African Journal of Basic & Applied Sciences 2 (5-6): 167-176, 2010
ISSN 2079-2034

Ecological Consequences of Rapid Urban Expansion: Tirunelveli, India

[1]N. Chandrasekar, [2]P.Sivasubramanian and [1]John Prince Soundranayagam

[1]Centre for GeoTechnology, Manonmaniam Sundaranar University, Tirunelveli-627012, India
[2]Department of Geology, V.O. Chidambaram College, Tuticorin-628 008, India

Abstract: Anthropogenic drivers such as the urbanization and economic dependence have being a major force shaping various landscapes. Tirunelveli city is no exception of such landscapes. The present study uses remote sensing and GIS techniques to identify the various land uses, their various transformations over a period of 7 years between 1999-2006 and their related environmental impacts. The study reveals that settlement area has enhanced about 39.19 sq.km and agricultural land has declined about 72.65 sq.km in seven years period. It also revealed that water bodies have also drastically reduced by 20.93sq.km. The implication of this unprecedented growth is the resulting environmental and ecological problems associated with unplanned urban growth and development such as flooding, urban heat island etc. However, Greening and due adherence to development control were suggested as amelioration to impending environmental crisis.

Key words: GIS · Remote sensing · Land use and land cover · Urban expansion · Tirunelveli

INTRODUCTION

Land use and land cover (LULC) data is essential in the analysis of environmental processes and its associated problems. These problems have to be understood if the living condition and standards are to be improved or maintained at sustainable level, in a particular area. Information on the rate and kind of change in the use of resources is essential for proper planning, management and regularizing the use of such resources. Thus the change in LULC can be linked directly to the human natural activities. Traditional methods of monitoring changes in the land use and land cover is time consuming and expensive. Remote sensing and GIS technology can effectively deal with spatial and temporal information related to the changes of LULC. Assessment of spatial and temporal changes in land use pattern is an effective tool for the evaluation of changes occurring in land use and also the extent of environmental degradation. Natural resources such as water bodies, waste and agriculture lands are responsive to human interaction and these together with terrain features determine the selection of proper land use pattern [1, 2]. The land use system is highly dynamic which undergoes significant changes on socioeconomic and natural environment. So the change in any form of land use is largely related either with the external forces and the pressure build-up within the system [3]. Changes in the system of land use can often, however, lead to very unfavorable secondary effects on fragile natural environment [4]. Xie, *et al.* [5] has analyzed the urban - rural land use changes during 1995-2006 in the China. Numerous studies have been attempted in analyzing the urban expansion in eastern and coastal part of the China. This has drawn the attention of authors to focus in India on global perspectives.

LULC changes can have important impact on the water and energy balance, directly affecting the climatic condition. These impacts become globally important through their accumulation effects and its impact on food security, i.e. a conversion of agricultural land in to rural and urban expansion due to population explosion [6].

Urbanization in India has never been a rapid as it is in recent times. As one of the fastest growing economics in the world, India faces stiff challenges in managing the urban sprawl. The urban areas contribute significantly to the national economy, while facing critical challenges in accessing basic services and necessary infrastructure, both social and economic [7, 8]. The overall rise in the population of the urban poor or the increase in travel times due to the congestion along road network are indicators of the effectiveness of planning and governance in assessing and catering to this demand.

Corresponding Author: John Prince Soundranayagam, Centre for GeoTechnology, Manonmaniam Sundaranar University, Tirunelveli-627012 India, E-mail: johnprince06@gmail.com.

