ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 9, Issue, 11, pp.60392-60396, November, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

ANALYSIS OF URBAN SPRAWL PATTERN OF JODHPUR CITY USING LANDSCAPE METRICS

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ARTICLE INFO

Article History:
Received 18th August, 2017
Received in revised form
26th September, 2017
Accepted 07th October, 2017
Published online 30th November, 2017

Key words:

Landscape spatial metrics,
Urban sprawl Assessment, GIS.

ABSTRACT

This paper shows the potential use of remote sensing technology and GIS for getting of accurate land-use information from landscape spatial metrics for analysis of urban sprawl of the Jodhpur city. This study also quantify and examine the characteristics of urban land cover changes (1990-2015) using the Landsat satellite images of 1990, 2000, 2010 and 2015. A supervised classification method has been applied to prepare the base maps with five land cover classes (built up area, mining area, vegetation, water body and other area). To observe the change detection, four different spatial landscape metrics viz. Mean Fractal Dimension Index (FRAC_MN), Area Weighted Mean Patch Fractal Dimension (AWMPFD), Euclidean Mean Nearest Neighbor (ENN_MN) and Core Area Percentage of Landscape (CPLAND) were calculated using Fragstats that shows detailed perspective of the landscape changes behavior.

Citation: Borana, S. L., Yadav, S. K. and Parihar, S. K. 2017. "Analysis of urban sprawl pattern of jodhpur city using landscape metrics", *International Journal of Current Research*, 9, (11), 60392-60396.

INTRODUCTION

India population has grown two-and-a-half times, during last five decades, but urban India has grown nearly five times. At the moment, India is one among the country of low level of urbanization. Same growth pattern has been seen in the built-up areas of the study area. Due to the development in road and rail network, high value of land at the center of the city, housing policy and program, development of new industrial and recreational zones and population explosion, the rate of urban growth has expanded into the rural-urban fringe. The unprecedented growth and urban sprawl are often unnoticed by the planners, as they are unable to visualize this type of growth patterns. Characterizing and understanding the changing patterns of urban growth is critical, given that urbanization continues to be one of the major global environmental changes in foreseeable future (Rashed, 2008). Landscape metrics is one of imperative methods for understanding the structure, function and dynamics of landscapes and has a pivotal role to play in finding those solutions and navigating a sustainable urban future (Wu, 2006; Jelinski et al., 2000). The development of remote sensing and geographic information techniques provides data source and powerful spatial analysis methods for the research on landscape metrics. Fragstats is a spatial pattern analysis program, used to evaluate the changes of landscape pattern in the study area based on the output result of the remote sensing mapping.

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Study area

Jodhpur city is located at 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). It is second largest urban city of the Rajasthan state after the Capital Jaipur. 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.

Data used and Methodology

Landsat satellite data (1990, 2000, 2010 and 2015) on scale 1:50,000 and ENVI software has been used for classification of geometrically and radiometrically images. Resampling method has been used to transform the images so that the original pixel value can be retained. For assessing the patterns of sprawl in Jodhpur city, landscape metrics are calculated using Fragstats software. In this study, selected landscape metrics i.e. Mean Fractal Dimension Index (FRAC_MN), Area Weighted Mean Patch Fractal Dimension (AWMPFD), Euclidean Mean Nearest Neighbor (ENN_MN) and Core Area Percentage of Landscape (CPLAND) are calculated to analyze the change in urban landscape. These indexes are a collection of metrics that quantify and analyze landscape patches on the basis of geometric shape, complexity and compactness. Methodology adopted for this study is given in Fig.2.

