Recent Research in Science and Technology 2011, 3(2): 70-76
ISSN: 2076-5061
www.recent-science.com

GEOGRAPHY AND GEOLOGY

GEOMATIC BASED URBAN SPRAWL DETECTION OF SALEM CITY, INDIA

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Abstract

Urban sprawl refers to the extent of urbanisation, which is a global phenomenon mainly driven by population growth and large scale migration. In developing countries like India, where the population is over one billion, one-sixth of the world's population, urban sprawl is taking its toll on the natural resources at an alarming pace. Urban planners require information related to the rate of growth, pattern and extent of sprawl to provide basic amenities such as water, sanitation, electricity, etc. In the absence of such information, most of the sprawl areas lack basic infrastructure facilities. Pattern and extent of sprawl could be dectected with the help of statelite images and temporal data. This is used to analysing the growth, pattern and extent of sprawl. This paper brings out the extent of sprawl taking place over a period of nearly four decades using GIS and Remote Sensing.

Keywords: Urban sprawl; Urbanisation; GIS; Remote sensing; trend; urban Change, detection

Introduction

The process of urbanisation is a universal phenomenon taking place the world over, where humans dwell. All countries are prone to this bewildering phenomenon chiefly responsible due to the increase in population growth, economy and infrastructure initiatives. The extent of urbanisation or the sprawl is one such phenomenon that drives the change in land use patterns. The sprawl normally takes place in radial direction around the city centre or in linear direction along the highways. Usually sprawl takes place on the urban fringe, at the edge of an urban area or along the highways. The study on urban sprawl (The Regionalist, 1997; Sierra Club, 1998) is attempted in the developed countries (Batty et al., 1999; Torrens and Alberti, 2000; Barnes et al., 2001, Hurd et al., 2001; Epstein et al., 2002) and recently in developing countries such as China (Yeh and Li, 2001; Cheng and Masser, 2003) and India (Jothimani, 1997; Lata et al., 2001; Sudhira et al., 2003). In India alone currently 25.73% of the population (Census of India, 2001) live in the urban centres, while it is projected that in the next fifteen years about 33% would be living in the urban centres. This indicates the alarming rate of urbanisation and the extent of sprawl that could take place. In order to understand this increasing rate of urban sprawl, an attempt is made to understand the sprawl dynamics and evolve appropriate management strategies that could aid in the region's sustainable development. Understanding such a phenomenon and its pattern helps in planning for effective natural resource utilisation and provision of infrastructure facilities.

The built-up is generally considered as the parameter for quantifying urban sprawl (Torrens and Alberti, 2000; Barnes et al., 2001; Epstein et al.,2002). It is quantified by considering the impervious or the built-up as the key feature of sprawl, which is delineated using toposheets or through the data acquired remotely. The convergence of GIS, remote sensing and database management systems has helped in quantifying, monitoring, modelling and subsequently predicting this phenomenon. At the landscape level, GIS aids in calculating the fragmentation, patchiness, porosity, patch density, interspersion and juxtaposition, relative richness, diversity, and dominance in order to characterise landscape properties in terms of structure, function, and change (ICIMOD, 1999; Civco et al., 2002). Modelling the spatial and temporal dimensions has been an intense subject of discussion and study for philosophy, mathematics, geography and cognitive science (Claramunt and Jiang, 2001). Modelling of the spatial dynamics rests mostly with the land cover/land use change studies (Lo and Yang, 2002) or urban growth studies. In order to predict the scenarios of land use change in the Ipswich watershed, USA over a period of two decades, Pontius et al. (2000) predict the future land use changes based on the model validated for 1971, 1985 and 1991.

