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Urban Growth Analysis Using Shannon's Entropy: A Case Study of Jodhpur City

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Abstract: ***One of the most important problems in urban development is Urban sprawl due to its negative impacts on environment. Therefore, urban sprawl should be precisely analyzed for effective urban planning. In this study, urban sprawl was examined over a period of 40 years using Shannon's entropy based on remote sensing and Geographic Information System (GIS). One of the major advantages of Remote Sensing technique is timelines in the availability of information over large area and simultaneous observation making it possible to detect temporal changes. Landsat data (1973, 1990, 2010, 2015), IRS P6 L-3 2010 Satellite Data and ground truth data were used for preparation of GIS based outputs maps of the Jodhpur City and surrounding areas. The built-up areas in 1973, 1990, 2000 and 2015 were extracted from Landsat images using the classification method, and changes occurred during 1973–2015 period were also investigated. The Shannon's entropy method was used to determine the degree of urban sprawl and results show that study area experienced important changes and have significant sprawl.***

Keywords: Urban Sprawl, Satellite data, GIS, Shannon's entropy

I. INTRODUCTION

Urban sprawl has become a hot topic in the urban planning and management of many countries in both the developed and the developing world. A number of authors have defined `Sprawl' in a variety of ways. Burchell et al (1998) synthesized forty years of research on the impacts of urban sprawl and concluded that the three conditions that define the negative impacts of sprawl are: leapfrog development, low-density and unlimited outward expansion. Cheng (2003) has also defined it as a rapid expansion of the built-up area into suburbs in a discontinuous low-density form. Recent literatures by (Sudhira and Ramachandra, 2007) has defined urban sprawl is change in land-use and land-cover of the region as sprawl induces the increase in built-up and paved area. According to Bhatta, (2010) a general consensus that urban sprawl is characterized by unplanned and uneven pattern of growth, driven by multitude of processes and leading to inefficient resource utilization. This knowledge is crucial to sustainable land management and urban development planning. Since, there is no universal solution for all forms of sprawling; there is a need for such study in the context of the study area.

II. STUDY AREA

Jodhpur city is located at a latitude of 26º 18' North and longitude of 73º 1' East and is located in the middle of the Thar Desert tract of western Rajasthan about 250 km from the Pakistan border (Fig.1). The second largest city of the Rajasthan state, Jodhpur is fast growing city surrounded by sand stone mining, Rocky area, Fallow land and Industrial Zones. While most of the commercial activities and unplanned settlement are located in the old city area and planned urban settlement, industries & mining area lies in the outskirts of the city. Its general topography is characterized by the hills located in the North and North-west. The

city has a natural drainage slope from North- North East to South-South East towards Jojari River and extensive stone quarries in the Northwest direction.

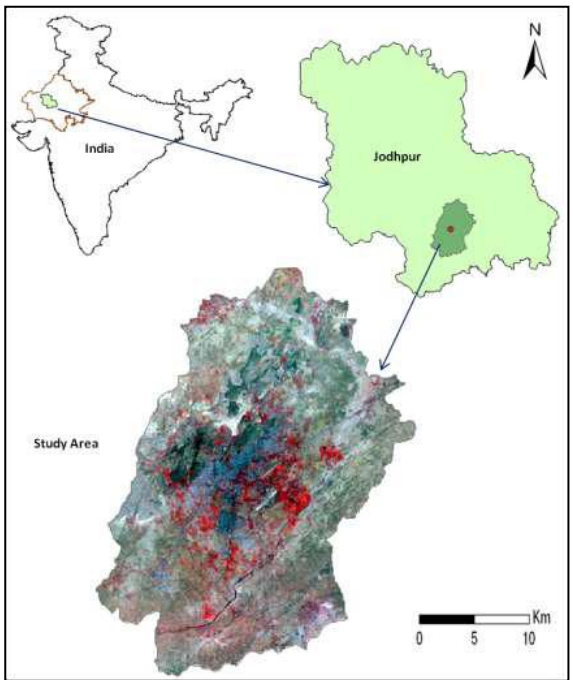

Fig.1. Location Map of The Study Area.

