GIS and Remote Sensing Applications to Study Urban Sprawl of Udaipur, India

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ABSTRACT: Urban sprawl has been one of the burgeoning issues of study in the present development situation where increasing population and migration for better livelihood opportunities have paved way for rapid expansion of the urban centres. GIS and remote sensing based study is carried out to comprehend the process of sprawl. Landsat MSS, TM and ETM Plus satellite imageries are used to study the phenomena for the years 1972, 1990 and 2000 respectively. Spatial analysis is done using GIS to chalk out the potentials and restraints of the region. The article aims to study the magnitude, growth and trend of urban sprawl taking place along the major transport arteries linking Udaipur city of Rajasthan, India with the major development hubs of the nation during the last decades. The region is witnessing intense concentration of tourism and industrial activities. As hypothesized urban development occurs along the arteries taking advantage of existing infrastructure in a state where there is a lack of planned development. In lieu of this, built-up land advance take place which is mostly along the major accessible routes where land price are increasing. This mechanism of land encroachment degrades the existing green belt and results in a chaotic growth of the urban settlement. This has led to redistribution of land by the complementary tendencies of concentration and dispersion.

KEYWORDS: GIS, Remote Sensing, Urban Sprawl

Introduction

In India, unprecedented population growth coupled with unplanned developmental activities has resulted in rapid but skewed urbanization. This has posed serious implications on the resource base, access to infrastructure and the development of the region. The problems created by the haphazard and unrestricted growth of city aggravates irregular and chaotic development of residential, industrial and commercial areas resulting in traffic bottle necks, slums, polluted environment and others all known and felt by the residents of the city.

The urbanization takes place either in radial direction around a well-established city or linearly along the highways. This dispersed development along highways or surrounding the city and in rural countryside is generally referred as sprawl. Sprawl is a term that is often used to describe perceived inefficiencies of development, including disproportionate growth of urban areas and excessive leapfrog development. Sprawl is a cumulative result of many individual decisions and it requires not only an understanding

of the factors that motivate an individual landowner to convert land, but also an understanding of how these factors and individual land-use decisions aggregate over space. Some of the causes of the sprawl include - population growth, economy and proximity to resources and basic amenities.

The Study Area

The Udaipur and its environs, which is taken as the study area, is spread over a territory of 508.75 km^2 and covers sixty seven villages in the vicinity of the Udaipur city with extension of 24^0 30' to 24^0 40' N and 73^0 37'30" to 73^0 52' 30" E. The north-south extension is 18.5 km and the east-west extension is 27.5 km (Fig. 1). The region has a population of about 553, 261 persons spread over sixty seven villages and the city as per 2001 census. Udaipur city is one of a medium sized town of Rajasthan State, India. In geographical terms, Udaipur city lies at $24^0$35' N latitude and $73^0$42'E longitude covering an area of about 64.28 sq. km. The expansion of urbanizing area along the major transport arteries of the country i.e. National Highway No. 8 connecting Delhi-Bombay, NH-76 towards Chittaurgarh has given it a prominent position making it an important issue for administrators and planners.