In urban growth modeling studies, the spatial phenomenon is simulated geometrically using techniques of cellular automata (CA). The CA technique is used extensively in the urban growth models (Clarke et al., 1996) and in urban simulation (Torrens and O' Sullivan, 2001; Waddell, 2002). The inadequacy in some of these is that the models fail to interact with the causal factors driving the sprawl such as the population growth, availability of land and proximity to city centers and highways. Cheng and Masser (2003) report the spatial logistic regression

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technique used for analyzing the urban growth pattern and subsequently model the same for a city in China. Their study also includes extensive exploratory data analyses considering the causal factors. The inadequacies in their technique related to accurately pinpoint spatially where the sprawl would occur. This problem could be effectively addressed when neural network is applied to the remote sensing data especially for classification and thematic representation (Foody, 2001). The neural spatial interaction models would relieve the model user of the need to specify exactly a model that includes all necessary terms to model the true spatial interaction function (Fischer, 2002).

However, monitoring of urban land use change using the techniques of remote sensing and GIS and its subsequent modeling to arrive at a conventional approach is lacking in the context of India. The objective of this investigation is to analyse and understand the urban sprawl pattern and dynamics to predict the future sprawls and address effective resource utilization for infrastructure allocation.

In order to quantify the urban forms such as built-up in terms of spatial phenomenon, the Shannon's entropy (Yeh and Li, 2001) and the landscape metrics (patchiness, map density) were computed for understanding the built-up dynamics. The landscape metrics, normally used in ecological investigations, is being extended to enhance the understanding of the urban forms. Computation of these indices helped in understanding the process of urbanisation at a landscape level.

Methodology to measure urban sprawl

Understanding the dynamic phenomenon such as urban sprawl requires land use change analyses, urban sprawl pattern identification and computation of landscape metrics. Drainage network (rivers, streams and water bodies), roads and railway network and the administrative boundaries were digitised from the toposheets as individual layers. The highway passing through city was digitized.Land cover and land use analysis for this region is done using IRS LISS III images. Urban sprawl over the period about 4 decades (1973–2010) is determined by computing the built up area of all the settlements from the Survey of India (SOI) toposheet of 58 I/2 (1972) and comparing it with the area obtained from the classified satellite imagery for the built-up theme.

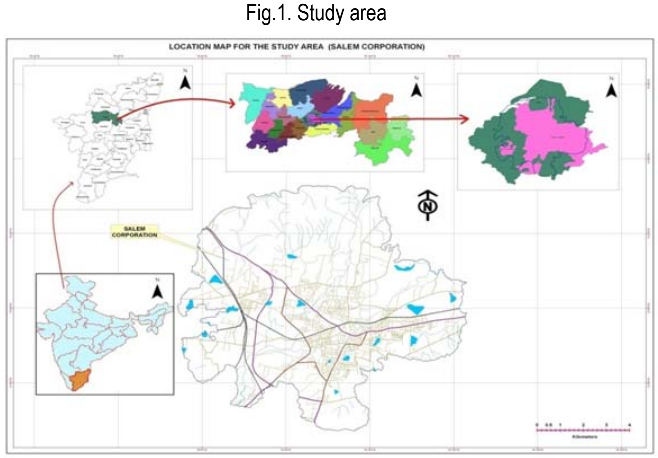
The image analyses included bands extraction, restoration, classification, and enhancement. The original classification of land-use of 12 categories was aggregated to vegetation, built-up (residential and commercial), crop lands and water bodies was computed.

Study area

The study area Salem city situated in Salem District of Tamilnadu, India. (Fig.1). The town is surrounded by hills on all sides: the Nagaramalai to the north, the Jarugumalai to the south, the Kanjamalai to the west, and the Godumalai to the east. It is divided by the river Thirumanimuthar in the main division. The fort area is the oldest part of the town. The study area covers the part of toposheets of Survey of India No.58 I/2 (1:50,000,1972), 11° 39' 0" to 11.65N and 78.16 to 78° 9' 36" E. Salem Corporation consists of 60 wards categorized under 4 Zonal namely Suramangalam Zonal, Hasthampatty Zonal, Ammapet Zonal, Kondalampatty Zonal with 91.34 (sq.km).It is 278m above Mean Sea Level. The soil types of the study area are red non-calcareous and red calcareous soils.

The average annual rainfall is 363.5 mm. mm. The temperature is generally very high during summer and it ranges from 20.0 to 37.9° degree celsius. According to 2001 census, the total population of the Salem town is around 30,16,346 of which 12,79,846 are workers and the rest are a non-worker. The area has a good transport system of road network and well connected by the adjacent towns namely Banglore,Chennai,Trichy and coimbatore. It also has the good communication facilities.