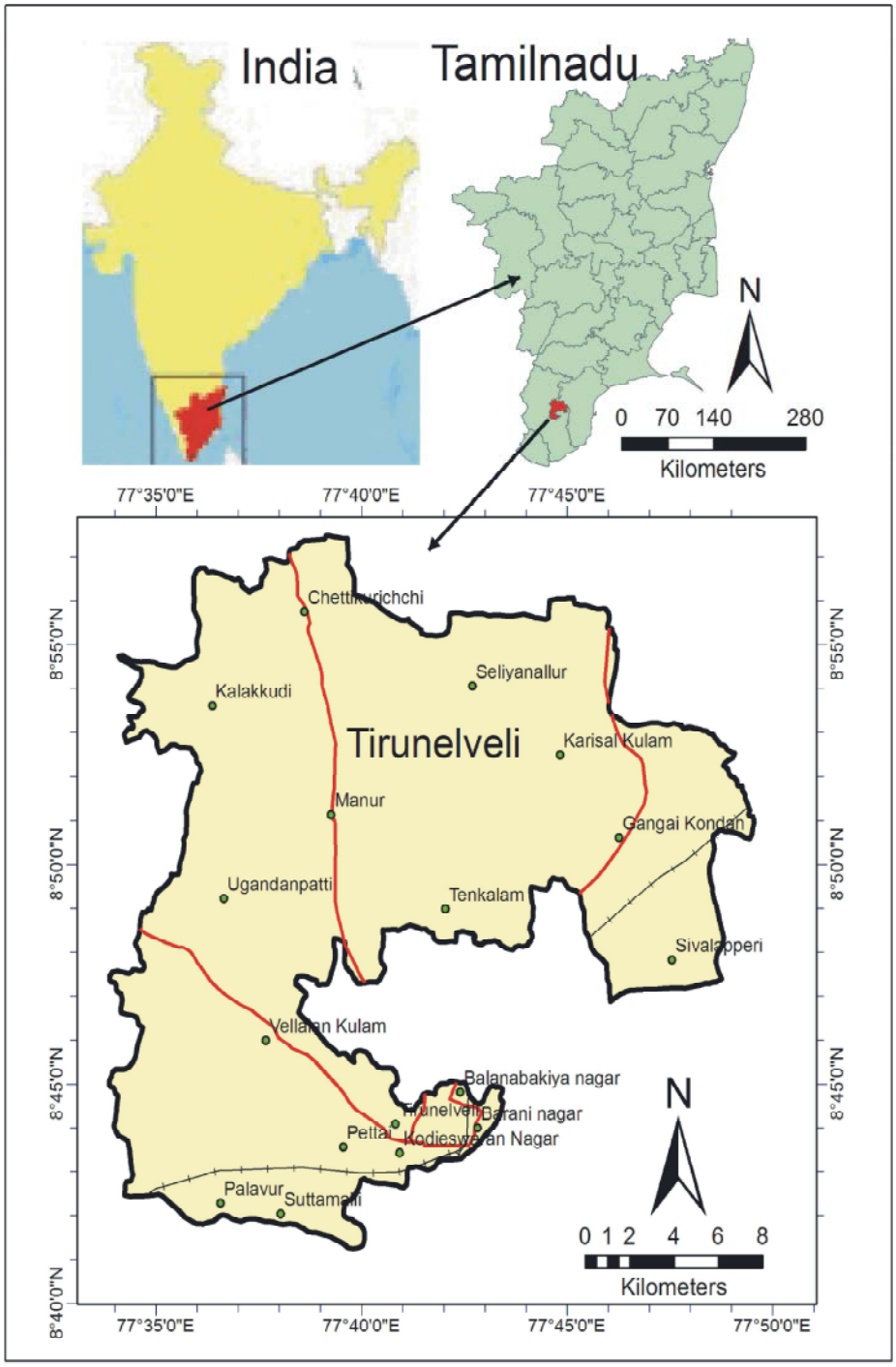

Fig. 1: Location map of the Study area

Provision of infrastructure and assurance of delivery of basic services cannot happen overnight and hence planning has to facilitate forecasting and service provision with appropriate financial mechanisms. The rapid growth of the population, haphazard expansion of local planning area and rapid destruction of agriculture lands in the Tirunelveli, the present study area (Figure 1), needs special attention to study the land use and land cover pattern and its changes with time using remote sensing data.

Present paper addresses the issues of urban sprawl in Indian context with a focus on Tirunelveli city with the utility of spatial planning tools.

Study Area: Tirunelveli is the sixth-largest city in the state of Tamil Nadu, India and the headquarters of the Tirunelveli District. The known history says that Tirunelveli had been under the prominence of the Pandya kings, serving as their secondary capital while Madurai remained its primary capital. It was an important city of the Chola kingdom (B.C.900-1200) and of the Vijayanagar Empire. The city was the chief commercial town in the period of Arcot Nawabs and Nayaks. They were among the various ruling dynasties of Tamil Nadu. In fact, they called the city "Nellai Cheemai", with cheemai meaning a developed foreign town. It was the Nayaks who, in 1781, granted its revenues and local administration to the British. In 1801, it was annexed by the British, who governed it until India achieved independence in 1947. The study area extends from 08° 58' - 08° 40' N latitude and 77°33'-77°51'E longitude (Figure 1). The total geographical area of the Tirunelveli is 485.05 sq.km. Most part of the study area is a plain region, the hilly areas confined along the western and the northern most fringes of the study area. The population of the Tirunelveli district is about 411,298. Males constitute 49% and females 51% of the total population. It has an average literacy rate of 78%, which is higher than the national average literacy rate.