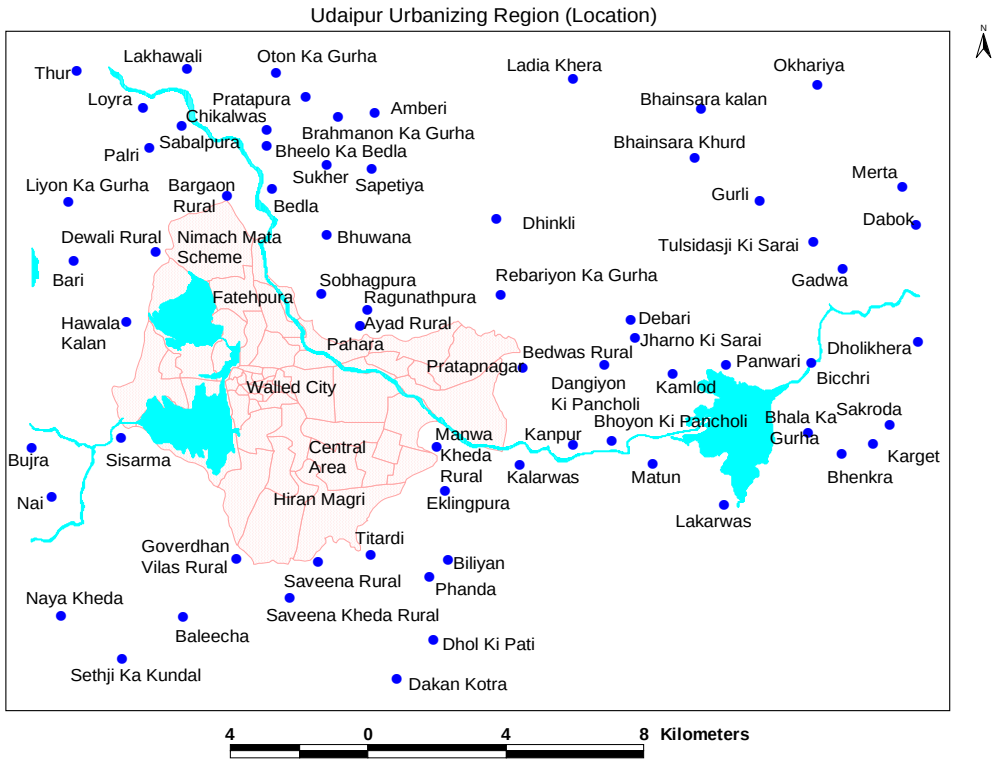

Figure 1: Location of settlements of Udaipur Urbanizing Region

The physiography consists of high hills, lakes, water bodies, ridges and plains along the river and its tributaries separated by hills. The region is surrounded by high hills and ridges across except a few gaps. The general slope of the area is from north-west to south-east which is followed by the main sustaining river of the region - the Ahar River. The region occupies a piedmont-like denuded upland site that is drained by Ahar River and is surrounded by hills locally known as “Magras”. Among the prominent magras is Kaler Magra on the west, Sajjangarh Magra and Bari ka Magra on the north-west, Neemuch Mata Magra on the north, Kala Magra and Bhuwana ka Magra on the north-east, Debari and Udaisagar Magra on the east, Hora Magra on the south-east, Machhla Magra on the south and Banki ka Magra on the south-west (Fig. 2). Again the region is studded with numerous reserve forest sites which include Kaler in the west; Sajjangarh in the north-west; Bhainsara, Bara Magra and Kantia in the north-east; Panwari, Bordi, Hinglashia and Sergia in the east; Hora, Bagdara, Amarbir and Santu in the south-east; Machhla in the south and Banki in south-west. The water bodies of Fateh Sagar, Picchola and Udai Sagar are important sources of water for the region. Ahar River, the life line of the urbanizing region divides the study area diagonally in approximately two equal halves. Historically, the choice and decision of this site for urban settlement was guided by the inherent natural and physical characteristics of the region.