Fig.1. Study area



Data collection

The data collection was done from both primary and secondary data sources. The primary data collected were the Survey of India toposheets of 1:50,000 scale for the corresponding region,Land sat corresponding path -143, row-52 for year 1973 from GLCF web site down loaded and the multispectral satellite imagery of the Indian Remote Sensing (IRS) satellite,

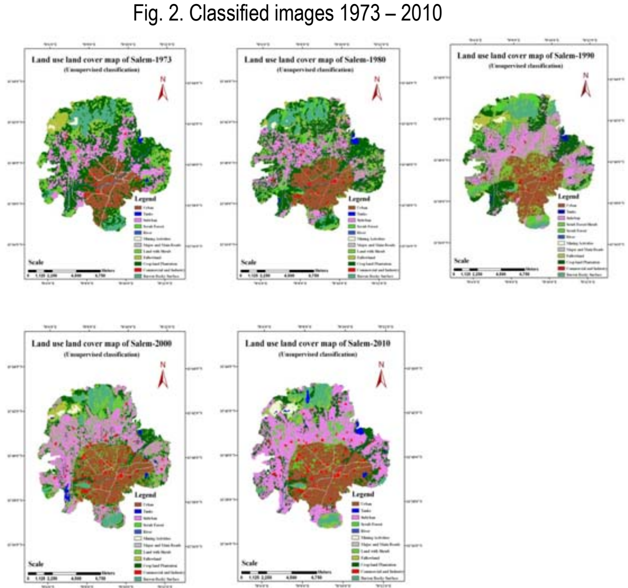
1980 MSS, LISS-III 1991,2000 and 2010 from the National Remote Sensing Agency, Hyderabad, India. The secondary data collected included the demographic details from the census abstracts of the study area for 1971, 1981, 1991 and 2001, from the Directorate of Census Operations, Census of India. The corporation map of this region was obtained from Town and Country Planning, Salem,Tamilnadu,India.

Results and discussion

Image analyses

The standard image processing techniques such as, image extraction, rectification, restoration, and classification were applied in the current study. Training polygons were chosen from the composite image and corresponding attribute data was obtained in the field using GPS. Based on these signatures, corresponding to various land features, image classification was done and the classified image is given in Fig. 2.

Fig. 2. Classified images 1973 – 2010



Built-up area

The rate of development of land in Udupi, Mangalore region, is outstripping the rate of population growth. This implies that the land is consumed at excessive rates and probably in unnecessary amounts as well. Between 1972 and 1999, population in the region grew by about 54% (Census of India, 1971, 1981, 1991) while the amount of developed land grew by

Fig. 3. Built-up from 1973–2010

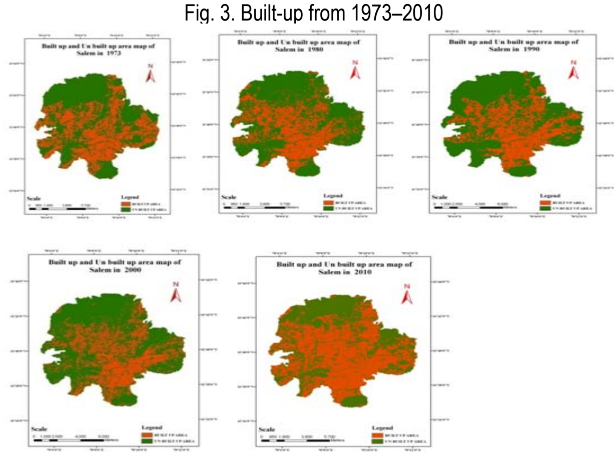
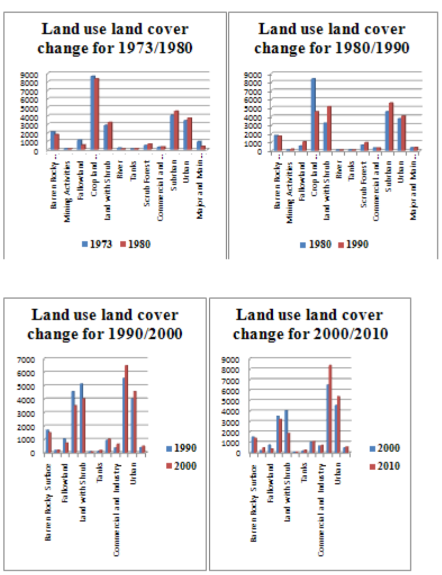