III. MATERIALS AND METHODS

Cloud-free satellite imageries of the study area were acquired from Landsat and Indian Remote Sensing (IRS) satellites for the years 1973, 1990, 2000, 2010, and 2015. Ancillary data from the SOI toposheet at 1:50 000 scale, Census of India decadal demographic database, and the Master Plan of Jodhpur were collect. Software ArcGIS 9.3 and ERDAS Imagine 9.1 were used for image processing and creation of the GIS maps. Satellite image interpretation involved the use of image preprocessing, processing, and post processing techniques. Figure 2 shows the flowchart of the methodology followed in the generation of built-up area maps for the study years. Bands near-infrared (NIR), red, and green were express through red, green, and blue , respectively, to create the false color composite (FCC) images as a part of image processing. These FCC's are shown in Figure 3.

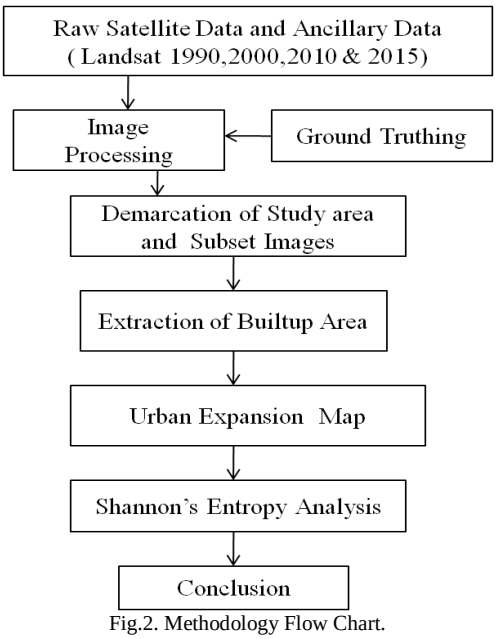

Fig.2. Methodology Flow Chart.

IV. Result and Discussion

A. Urban Growth in the Study Area

Jodhpur, the second largest city in Rajasthan, is one among the popular tourist destinations of India. It is known as the "Sun City" because of its bright and sunny weather. Jodhpur, with a current population of 12.65 lakhs is one of the fastest growing cities of the country with an annual average growth rate of 3% slightly more than that of the nation's urban growth.

The future land use strategy of Jodhpur aims at the growth in the tourism and industrial sectors. Jodhpur will continue to grow as a tourist destination; hence, many tourism related businesses thrive in the town. Other developing residential nodes include Rajiv Gandhi Nagar, Ramraj Nagar, Vivek Vihar etc, in the south and southwest. Several industries, educational institutions and military establishments are the major developments proposed in the north and eastern direction. By 2030, some zones will continue to exhibit low density pattern with population density less than 5000 persons/sq. km. This is mainly due to the presence of natural spatial growth constraints like nallahs, hills, etc. In case of zones in the vicinity of the development hubs and proposed SEZ, the densification will significantly intensify. The employment projection is carried out considering the future growth drivers or major economic activities like the development of several industries in and around RIICO industrial area, military establishments such as Army aviation centers, institutions for higher learning such as IIT, Law & Ayurvedic University, Private Engineering colleges etc. In 2030, the employment for the study area is anticipated to be 9 lakhs.

B. Physical Expansion Trend in Study Area

The rapid growth of population of the city has put great pressure on the demand for urban spaces. In response to this demand, efforts are being made by the city government to incorporate the peripheral areas of the city, which is resulting in hastening the expansion of the built-up area of the city. Accordingly, Jodhpur has experienced rapid physical expansion (Table-1).

Table-1: Physical Growth (Built-up area) of the Jodhpur City.