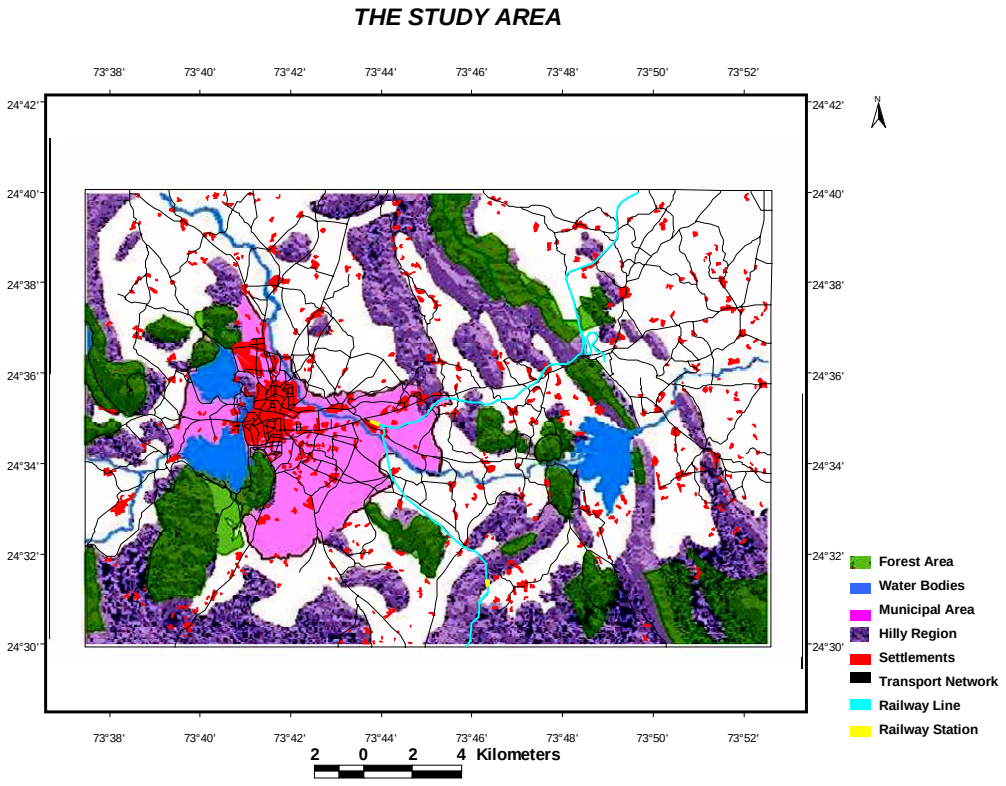

Figure 2: Potentials and Constraints of the Study Area

Process of Urban Sprawl - Application of Remote Sensing Data

One of the prerequisite for understanding urban sprawl is successful land use change detection. This is made possible by accurate registration of the satellite imageries so that

the overhead pixels represent the same location. There is a wide range of techniques used for land use change detection to study urban sprawl. Some of the major techniques include composite image, image comparison, comparison of classified images, combination of classified images, and radar classification and so on. The technique employed in the given study is based on the comparison of the classified images. In order to work with the analysis, the primary construct is to acquire the data source.

To work out the change detection Landsat satellite imageries of three time period are used. The first imagery Landsat MSS acquired on 23rd Sept., 1972 was used with three bands namely, red, green and blue at 80m resolution. The next time frame used was Landsat TM acquired on 19th Oct., 1990 with four bands namely, infrared, red, green and blue at a 30m resolution. The last acquired in the series of Landsat was Landsat ETM Plus captured on 22nd Oct., 2000 with four bands namely, infrared, red, green and blue merged with the pan image with 15m resolution. The imageries help understand the process of urban sprawl in the region over last 28 years. To stage the study, the imagery of three time frames is used instead of just two. These three time periods assist the analysis of the direction, process and magnitude of the sprawl prior to open door policy in terms of economic reforms taking place in the nation i.e., year 1972 to 1990 and then a post economic reform scenario in terms of globalization from the year 1990 to 2000. In addition land use maps and statistical inventory corresponding to the three time periods was also used as input. The pair wise comparison of the land use maps as well as their statistical inventories was made in order to deduce changes in terms of area as well as geographic location.

The remote sensing data was acquired by Global Land Cover Facility. Erdas Imagine software was used for this task. Firstly different bands of the imagery were stacked to produce a false color composite. The area of interest was calculated and finally the required image was extracted by sub-setting of the image. The subset image was then reprojected. To detect the land use change comparison of classified images was done. For this purpose the classification of the images was required. The adopted interpretation technique which was preferred to the standard classification is based on visual interpretation assisted by computer. The process consists of displaying the rectified imagery on the screen and digitizing the polygons representing different land use categories. The categorization of land use attributes is based on image characteristics such as tone, texture, color and pattern. The subset image was then interpreted with reference to ground verifications wherever required. The whole exercise also used local knowledge and ground observations mostly derived from the topographical sheets for the region.

Each image set has been broadly classified into five different categories viz., forest and scrub land, built-up area, water, crop land and barren land. The polygons were identified by independent labels attached to the centroid of each polygon. These polygons were labeled as training sites. Thirty confirmed training sites per land use category were selected using signature editor and the values were merged to give an average pattern for the category. The signatures were then assigned conventional colors based on standard theme. Red color was allotted to built-up land, cyan for water, dark green for forest and scrub land, yellow for crop land and tan for barren land. These signatures together with

the subset image formulated the supervised classification. The technique employed for ground truthing aimed at localizing and characterizing field observations. Finally, this full database was attached to the coverage in which each polygon was characterized by many attributes like the category number, area and perimeter of the polygons. Urbanizing region was identified and assessed in order to produce the evaluation made between these three periods. By keeping in all the five land use categories the impact of urbanization on other land uses and vice versa was investigated.