Tirunelveli is also called Nellai. The translation in Tamil for paddy (rice fields) is "Nell". Both the names, Tirunelveli and Nellai, directly associate it to rice fields. Even on satellite imagery, it can be seen that the city is surrounded by fertile paddy fields, enriched by the perennial river "Thamirabarani". The river has a wide network of canals and waterways which irrigate numerous rice fields and support the villages around the district which primarily thrive on cultivating rice. The region is also heavily dependent on the monsoon rains.

Though the main occupation of the people is cultivation, in recent years industries and services are also competing with this ancient occupation. India Cements, Co-operative Spinning Mills and other spinning mills, Sun Paper Mill are a few large scale industrial units functioning within the study area. The chief items produced by large scale industries in the district are cement, cotton yarn, textiles, chemicals and chemical products. Heavy mineral placer sands consisting of illuminate and associated garnet sands occur widely in the Ovari, Navaladi area. This resource favors the heavy mineral separation industries.

Data and Methodology: Spatial information on settlement, agriculture lands, surface water bodies and forest resources during 7 years from 1999 - 2006 for Tirunelveli were carried out using SOI toposheets and IRS ID LISS III Data. The Survey of India (SOI) toposheets - No. 58H /09, 58 H/10,58H /13, 58 H/14 on 1:50,000 scale have been used for generating the basic thematic maps (e.g. water bodies, settlements and agriculture land). Area under different land use classes were computed using the ARC GIS. Field survey was carried out to verify various land use classes and sub - classes.

IRS1D LISS III Image data on 26 June 1999 and 13 June, 2006 of the same projections and identical scale of the study area were examined using ERDAS Imagine software. These data were registered with each other using 10 GCPs (Ground Control Points) that are distributed uniformly over the study area. In this study, supervised classification was applied to classify images into different classes of LULC. LULC training sets were prepared representing each known LULC category that appears fairly homogeneous on the image. In total six LULC classes were recognized [9, 10]. Using these signature files, supervised classification was done by Maximum likelihood classification algorithm processing in ERDAS IMAGINE 8.5 software. Accuracy of the classification of each datasets and classifier was expressed as an error matrix from which the overall accuracy, user's accuracy, producer's accuracy, the Kappa statistics were derived. These image classification algorithms provided better accuracy of 92% and 93% respectively for the year 1999 and 2006.

Urban Sprawl of Tirunelveli: Tirunelveli is an ancient city with rich cultural heritage, including the largest Shiva Temple in Tamil Nadu. The city is considered to be one of the oldest in the Indian subcontinent, with a history that dates back to 1000 BC. It is located on the western side of the perennial river Thamirabarani. Even though agriculture is the traditional activity of Tirunelveli, several industries were developed in recent times within Tirunelveli based on the natural resources available within the study area. The industries prevalent in the district may be classified under (i) household industries (ii) small scale and (iii) medium and large scale industries. Beedi rolling, safety-matches making, mat weaving and processing and manufacture of palm fibre and articles from palm trees and handloom weaving of textiles are the main household industries. Workers in household industries are concentrated mostly in out skirts of Tirunelveli city. There are about 2300 small scale industries. Of all the 18 major groups, units manufacturing chemical products alone

Table 1: Land use and land cover change of Tirunelveli (1999 - 2006)1999 (area in sq.km)

Sl.No	Land use category	Area in1999 sq.km	Percentage	Area in 2006 sq.km	Percentage	Change in Areasq.km
1	Settlement	44.31	9.13	83.49	17.21	39.19
2	Water body	33.55	6.92	12.62	2.60	-20.93
3	Agricultural Land				0.00	
(i)	Crop Land	174.05	35.88	100.04	20.62	-74.02
(ii)	Plantation	4.22	0.87	5.38	1.11	1.16
4	Waste Land		0.00		0.00	
(i)	Open scrub	136.01	28.04	91.33	18.83	-44.69
(ii)	Dense scrub	42.07	8.67	119.56	24.65	77.49
(iii)	Mining	5.05	1.04	11.64	2.40	6.58
(iv)	Grass land	32.42	6.68	32.04	6.61	-0.38
5	Forest	13.37	2.76	28.96	5.97	15.59
Total	485.05	100.00	485.05	100.00		

account for nearly one third. There are more than 20 textile mills situated in this district for the production of yarn. The first spinning mill under co-operative moment was established in this district during 1958 at Pettai near Tirunelveli. Most of them are situated in Ambasamudram, Tirunelveli and Nanguneri taluks. Tamil Nadu Sugar Corporation Limited has established a factory at Tirunelveli which has a capacity to crush 1250 tonnes of cane a day.