Year	Urban Area (Km2)	Growth	Growth Rate
1990	24.97	-	-
2000	68.98	44.01	1.76
2010	114.42	45.44	0.65
2015	131.25	16.83	0.15

The physical expansion of the built-up area of the city during the period 1950 to 1973 was characterized by a compact type of development. From 1973 to 1990, the built-up area increased by 24.97 sq km.(Fig.3) The next period of physical expansion of the city was between 1990 and 2000, when the built-up area expanded by 68.98 sq km. During the most recent period of physical expansion, between 2000 and 2010, the physical built-up area of Jodhpur increased by 114.42 sq km. Expansion of the city was characterized by the development of scattered and fragmented settlements in the peripheral areas of the city, with both legal residents and squatters. In 2015, Jodhpur city had an estimated total of 131.25 sq km with squatter settlements and estimated growth rate was 15 % of the total built-up area.

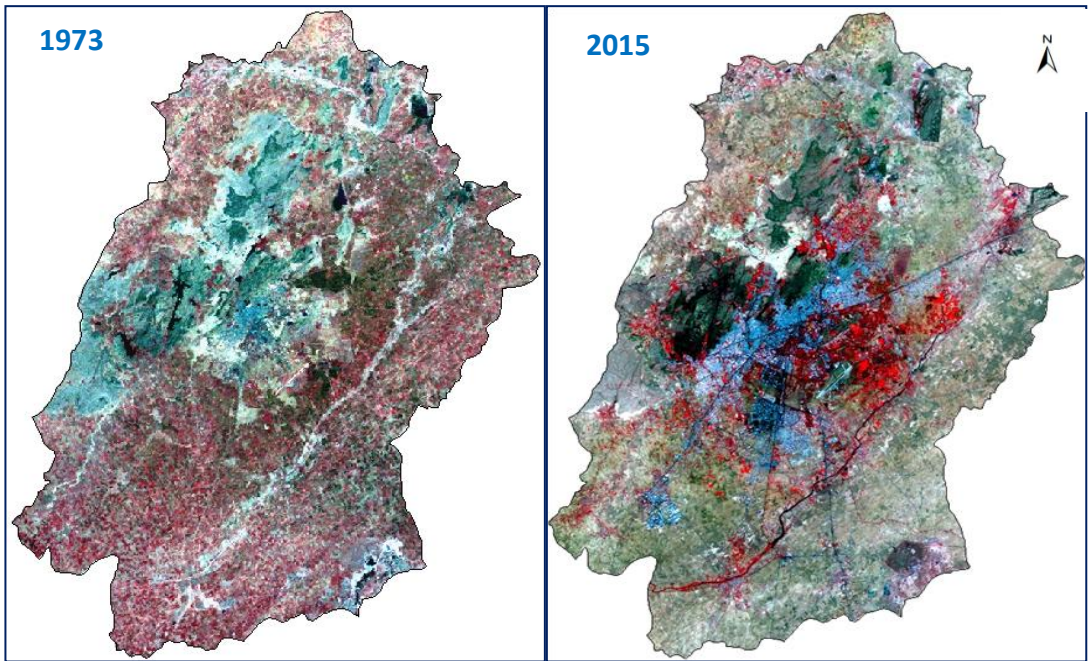

Fig. 3. Urban Expansion of the Jodhpur City as seen in Satellite Images.

C. URBAN SPRAWL MEASUREMENT TECHNIQUES

Urbanization takes place either in radial direction around a city center or linearly along major road networks. Such dispersed nature of urban development along major road networks or surrounding city center is often referred to as sprawl (Sudhira et al. 2004). Some of the major factors responsible for urban sprawl are population growth, proximity to major resources, services and infrastructure. The pattern of sprawl has to be identified and analyzed effectively to help urban and regional planning. In this study, urban sprawl over the period of 1973 to 2015 was determined by computing the area of all the built lands from the land cover maps (Fig.4). The Shannon's entropy along with GIS tools were applied to measure the sprawl during the study period.