Magnitude, Growth and Trend of Urban Sprawl

The magnitude of the urban sprawl depicts the state of land use and urbanization process at a particular point of time. This facilitates the understanding of the ground realities which have not been taken into in-depth consideration while preparing the master plan of Udaipur. To understand the magnitude of sprawl land use patterns in 1972, 1990 and 2000 are studied using Landsat imageries. The scenario in the year 1972 depicts the region has a vast forest and scrub land covering about thirty per cent of the total area. The region had a built-up land of merely 6.93 per cent of the total land. The figure reveals the fact that the only few major built-up hubs were located near the lake bodies at Udaipur city center with dispersed settlements in and around the northern and eastern region. Build up areas in 1972 include the walled city area, Baleecha, Sethji-ka-Kundal, Khempura, Hiranmagri, Ratakhet and emerging nodes of built up land in and around the Dabok region (Fig. 3).

Table 1 depicts that barren land accounts for 23.73 per cent mostly in the area far from the urban center where no settlements have been found. Barren land is found predominantly in the north-eastern region. The year 1990 has 28.94 per cent of forest and scrub land area and 28.12 per cent of crop land area. This depicts how the process of land acquisition has taken place by engulfing these areas under the built-up and barren domain. The phenomenon has consequently led to the increase in the barren land to 32.64 per cent and built-up area to 7.61 per cent. During this phase the built-up area expanded to include Goverdhan Vilas, Saveena, Saveena Kheda, Bamnon-ki-Madri, Hiranmagri, Manwa Kheda, Eklingpura in the south and south west and has mostly engulfed the crop and cultivated areas of Pratap Nagar towards the eastern section of the city extension (Fig. 4).

Table 1: Per cent Proportion of Land Use to Total Land: Temporal Study

Land Use Categories	*Year 1972*	*Year 1990*	*Year 2000*
Forest/ Scrub Land	29.86	28.94	25.07
Water	1.04	2.69	0.49
Built-Up Land	6.93	7.61	11.55
Crop Land	38.43	28.12	14.51
Barren Land	23.73	32.64	48.38
Total	100.00	100.00	100.00