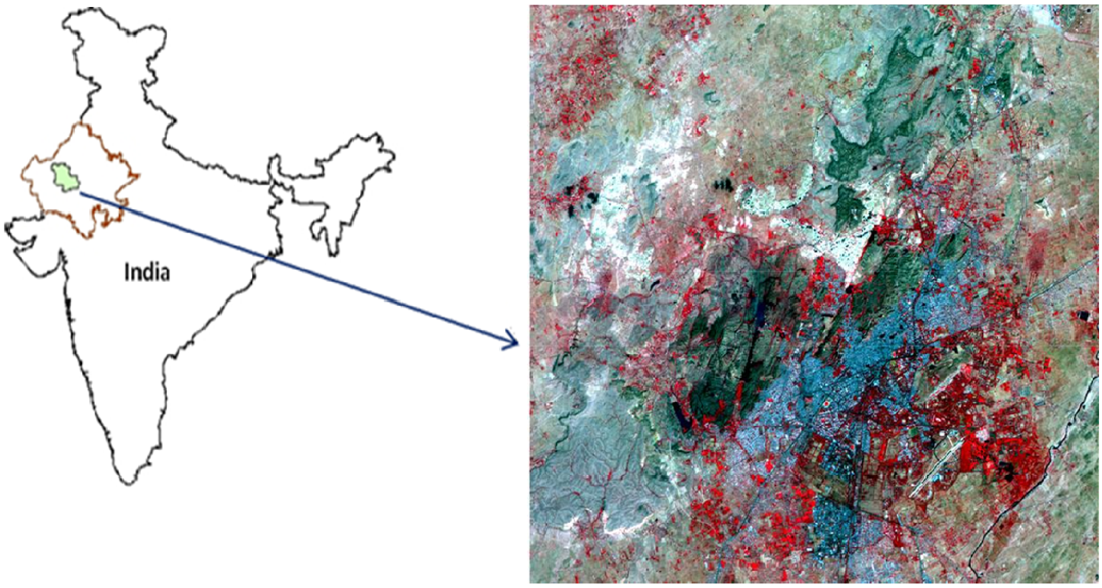

Fig.1. Location map of the Study Area

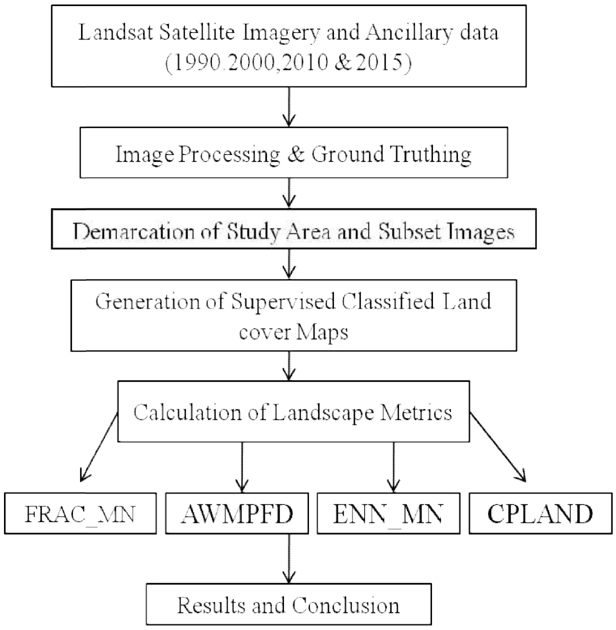

Fig.2. Methodology Adopted

Table 1. Different Landscape Metrics (1990-2015)

Landscape-Matrices /Year	FRAC_MN	ENN_MN	FRAC_AM	CPLAND
1990	1.0413	113.5834	1.2959	4.19
2000	1.0367	100.4505	1.3266	11.61
2010	1.0381	102.6955	1.3264	19.26
2015	1.043	98.3743	1.3245	21.25

RESULTS AND DISCUSSION

Using Fragstats software the value of four different landscape metrics has been calculated for the year (1990, 2000, 2010 and 2015). The landscape metrics for urban built up area is given in Table-1.Detailed discussion of each landscape metrics are given below:

A. Mean Fractal Dimension Index (FRAC_MN)

A FRAC_MN value greater than 1 for a 2-dimensional patch indicates a departure from Euclidean geometry (i.e., an increase in shape complexity). FRAC_MN approaches 1 for shapes with very simple perimeters such as squares, and approaches 2 for shapes with highly convoluted, plane-filling perimeters. FRAC_MN values of built-up area and mining area land cover types are increasing (Fig.3). All the values are showing just above one and less than two. This proves the shape of built-up cover type is changing from simple square shape to complex shapes over time. The more complex the shapes the more the urban growth is dispersed and unplanned. Therefore, the FRAC_MN values indicate massive and haphazard growth of urban patches.

