al*. (2010) showed 8 classification using Landsat TM amd ETM+ data between 1991 and 2001 while the present study analysed 9 different classes using remote sensing and GIS data between 1977 and 2015 [23]. In a previous report, it was shown that the transition of total agricultural land from 18% to 6% between 1991 and 2009 in Vellore city [5]. However, no study has yet been carried out to examine the landuse change consequences in these gradually growing areas for four decades and predicted future trend for understanding sustainability. The present study focuses on landuse change which hints steady transition in the areas majorly around the Vellore city for conversion of agricultural land to build up areas (Fig. 7).

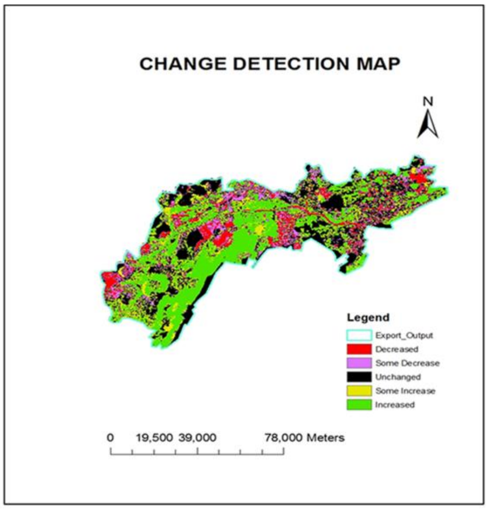

Figure 8: Change detection map

CONCLUSIONS

Vellore district is in transition state. Increasing anthropogenic activity, administrative decision of making it a smart city, and many other relative attributes cause rapid population pressure increases the area of built-up land and decreases cultivated land but area under cropland increases. In future barren or uncultivated land will be decreased due to increasing urban population. Proper irrigation system or planned, proper treatment of the land is necessary for making land suitability for cultivation. Crop rotation, multiple crop system, and modern irrigation system can increase the rate of production. Proper planning is also obligatory for saving the biodiversity.

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