Source: Analysis of Satellite Imageries

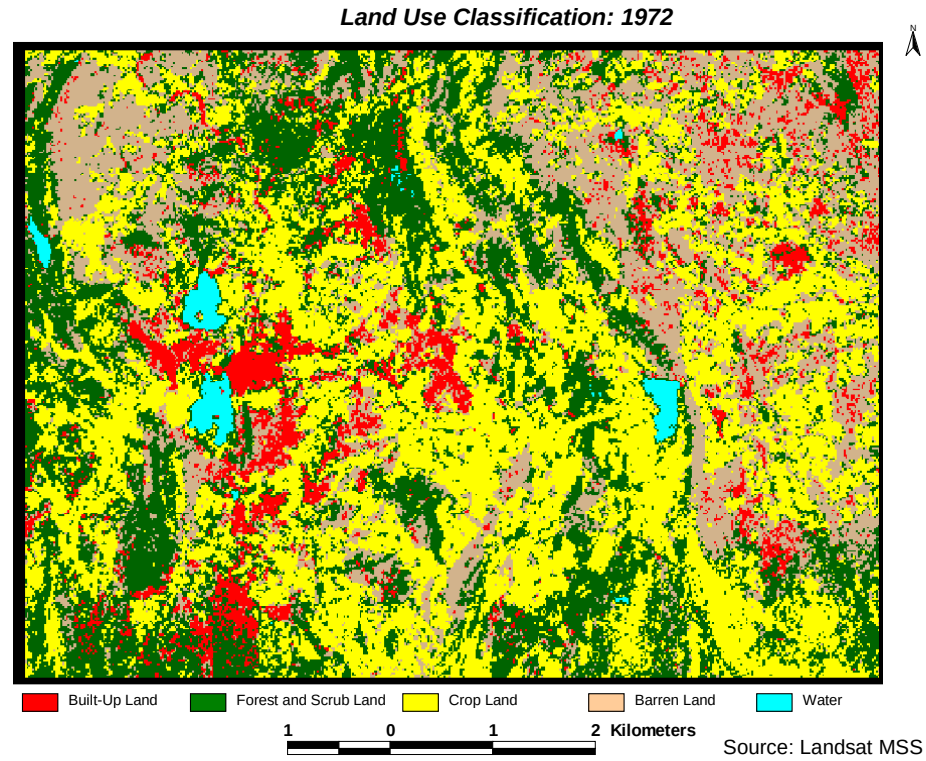

Figure 3: Land Use Classification: 1972

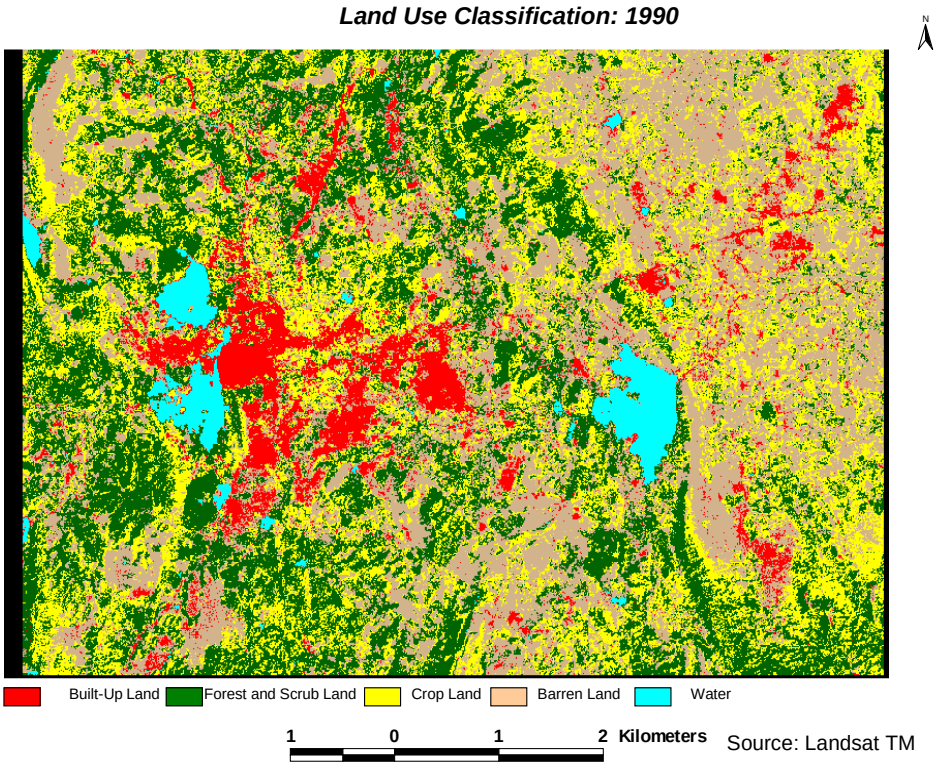

Figure 4: Land Use Classification: 1990

The growth and trend of urban sprawl is analyzed with help of change in the per cent of various land use categories during the period. Table 2 describes the period of eighteen years from 1972 to 1990 illustrating an increase of 9.8 per cent in the built-up land and to compensate a decline of 26.82 per cent in the crop areas and 3.08 per cent in the forest and scrub land. Substantial increase of 37.54 per cent is also reported in the barren land. This depicts that the land has been cleared and sold out in the commercial market where the infrastructural development is yet to take place. The given land occupancy phenomena is likely to be used for the process of urbanization in near future. The two time frames depict an increase in the water spread, only reason being the drought in 1972.

Table 2: Temporal Per cent Change of Land Use Patterns

Land Use	*Year: 1972-90*	*Year: 1990-2000*	*Year: 1972-2000*
Forest/ Scrub Land	-3.08	-13.37	-16.04
Water	158.65	-81.78	-52.88
Built-Up Land	9.8	51.77	66.66
Crop Land	-26.82	-48.39	-62.22
Barren Land	37.54	48.22	103.87