Tirunelveli city is traditionally known for having good education centers, high potential groundwater resource, well connected road and rail networks. This city is popularly known as pilgrimage centre for all religions. Even though people work in different places within the district, people prefer to settle at Tirunelveli for the above said reasons. Because of the steady growth in population in the study area, urban sprawl has extended outward by encroaching nearby fertile agricultural land and water tanks. This is well documented in our present study (Table 1). The classified landuse and land cover map for the year 1999 and 2006 shown in the Figure 2 and Figure 3 respectively.

Settlement: The area of settlement in 1999 was about 44.31 sq.km (9.31 %) , while in the year 2006 the settlement drastically increased by 83.49 sq.km (17.21%). In the last 7 years the settlement was increased about 39.19 sq.km (Figure 4). This change was mainly due to expansion of urban in the form of newly developed Sankar Nagar, Balabackia Nagar, Kodieswaran Nagar and Barani Nagar area in the pre-existing agricultural land, waste land and water bodies.

Water Bodies: In 1999, the area of surface water body (rivers, streams, lakes, tanks and reservoirs) was 33.55 sq.km (6.92%). While in the year 2006, it has drastically reduced to 12.62 sq.km (2.60%). For the 7 years about 20.93sq.km area of the surface water bodies decreased and converted as government buildings, settlements and some water bodies are converted as waste land because of improper maintenance (Figure 5, Table 1).

Agricultural Land: The total agriculture land (crop land and plantation) in 1999 was about 178.27 sq.km (36.75%). In 2006, it was reduced to 105.42 sq.km (21.73%). During the last 7 years total area of the agriculture land was decreased about 75.18 sq.km (Figure 6). The agricultural land was mainly converted as settlement and partly as mining area. Because of the development of the city, the land value has escalated and caused the conversion of agricultural land to settlement.

Waste Land

Open Scrub: The total area of the open scrub in the year 1999 was 136.01 sq.km (28.04%) and in the year 2006 the open scrub had come down to 91.33 sq.km (18.83%). During the study period the open scrub has decreased by 44.69 sq.km (Table1). The forest department had developed the open scrub and converted them in to dense scrub.

Dense Scrub: Total area of the dense scrub in the year 1999 was 42.07 sq.km (8.67%) and in 2006 it was 119.56 sq.km (24.65%). In the seven year period the dense scrub had increased by 77.49 sq.km (Table 1).