Table-2: Built-up Area of Jodhpur City. (1973-2015) (km^2)

Year	Direction (Zones)								Column Total
	NNE	NEE	NNW	NWW	SSE	SEE	SSW	SWW	
1973	2.1	0.36	1.16	0.79	0.07	0.72	0.66	1.26	7.12
1990	4.93	3.15	1.41	1.31	2.01	2.12	6.02	4.02	24.97
2000	9.57	13.64	4.74	3.69	5.48	5.99	12.89	12.97	68.97
2010	13.51	20.51	5.07	5.79	15.07	8.40	30.34	15.73	114.42
2015	14.98	23.96	6.76	6.84	16.87	10.42	34.89	16.53	131.25
Row Total	45.09	61.62	19.14	18.42	39.5	27.65	84.8	50.51	346.73

Table-3: Observed Decadal Growth in Built-up Area (km2).

Temporal Span	Direction (Zones)								Whole Region
	NNE	NEE	NNW	NWW	SSE	SEE	SSW	SWW	
1973-1990	2.83	2.79	0.25	0.52	1.94	1.4	5.36	2.76	17.85
1990-2000	4.64	10.49	3.33	2.38	3.47	3.87	6.87	8.95	44
2000-2010	3.94	6.87	0.33	2.1	9.59	2.41	17.45	2.76	45.45
2010-2015	1.47	3.45	1.69	1.05	1.8	2.02	4.55	0.8	16.83
Total	12.88	23.6	5.6	6.05	16.8	9.7	34.23	15.27	124.13

For calculation of the entropy the city, area was divided into eight zones and temporal span of four temporal spans has been analyzed in GIS (Fig.4).