Source: Analysis of Satellite Imageries

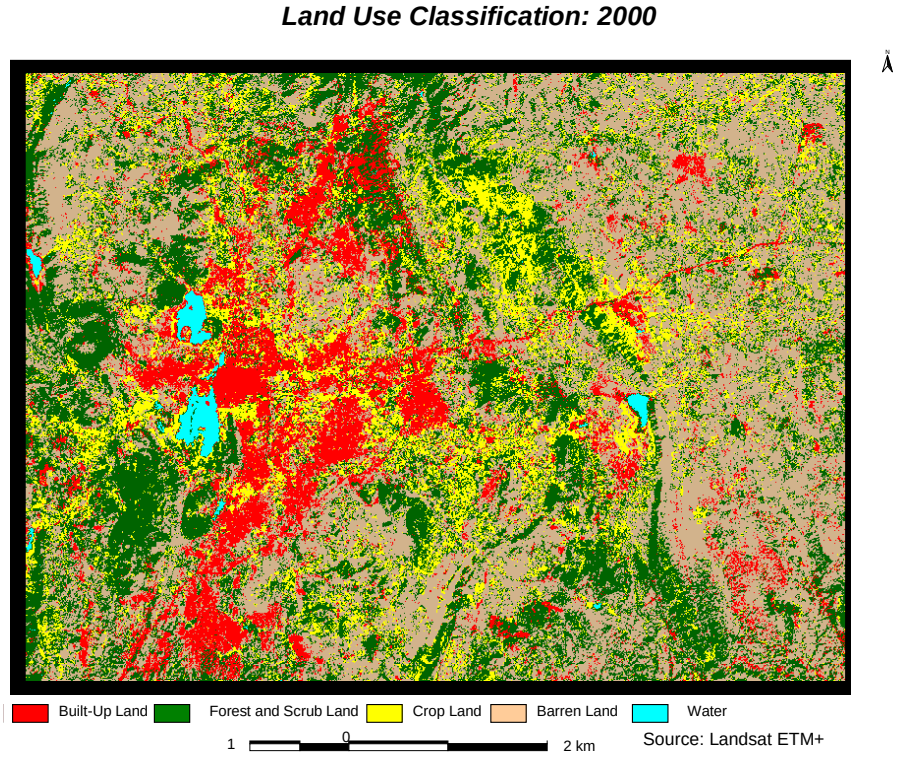

Figure 5: Land Use Classification: 2000

The post 1990 period depicts an analysis up to year 2000 revealing a drastic change in the normal course of urbanization. The year records the built-up areas increasing to 11.55 per cent from around 7.61 per cent. The year 2000 has shown a remarkable growth of built up areas in large sized settlements away from the city limits. Such settlements include Bedla,

Ragunathpura, Shobagpura, Bargoan, Bhuwana and Sukher towards the north; Kanpur, Kalarwas, Kharwala and Lakarwas towards the east; a continuous belt of expansion from Goverdhan Vilas to Baleecha along the national highway is prominent. The areas near the Udaisagar show the presence of brick clinkers near the lake body. Resulting pollution is a matter of concern for the ecology of the region. The eastern belt has shown an increase in the industrial establishments. This belt received a boost after the economic reforms and region has suddenly blossomed along the eastern flanks (Fig. 5).

The process has led to elimination of the crop, forest and scrub land mostly towards the eastern outer limits of the city. The growth of built-up areas is mainly towards the north-south route along the national highway in a linear fashion. The eastern sections have also reported growth in the population. Rest of the region still depicts dispersed built-up land patterns. The period 1990 to 2000 depicts a remarkable increase of 51.77 per cent in the built-up areas which shows how the open door policy, relaxation in trade norms, quotas and tariffs, flow of foreign investments resulting from the economic reforms has boosted the process of urbanization.