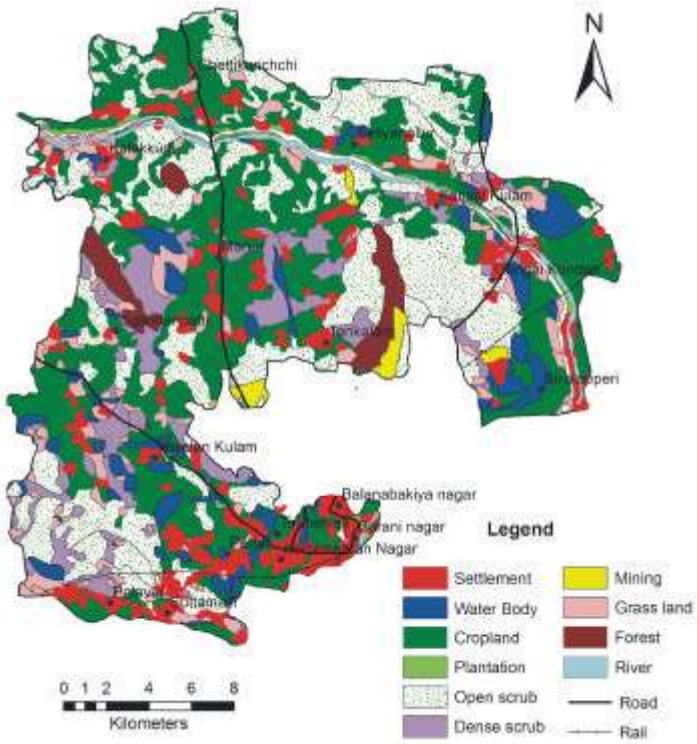

Fig. 2: 1999 Landuse, Land cover classification of Tirunelveli

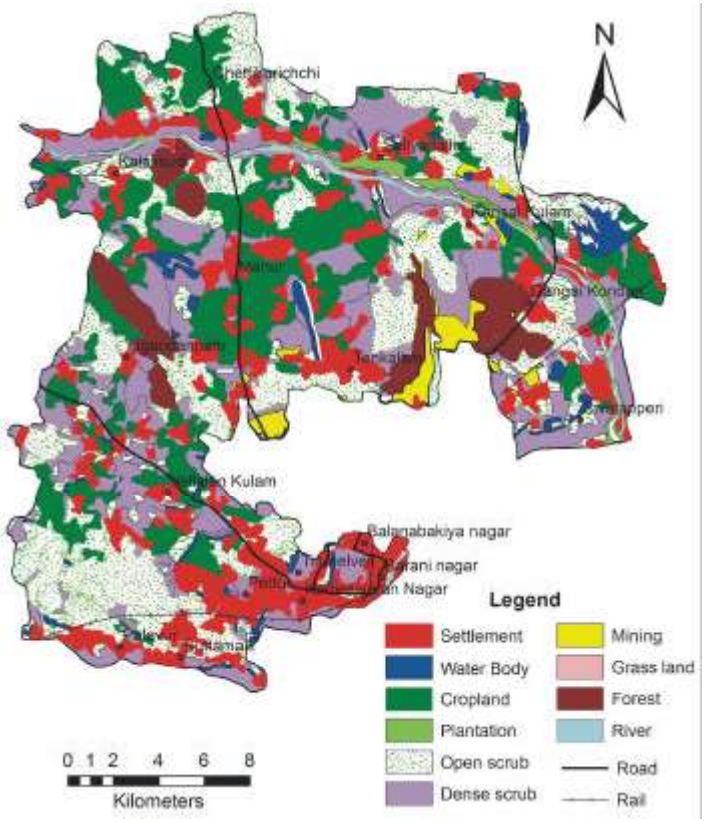

Fig. 3: 2006 Landuse, Land cover classification of Tirunelveli

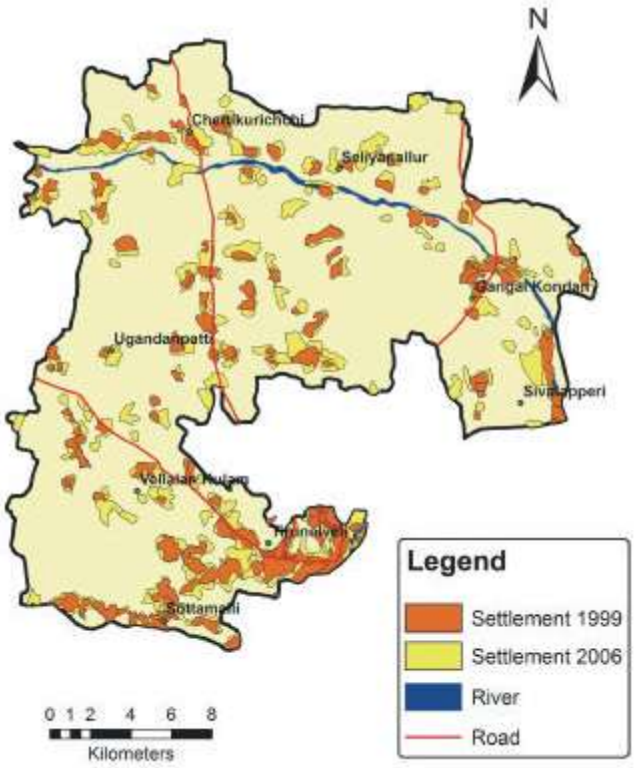

Fig. 4: Overlay map of Settlement, Tirunelveli

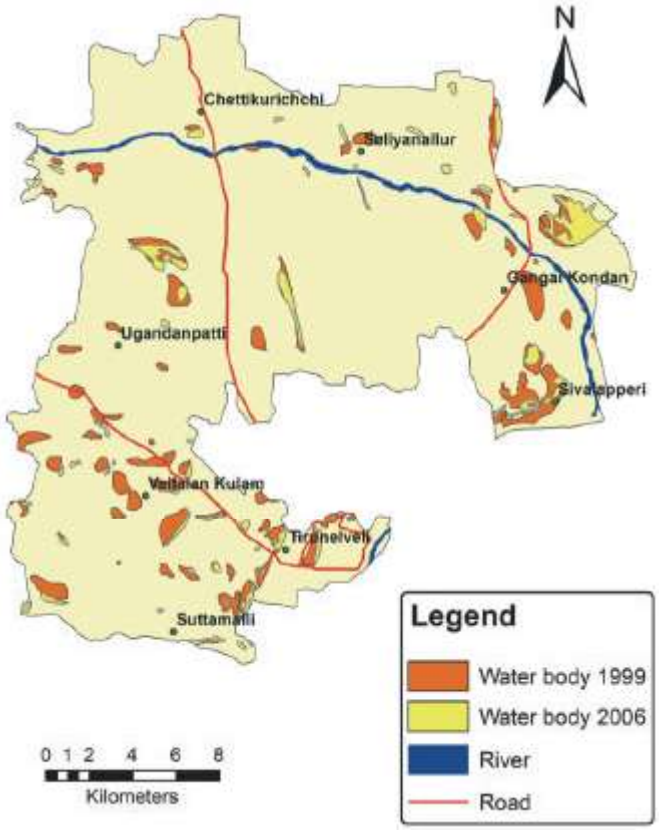

Fig. 5: Overlay map of Water body, Tirunelveli

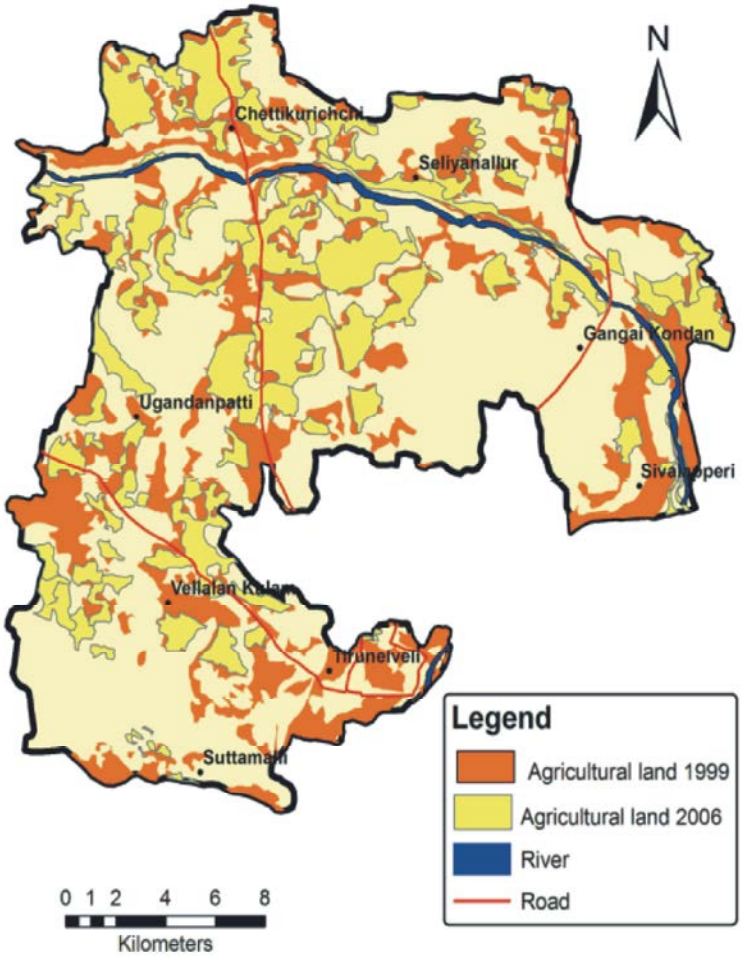

Fig. 6: Overlay map of Agricultural land , Tirunelveli

Mining Area: Tirunelveli is rich in lime stone. The total mining area in 1999 was about 5.05 sq.km (1.04%) and in 2006 it was about 11.64 sq.km (2.40%) (Table 1). The infrastructure development in India has caused the demand for cement and its raw material lime stone. The increase in demand for lime stone has increased the mining area by 6.58 sq.km in 7 years period.

Grass Land: The total area of grassland in 1999 was about 32.42 (6.68 %) and in 2006 it was about 32.04 sq.km (6.61%). During the 7 years the total area of grassland had not changed significantly (Table 1).

Forest: The forest land area in 1999 was 13.37 sq.km (2.76%), while in 2006 forest land has increased by 28.96 sq.km (5.97%). During 7 years period the forest area was increased by 15.59 sq.km (Table 1).

RESULT AND DISCUSSION

The dynamic process of the spatial-temporal characteristics of land use changes during 7 years from 1999 to 2006 in the Tirunelveli, Tamilnadu was analyzed to improve understanding and to find the driving forces of land use changes so that sustainable land utilization could be practiced. In the present study, overlay analysis was performed to detect "where the land use change has occurred and which type of land has transformed to what?" The data derived from this study is given in Table 2. In Table 2, the vertical column shows total amount of land used for a particular class in 1999. Horizontal line shows the total changes that have happened in a particular class within seven years period and what type of land has contributed for this change.