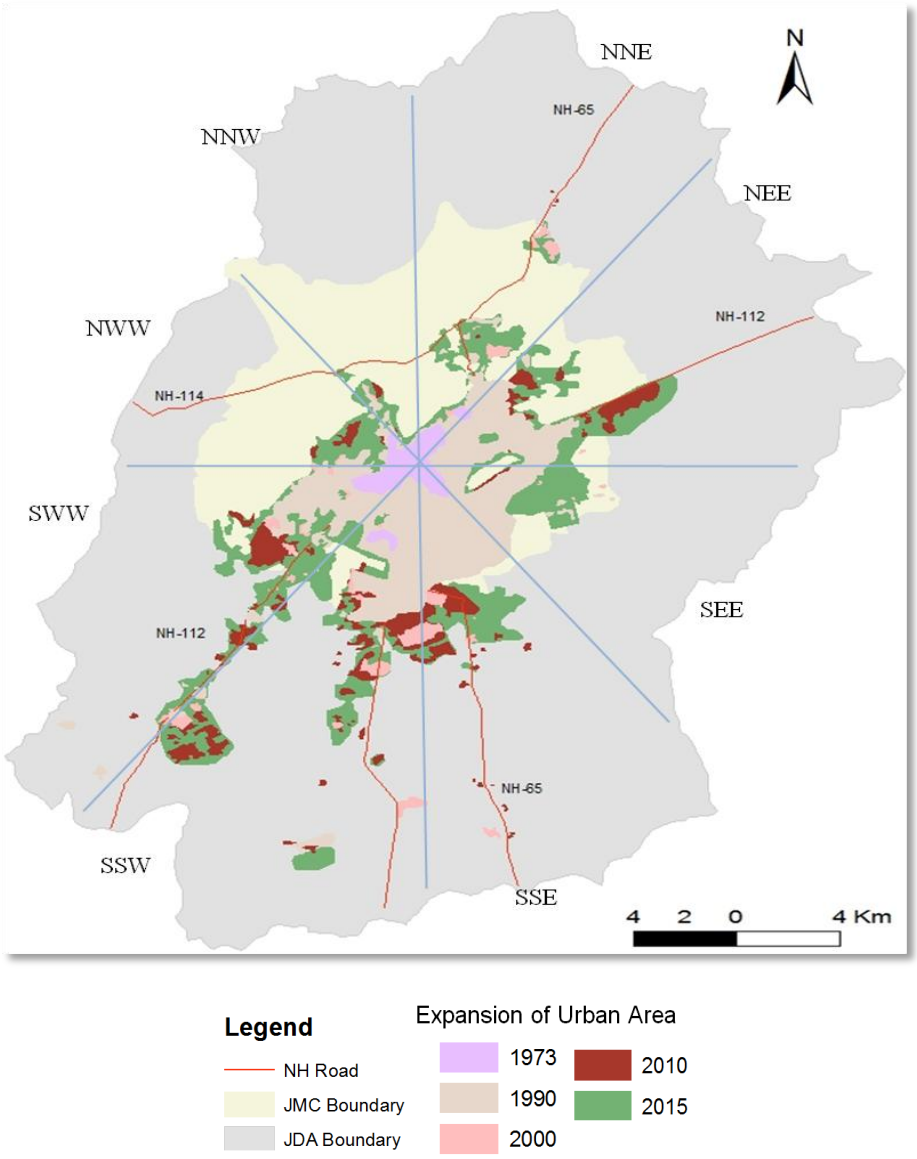

Fig.4. Land use dynamics in eight zones of the Jodhpur city (1973-2015).

D Analysis of Urban Growth Using Shannon Entropy

Shannon's entropy is a popular method for determining the sprawled urban pattern (Kumar etal., 2007; Lata et al., 2001; Li & Yeh, 2004; Sudhira et al., 2004; Yeh & Li, 2001; Bothale and Sharma, 2007, Li. 2009). Using this method, each temporal span it (Hi) has been computed with the help of Equation as:

$$Hi = - \sum Pj \log_e Pj$$

Where, Pj = proportion of the variable in the j column (i.e., proportion of built-up growth rate in j zone, calculated by: built-up growth in j zone/sum of built-up growth rates for all zones) and m=number of zones (8).

The value of entropy ranges from 0 to log m. Value of 0 indicates that the distribution is very compact, while values closer to log (m) reveal that the distribution is much dispersed. Higher values of entropy indicate the occurrence of sprawl. Two types of thematic layers are needed for calculating the entropy value in different years, including the layer of ward boundaries and the layer of built-up area. As the entropy values are much higher than the half-way mark of log (m), the city is said to be experiencing sprawl with increasing tendency (Table- 4&5). The entropy value is higher than the halfway mark of log (n) i.e. 1 in every direction except to the north which means these zones are sprawling, especially the south and northwest zone has a highest possible sprawl (Table- 4 & Fig. 5).

Table - 4: Decade wise and Direction wise Shannon Entropy.

	Direction (Zones)							
Temporal Span	**NNE**	**NEE**	**NNW**	**NWW**	**SSE**	**SEE**	**SSW**	**SWW**
1973-1990	0.0314	0.018	0.005	0.015	0.645	0.045	0.189	0.051
1990-2000	0.0761	0.027	0.191	0.147	0.139	0.147	0.092	0.179
2000-2010	0.085	0.010	0.014	0.118	0.363	0.083	0.281	0.044
2010-2015	0.091	0.014	0.277	0.151	0.099	0.200	0.125	0.042
Entropy (H)	1.056	0.399	1.095	1.274	1.666	1.373	1.661	1.056
H Maximum Log2(4)=2; H/2= 1								

Table-5: Shannon Entropy Analysis (Temporal Span wise)

Temporal Span	1973-1990	1990-2000	2000-2010	2010-2015
Entropy (H)	1.6751	2.8518	2.3672	2.6888
H Maximum Log2(8)=3; H/2= 1.5				