Expansion of Built-Up Area

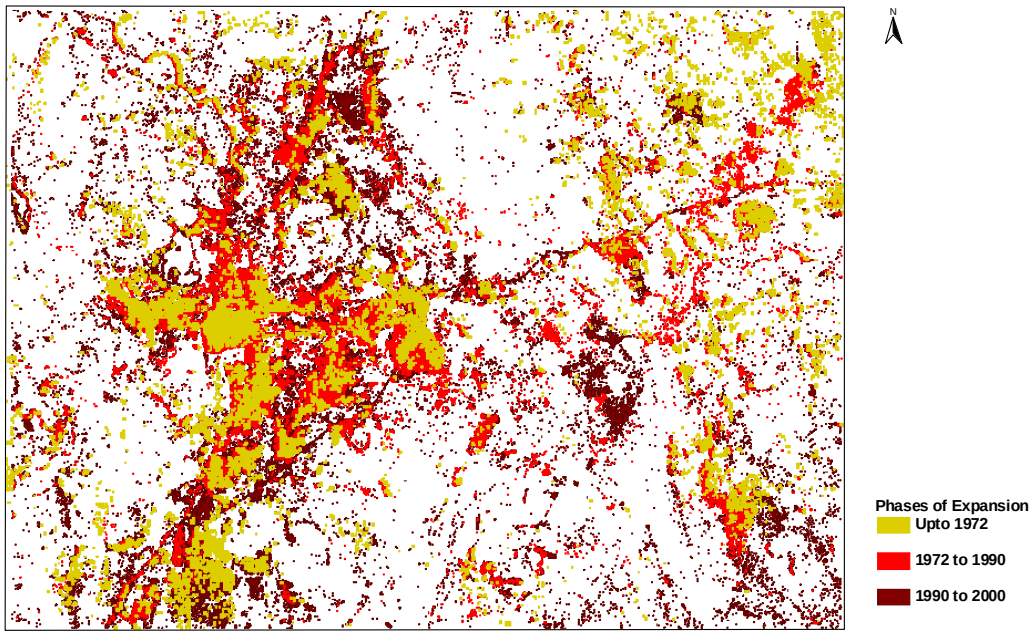

Figure 6: Expansion of Built-Up Area

With the upcoming multiplex, residential townships, call centers, MNC's, shopping malls and related trade sector activities in the region chunks of land have been consumed, engulfing more and more of the crop and cultivated land through the process of urbanization. The loss in crop land accounted for 48.39 per cent in the decadal period of 1990 to 2000 which is more than double that of the period 1972-90.

The forest and scrub land has declined by 13.37 per cent in the period from 1990-2000 which is ten per cent points higher than the decline from the 1972-1990 periods. The later period resulted in a rapid decline in the village tanks and smaller water bodies mainly because of the process of acquisition and occupancy of land by the dwellers. Generally, land transformation has caused a hike in urban land prices. The barren land has increased by 103.87 per cent and built up area has increased by 66.66 per cent in the span of 28 years. The study is therefore an important step towards realizing that the land acquisitions are taking place at a fast rate (Fig. 6).

Table 3: Per cent of Land Encroachment in 2000 with regards 1972

Land Encroachment (Per cent)		***Year 1972***				
		Water	***Built-Up Land***	***Crop Land***	***Barren Land***	***Forest/ Scrub Land***
Year 2000	***Water***	0.51	0.00	0.00	0.00	0.17
	Built-Up Land	0.00	3.74	4.08	2.38	3.40
	Crop Land	0.17	0.17	7.31	1.87	3.57
	Barren Land	0.17	2.89	16.50	14.12	9.52
	Forest/ Scrub Land	0.34	1.02	12.41	3.23	12.41

Source: Analysis of Satellite Imageries

Table 3 clearly depicts around 12.92 per cent of the forest and scrub land is transformed into either the built-up area or barren land. It is important to take into account that the cutting of forest is totally an illegal process. If done legally the Forest Department needs to be involved which is a long and cumbersome process. Around 20.58 per cent of the crop land been transformed into built-up land or barren land. This implies that the urban expansion and growth is adversely impacting the green belt and agriculture of the region.

As per the analysis of satellite imagery 4.08 per cent of the crop land, 2.38 per cent barren land and 3.40 per cent of forest and scrub land has been transformed into built up land in a span of twenty eight years. Around 16.50 per cent of crop land and 9.52 per cent of the forest and scrub land has become barren land which means that the land has been cleared and sold for further expansion but the construction activities are yet to take place.

Cost of Sprawl in Udaipur

Table 4 reveals the consequences of sprawl on the economic, natural and aesthetic aspects of the region. Each aspect is divided into minor headings and the corresponding region to each of these phenomena is described. The implications of sprawl on the various areas in and around the city are mentioned below.

Table 4: Cost of sprawling on various aspects with examples

Aspects	*Cost of Sprawl*	*Examples substantiating the Fact*
Economic	Loss of open space	Goverdhan Vilas, Saveena, Kanpur
	Increased cost of infrastructure	Fatehpura, Hiran Magri Sector- 3, 4, 5, 6, 14
	Loss of farm and forest	Sisarma, Bargaon, Bedla, Liyo-ka-Gurha
	Fragmentation of farms	Crop land area- Compare Fig.3.1 and 3.3
	Urban decay and increase in energy consumption	Places connected by city bus services- Titardi, baleecha, Loyra, Nai, Sisarma
	Higher tax burden	Conversion tax on land by UIT and State Government
	Higher land prices	Along major transport arteries- Bhuwana, Baleecha, Dabok
	Higher human and wildlife conflicts	Sajjangarh, Bari
	Adverse impact on environmental resources	Construction of built-up area along green belts
	Greater fiscal disparities among localities	Comparison of Nora and Sisarma vs. Fatehpura
Physical	Congested roads and heavy traffic	Suraj Pol, Hathi Pol, Amal-ka-Kanta
	Overcrowded market and lanes	Walled city
	Longer commuting time with increased distances	Bedla, Bhuwana, Saveena, Titardi, Goverdhan Vilas
	More aggressive driving	Road crossings, highways and expressways
Social	Decreased social interaction	Distant residential settlements- Titardi, Kalarwas, Sukher
	Limited meaningful consumer choice	About where and how to live- at outer limits of Udaipur Urbanizing region
Emotional	Loss of community spirit	Shift of Bohras from Bohrawadi to Kharol Colony, Shift of Muslims from old city to Mulla Talai
	Loss of sense of ownership and land	Multistory- Keshav Nagar, Shobhagpura, New Bhopalpura, University Road
Aesthetic	Decreased leisure time	Influx of corporate sector
	Monotonous landscape	Hiran Magri Sector-3, 4, 5, 6, 11, 12, 13, 14