Table 2: Land Transformation in Tirunelveli (1999-2006)

	Settlement	Water body	Agricultural Land	Waste Land	Forest	Total
2006						
Settlement	30.49	3.27	31.47	18.19	0.06	83.49
Water body	0.30	7.30	2.42	2.60	0.00	12.62
Agricultural Land	4.47	4.57	68.52	27.58	0.27	105.42
Waste Land	8.92	18.41	74.78	150.19	2.28	254.57
Forest	0.13	0.01	1.07	16.99	10.76	28.96
Total	44.31	33.55	178.27	215.55	13.38	

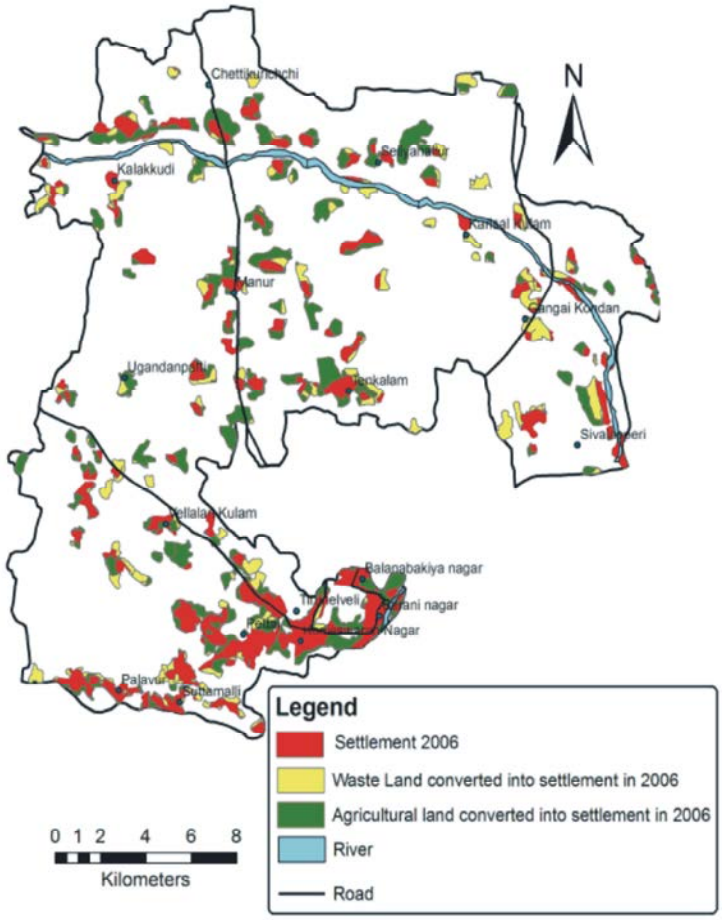

Fig. 7 : Conversion map of Agricultural Land and waste land to Settlement

Settlement area of Tirunelveli has increased about 39.19 sq.km in the period between 1999 and 2006. For this rapid increase in settlement, agricultural land and waste land are the main contributors. Agricultural land has contributed 31.47 sq.km and waste land has contributed 18.19 sq.km (Table 2). The Figure 7 clearly shows changes that have happened in the settlement area in the year 2006. From the figure one can easily identify exactly where the agricultural and waste land was transformed into settlements. New settlement such as Balabackia Nagar, Kodieswaran Nagar , Barani Nagar and Sankar Nagar were developed within agricultural area. These transformation activities have reduced the agricultural area. Due to the infrastructural developmental activity, new bye-pass roads, ring roads and four-way lanes were constructed within the city. These newly developed roads facilitate the development of new industrial and settlement area along the sides of these roads and caused the reduction in agricultural area.