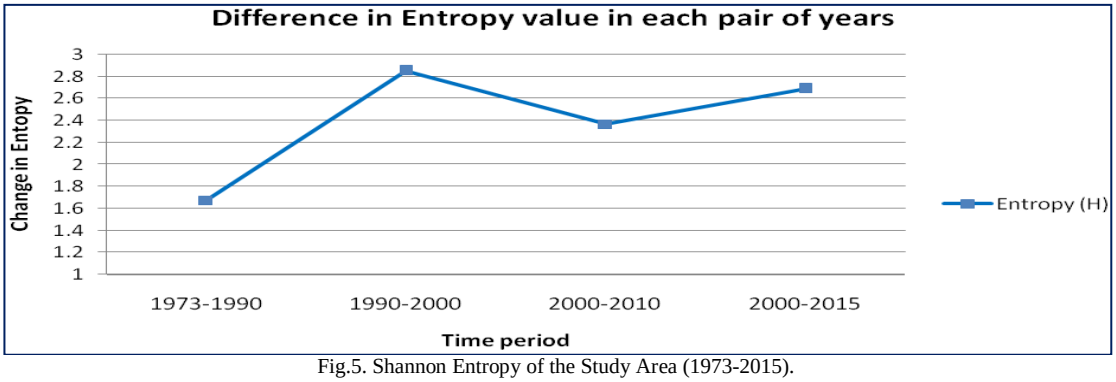

Fig.5. Shannon Entropy of the Study Area (1973-2015).

E. Degree of Goodness of Urban Growth

This can be calculated for each temporal span as:

$$G_i = \log_e \left[\frac{1}{\chi^2 \left(\frac{H_i}{\log_e m} \right)} \right]$$

Where, Gi =degree-of-goodness of urban growth for i = degree-of-freedom for i^{th} temporal span, $\chi 2$ = degree-of-freedom for I temporal span, Hi =entropy for i temporal span, m=total number of zones. For each zone (Table-5), it has been calculated replacing i by j and m by n as follows:

$$G_j = \log_e \left[\frac{1}{\chi^2 \left(\frac{H_j}{\log_e n} \right)} \right]$$

where $\chi 2$ is the overall degree of freedom and Hi is overall sprawl. It can also be identified by the magnitudes from Table-6 and Table-7 that show how goodness varies in different zones in different time periods and in different directions (positive or negative).

Table-6: Degree- of- Goodness (Temporal Span wise)

Temporal Span	1973-1990	1990-2000	2000-2010	2010-2015
Degree- of- Goodness	0.255	-0.512	-0.243	-0.427

Table-7: Degree-of-Goodness (Zones wise)

1973-2015	**NNE**	**NEE**	**NNW**	**NWW**	**SSE**	**SEE**	**SSW**	**SWW**
Degree-of-Goodness	1.506	2.907	1.453	1.235	0.848	1.127	0.853	1.506

V. CONCLUSION

This study amply demonstrates the use of remote sensing and GIS to analyze the urban sprawl mapping and detect changes of urban built up area through different year. The urban expansion in the study region is governed by the road network mainly following a ribbon shaped linear spread. A marked growth has been noticed along the national highways and roads connecting the city in three directions namely Pal Road in SSW, Pali Road in SSE and Mandore Road in NNW. The urban expansion in the study region is governed by the road network mainly following a ribbon shaped linear spread. 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.

The impact of urban sprawl is felt mainly on agricultural land, forested land, and fallow land. New urban development occurs mainly on agricultural land. There is little urban growth in North West due to hills and mining areas. While most of the economic activities are located in and around the old city area, the residential colonies have grown in the south western, north eastern, south eastern and southern parts, which are far off from the old city (the main centre of activities). Considering the development status, the physical development can be categorized into two parts (i) Old city area (ii) Outside Old city area. The old city area is continuously developed area having densely populated residential and commercial land uses with no scope for physical expansion.

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