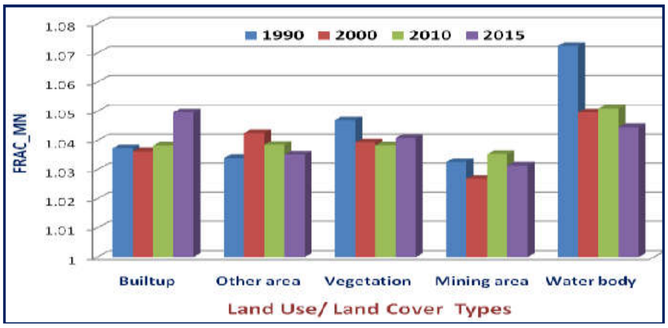

Fig.3. Mean Fractal Dimension Index of the Study Area

B. Area Weighted Mean Patch Fractal Dimension (AWMPFD)

According to McGarigal *et al.* (2002), it is necessary to measure and calculate the level of crumbling (fragmentation) and complication of patches to the area so as to understand the degree of complexity of a polygon. The Fractal Dimension describes the complexity and fragmentation of a patch by a perimeter–area proportion. Fractal Dimension values range between one and two. Low values are derived when a patch has a compact rectangular form with a relatively small perimeter relative to the area. If the patches are more complex and fragmented, the perimeter increases and yields a higher fractal dimension (Herold *et al*., 2002). The Fractal Dimension can be applied as a derived metric called area weighted mean patch fractal dimension (AWMPFD). It is derived using the following formula in Fragstats.

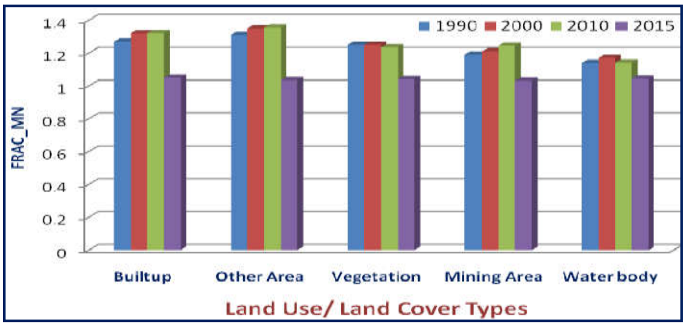

Fig. 4. Area Weighted Mean Patch Fractal Dimension of the Study Area

$$AWMPFD = \sum_{i=1}^{m} \sum_{j=1}^{n} \left[\left(\frac{2 \ln(0.25 P_{ij})}{\ln a_{ij}} \right) \left(\frac{a_{ij}}{A} \right) \right]$$

m- Number of patch types (classes)

n- Number of patches of a class

$p_{(ij)}$- perimeter of patch ij

$a_{(ij)}$- area of patch ij

A- Total landscape area

The study area, particularly the built-up class, is relatively compact in shape as compared to other classes. The level of compactness of the polygons was relatively higher in 1990 than in 2015 (Fig.4). This implied that the urban expansion to the periphery landuse was relatively lower and less fragmentation during early period (1990) than late periods. The value Fractal Dimension calculated in FRAGSTATS (1.27 and 1.32 in 1990 and 2015 respectively) shows that there was very slight difference in the complexity of the polygons in two study times. According to Cabral *et al*, 2006, values greater than 1 in a fractal dimension indicate an increase in shape complexity. Relatively little change has been recognized in AWMFD of two time frames. This reflects that an effect of an increment in CA, LPI and ED, in this context, has just slightly affected complexity of the shape.

C. Euclidean Mean Nearest Neighbor (ENN_MN)

In order to examine the changes occurred between different time periods, it is crucial to analyze the minimum distances between the classes. In this case, the FRAGSTATS manipulated the ENN_MN distance which represents the average minimum distance between the individual built areas (urban) patch. Literature reviewed (Herold *et al,* 2003) also revealed that, ENN_MN considered as a measure of the open space between urbanized areas. Thus, a decrease in ENN_MN from 112.67 in 1990 to 94.23 in 2015 indicated a decrease in the distance between the built up patches.