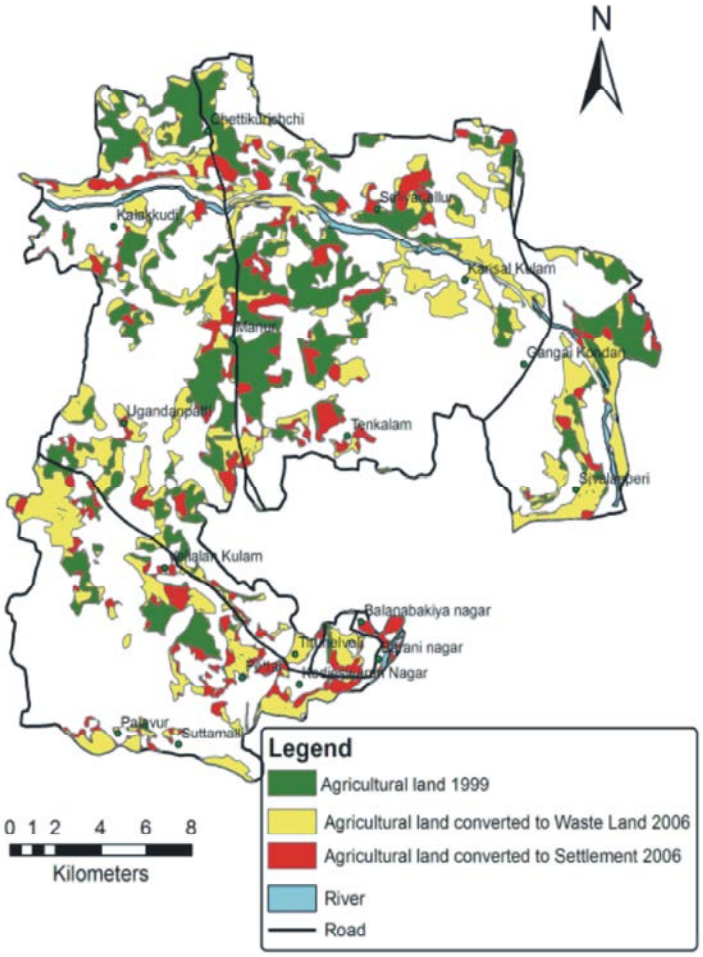

Fig. 8: Conversion map of Agricultural Land to Settlement and waste land

In the year 1999 the total surface of water body was 33.55sq.km and in seven years water body has been converted to wasteland 18.41sq.km, agricultural land 4.57 sq.km and settlements 3.27sq.km. In the fringes of the city most of the agricultural lands were converted in to settlements. The irrigational tanks supply water to the above said agricultural land has been abundant and invaded by thorny bushes and becomes waste land. The implication of this rapid loss in agricultural land, water body and expansion of settlement area result in more solar energy being stored and converted to sensible heat and the removal of vegetation covers reduces those natural cooling effects of shading and evapotranspiration.

CONCLUSION

The present study reveals the possibility of applying Remote Sensing and Geographical Information Systems (GIS) techniques on evaluating the loss of agricultural land due to urban expansion and also on the exploitation of other environmental natural resources. The results showed that urbanisation leads to LULC change and landscape pattern alteration which responded obviously to the urbanisation phases. The loss of agricultural land and water bodies due to urban expansion in Tirunelveli cannot be totally halted, but needs sustainable planning and management in protecting the loss of agricultural land and water bodies. Urban expansion has led to degradation of ecosystem. Despite its degradation, Tirunelveli had witnesses several socio-economic developments. Enhancement of agriculture land and reclamations of the waste land in to pastureland can avoid the shortage of food grains in future and water resources in near future. Similarly the urban expansion could be avoided in the low lying or previously occupied by water bodies to avoid the inundation which has been well evidenced from our data base. However it is necessary to obtain data in long time to the study of urbanisation, a process with ecosystem.

ACKNOWLEDGEMENT

We thank Tamilnadu State planning commission, Chennai for financial support to carryout the project under state land use board(SLUB).

REFERENCES

1. Turner, B.L. and William B. Meyer, 1994. Changes in Land Use and Land Cover: A Global Perspective, Cambridge University Press, USA.
2. Wolman, M.G., 1987 F. G. A. Fournier (editors) 1987. Land Transformation in Agriculture, John Wiley and Sons, Chichester, UK.
3. Foody, G.M., 2002. Status of Land Cover Classification Accuracy Assessment, Remote Sensing of Environ., 80: 185-201.
4. Dhinwa, P.S., S.K. Pathan, S.V.C. Sastry, M. Rao, K.L. Majumdar, M.L. Chotani, J.P. Singh and R.P. Sinha, 1992. Landuse changes analysis of Bharatpur district using GIS. J. The Indian Society of Remote Sensing, 20(4): 237-250.
5. Xie, Y.C., C.L. Fang, G.C.S. Lin, H.M. Gong and B. Qiao, 2007. Tempo-spatial patterns of land use changes and urban development in globalizing China: a study of Beijing. Sensors. 7 : 2881-2906.
6. Brown, L.R., 1995. Who will feed china: Wake-Up call for a small planet. The worldwatch Environmental Alert Series. New York
7. Liu, S., P. Sylvia and X. Li, 2002 Spatial patterns of urban land use growth in Beijing, J. Geographical Sci., 12(3): 266-274.
8. Wahab, M.A. and H.M.S. Hasanean, 1999. Contrasting features of two tropical summers from satellite observations. Atmospheric Res., 50: 105-1170.
9. Sha, A.K., M.K. Arora, E. Csaplovics and R.P. Gupta**,** 2005. Land Cover Classification Using IRS LISS III Image and DEM in a Rugged Terrain: A Case Study in Himalayas, Geocarto International, pp: 20-2.
10. Wu, L.X., B. Sun, S.L. Zhou, S.E. Huang and Q.G. Zhao, 2004. A new fusion technique of remote sensing images for land use/cover. Pedosphere, 14: 187-194.