Fig. 3. built-up from 1971–1999about 146%, or nearly three times the rate of population growth. This means that the per capita consumption of land has increased exceptionally over three decades. The per capita land consumption refers to utilisation of all lands for development initiatives like the commercial, industrial, educational, and recreational establishments along with the residential establishments per person. Since most of the initiatives pave way for creation of jobs and subsequently help in earning livelihood, the development of land is seen as a direct consequence of a region's economic development and hence one can conclude that the per capita land consumption is inclusive of all the associated land development.

Urban sprawl and Land use and Land cover change

Characterising pattern involves detecting and quantifying it with appropriate scales and summarising it statistically. There are scores of metrics now available to describe landscape pattern. The only major components that were considered for this study are composition and structure. The landscape pattern metrics are used in studying forest patches (Trani and Giles, 1999; Civco et al., 2002). Most of the indices are correlated among themselves, because there are only a few primary measurements that can be made from patches (patch type, area, edge, and neighbour type), and all metrics are then derived from these primary measures.The below fig.(4&4a). shows urban occupancy area and land use land cover change over the years 1973-2010.

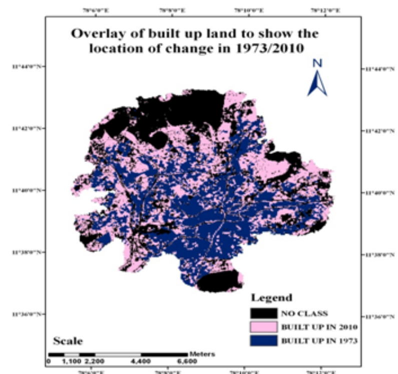
Fig. 4. Built-up from 1973–2010



Dynamics of urban sprawl and Urban change

Defining this dynamic phenomenon and predicting the future sprawl is a greater challenge than the quantification of sprawls. Although different sprawl types were identified and defined there has been an inadequacy with respect to developing mathematical relationships to define them. This necessitates characterisation and modelling of urban sprawl, which will aid in regional planning and sustainable development.Urban sprawl dynamics was analysed considering some of the causal factors.

Fig. 5. Overlay build up land 1973/2010



Urban trend

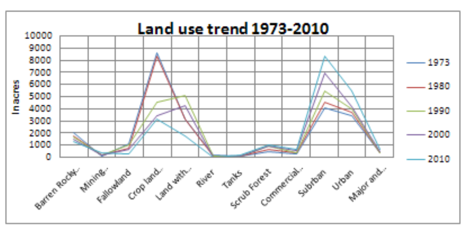
Likely increase in the built-up area is predicted using Fig. (6 &6a). To project LULC for 2020 and 2050, corresponding Class for average for 37 years and it is multiplied with future number of years was computed considering average based on the historical area expansion of 1973-2010.The rational behind this is to identify such factors that play a significant role in the process of urbanisation. The causal factors that were considered responsible for sprawl were population density and annual population growth rate. The factor population has been accepted as a key factor of urban sprawl.