Conclusion

The urban expansion in the study region is governed by the transport network mainly following a ribbon shaped linear spread. A marked growth has been noticed along the national highways and roads connecting the city radially in all directions. The main arteries along which the sprawl is taking place include, Ahmadabad route towards the SSW, Rajsamand and Ajmer route in NNE that are part of the National Golden Quadrilateral and Chittaurgarh route towards NEE that is part of the East-West corridor. This finding suggests that the road network has a significant influence on the expansion and transformation of land for different uses in and around the city. Also the plain areas where the accessibility is easy, the expansion of the built-up activities has increased tremendously, for example in the western plain area bordering Udaisagar, northern belt towards Bhuwana-Sukher and the western regions surrounding the lakes. Intense expansion of built up area is significant in the eastern flanks due to the industrial activities. Land has also been allotted to Special Economic Zone coming up at Kalarwas. The northern belt towards Bhuwana and Sukher has marble industry and is an export zone of handicrafts and marbles. The southern belt consisting of Saveena Kheda has grown up as a commercial node with the development Transport Nagar. All the

transformation and encroachment of land is mainly governed by its accessibility, availability and value. These phenomena interact with each other and give rise to redistribution of land through complementary tendencies of concentration and dispersion.

References

Cheng, J. and Masser, I. (2003) Urban Growth Pattern Modelling: A Case Study of Wuhan City, PR China, ***Landscape and Urban Planning***, 52, pp. 199 - 217.

Downs, A. (1999) Some realities about sprawl and urban decline, ***Housing Policy Decline***, 10, pp.955-74

Duany A., Elizabeth Plater-Zyberk and Jeff Speck (2000) ***Suburban Nation: The Rise of Sprawl and the Decline of the American Dream***, New York: North Point Press.

Fang S., Gertner G. Z., Sun Z. and Anderson A.A. (2005) The Impacts of Interactions in Spatial Simulation of the Dynamics of Urban Sprawl, ***Landscape and Economic Planning***, 73, 4, pp.294-306.

Fazal, S. (2004) The Role of Accessibility in Urban Land Transformation: A GIS based Study of a Growing Urban Center in a Developing Economy, ***Asian Profile***, 32, 1, pp.61-76.

Galster G., Hansan R., Ratcliffe M., Wolman H., Coleman S., and Freihage J., (2001) Wrestling Sprawl to the Ground: Defining and Measuring an Elusive Concept, ***Housing Policy Debate***, 12, pp. 681-718.

Gopi, K. N. (1978) ***Process of Urban Fringe: A Model***, Concept Publishing Co., New Delhi.

Husain, I.and Siddiqi L., (1979) Urban Encroachment on Rural Lands: A Case Study of Modinagar, ***The Geographer***, Aligarh, 26, pp. 11-21

Hussain, M. I. (1983) Urban Expansion and Encroachment, ***The Geographer***, 30, pp.82-93.

Jothimani, P. (1997) Operational Urban Sprawl Monitoring using Satellite Remote Sensing: Excerpts from the studies of Ahmedabad, Vadodara and Surat, India, Paper presented at 18th ***Asian Conference on Remote Sensing***, Malaysia.

Turkstra J. (1996) Urban Growth and Land Use Options for Lower-Income Groups: A Case Study of Villavicencio, Columbia. ***ITC Journal***, 1, pp. 57 – 63.

Yeh, A. G. O. and Xia Li (1996) Urban Growth Management in the Pearl River delta: An Integrated Remote Sensing and GIS approach. ***ITC Journal***, Special Habitat-II Issue, 1, pp. 77-86.