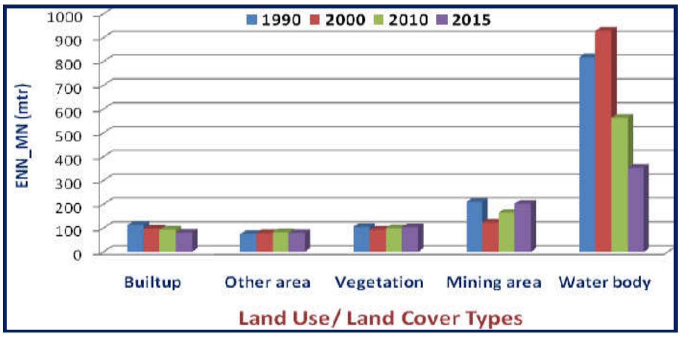

Fig.5. Euclidean Mean Nearest Neighbor of the Study Area

Mean Euclidean Nearest-Neighbour Distance (ENN_MN) approaches 0 as the distance to the nearest neighbour decreases. It is perhaps the simplest measure of patch context and has been used extensively to quantify patch isolation. ENN_MN of built-up area land cover type is decreasing over time (Fig.5). This proves that the urban patches of built-up area type are getting closer to each other. It means the urban areas are getting clumsy indicating absence of proper planning.

D. Core Area Percentage of Landscape (CPLAND)

Core Area Percentage of Landscape (CPLAND) approaches 0 when core area of the corresponding patch type (class) becomes increasingly rare in the landscape, because of increasing smaller patches and/or more convoluted patch shapes. CPLAND approaches 100 when the entire landscape consists of a single patch type (i.e., when the entire image is comprised of a single patch). Here edge influence distance of 100 m has been specified for generating CPLAND values. In this case, CPLAND of built-up area, vegetation and mining area is increasing and other area is decreasing (Fig.6).

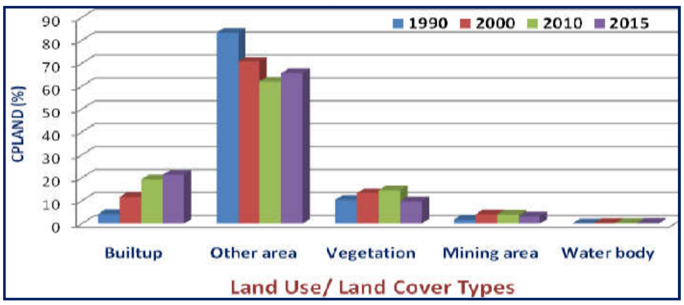

Fig.6. Core Area Percentage of Landscape of the Study Area

E. Findings

The finding of the landscape analysis are summaries as follows;

1. All the values of FRAC_MN are showing just above one and less than two. The FRAC_MN values indicate massive and haphazard growth of urban patches.
2. Area Weighted Mean Patch Fractal Dimension indicated that the level of compactness of the polygons was relatively higher in 1990 than 2015. This means the urban sprawl has radiated irregularly in to different directions.
3. As Euclidean Mean Nearest Neighbor (ENN_MN) revealed that the measure of the open space between urbanized areas. Thus, there was decrement in ENN_MN from 249.2 in 1990 to 210.3 in 2015 indicated a decrease in the distance between the built up patches.
4. The edge influence distance of 100 m has been specified for generating CPLAND values. In this case, CPLAND of built-up area, vegetation and mining area is increasing and other area is decreasing.

Conclusion

This study has shows the potential use of satellite remote sensing and Spatial Metrics in producing accurate landscape change analysis of the Jodhpur for the past 25 years between 1990 and 2015. The analysis results of the landscape metrics give precious information for characterization of five urban land cover types. Results show that it is a fast and accurate way to assessment the impact of urban sprawl on landscape pattern using multitemporal remote sensing data and landscape matrices.

Acknowledgment

The authors are thankful to the Director DL, Jodhpur for help and encouragement during the study. The authors are also thankful to Head Mining Department for his critical suggestion and encouragement.

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