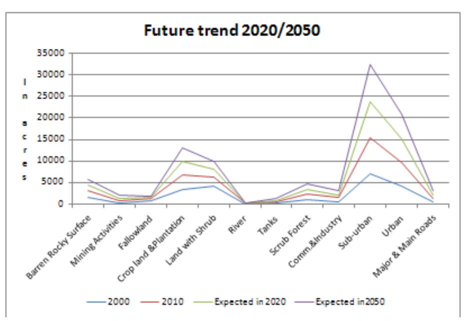
Fig. 6 &6a. Year wise percentage of Change in area 1973-2050

	1973/80	1980/90	1990/00	2000/10	2020	2050
Barren Rocky Surface	-14.9882	-3.82293	-8.2920164	-10.7049441	-10.2184	-40.8737
Mining Activities	8.196863	32.5599	42.3190347	79.85717291	44.03594	176.1438
Fallowland	-35.4439	40.39312	-28.703682	-51.19299279	-20.2561	-81.0243
Crop &Plantation	-3.29081	-45.4967	-23.022392	-8.313749479	-21.655	-86.6202
Land with Shrub	-1.35872	62.90303	-16.242622	-56.94093475	-3.14574	-12.583
River	-34.5924	-37.181	-11.57706	-5.897227576	-24.121	-96.484
Tanks	9.262548	29.67048	70.7593961	33.48125031	38.69559	154.7824
Scrub Forest	33.59966	40.93022	7.52007951	7.958739836	24.32668	97.30671
Com&Industry	15.54879	1.846978	89.0543917	9.421015418	31.31653	125.2661
Suburban	13.21398	21.08772	26.2878283	19.72604578	21.70691	86.82765
Urban	8.967581	7.990175	5.90838077	28.6287663	13.91754	55.67017
Roads	10.76616	6.682594	23.7695537	54.10306524	25.76253	103.0501

Class	1973	1980	1990	2000	2010	2020	2050
Barren Rocky Surface	2080.283	1768.485	1700.877	1559.84	1392.86	1382.642	1341.768
Mining Activities	128.5443	139.0809	184.3655	262.3872	471.9222	515.9581	692.1019
Fallow land	1139.552	735.65	1032.802	736.3498	359.3903	339.1342	258.1099
Crop &Plantation	8630.038	8346.04	4548.867	3501.609	3210.494	3188.839	3102.219
Land with Shrub	3186.668	3143.37	5120.645	4288.918	1846.768	1843.622	1831.039
River	196.4924	128.521	80.73561	71.3888	67.17884	43.05784	-53.4262
Tanks	84.28771	92.0949	119.4199	203.9207	272.1959	310.8915	465.6739
Scrub Forest	501.0559	669.409	943.3996	1014.344	1095.073	1119.4	1216.706
Com&Industry	291.7822	337.1508	343.3779	649.171	710.3295	741.646	866.9121
Sub-urban	4037.359	4570.855	5534.744	6989.708	8368.501	8390.208	8477.036
Urban	3409.983	3715.776	4012.673	4249.757	5466.41	5480.328	5535.998
Major & Main Roads	336.5053	372.734	397.6423	492.1601	758.4338	784.1963	887.2464

Fig.6. Land use trend 1973-2010





It is found that the percentage built-up for 2020 and 2050 would be 66.94 and 267 %, respectively. This implies that by 2020 and 2050, the built-up area in the region would rise to 24,281,38,946 acres in built-up area to the current sprawl of 14,545 acres over the region. Thus, indicating that the pressure on land would further grow and the agriculture fields, open grounds and region around the highways would become prime targets for sprawl. This would also give a picture of the pressures on the land, which the planners have to address in their planning exercises. With an understanding of the land requirement under the current trend, the techniques of GIS and remote sensing can be applied for effective infrastructure facilities and resource utilisation.

Conclusion

With the population of India increasing as ever, the pressures on land and resources are also increasing. The urban sprawl is seen as one of the potential threats to sustainable development where urban planning with effective resource utilisation and allocation of infrastructure initiatives are key concerns. The study attempts to identify such sprawls,chnge in land use land cover change for 1973-2010 and same to predict for future 2020and 2050. The study was carried out Salem corporation,Tamil nadu,India using the techniques of GIS and remote sensing to identify and detect the urban sprawl. The spatial data along with the attribute data of the region aided to analyse statistically and fore casting.

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Acknowledgement

Authors are highly thankful to Director, National Remote Sensing Agency, Hyderabad and the Director, Town and Country Planning Office, Salem,Tamilnadu,India for their kind help in providing reference data and valuable suggestions.

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