



Quantifying Urban Sprawl for Rajkot City using Geospatial Technology

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ABSTRACT

Urban sprawl is one of the avidly urban issues today. "Sprawling" means the spreading of urban area towards rural area surrounding it. There are different social and economic factors which led to urban sprawl. The study of urban sprawl in this paper attempts to measure the sprawl of urban areas into rural areas and the type of sprawl and the pre-dominant causes responsible for sprawl. It first reviews and analyses past research on the definitions of urban form, compactness and sprawl, and corresponding quantitative variables. Measures of urban sprawl will be identified and procedures will be developed to compute these indicators in GIS environment. The indicators of sprawl defined by (Galster et al, 2001) are considered as major characteristics of sprawl which have been adopted in this paper to develop a set of variables for quantification, characterization and dimension of sprawl. The study has been done on grid level (Grid Size = 500m x 500 m). The density index shows that in 2001 Rajkot had 9292 persons per grid of 500 meters x 500 meters which has decreased to 7394 persons per grid which shows that the population is moving from center to outer fringes. The value of concentration index has decreased from 0.56 in 2001 to 0.23 in 2011 which shows the sprawl development pattern. Centrality has been one of the major indicators of urban sprawl the value of centrality has been observed as 3.7 in 2001 and it has increased to 7.6 in 2011 which indicates sprawl.

1. Introduction

The concept of sprawl has different meaning in different literature. Their review of the literature found that sprawl can alternatively or simultaneously refer to: (1) certain patterns of land-use, (2) processes of land development, (3) causes of particular land-use behaviors, and (4) consequences of land-use behaviors. They have reviewed many definitions of sprawl from different perspectives. It seems that sprawl is used both as a noun (condition) and verb (process); and suffers from a lack of clarity even though many would claim to 'know it when they see it' (Galster et al 2001). Urban sprawl is defined as "The extension of the area of cities beyond the walkable range and the emergence of endless' cities", by (Angel, Parent, & Civco, 2007).

Geographical Information system and Remote Sensing is a vital technology in any evolving urban growth study. Therefore, it's a collection, interpretation, analysis, managing, storing and distribution of Geospatial data which is very much important for urban sprawl detection and planning activities for managing the unplanned growth of a city. Remote Sensing can give detailed information about spatial and temporal information of urban morphology, infrastructure, land cover / land use patterns (Bhatta, 2010). Remote sensing data are capable of detecting and measuring a verity of elements relating to the morphology of cities, such as the amount, shape, density, textural form, and spread of built up areas (Webster, 1995). Four dimensions of any remote

sensing image which has to be considered are spatial, spectral, radiometric and temporal.

To identify the quantification, characterization and dimension of sprawl using index defined by George Galster in his paper 'Wrestling Sprawl to the Ground: Defining and measuring an elusive Concept'. The main objective of this paper is to calculate and analysis the results of this index.

1.1 Study Area and Data Used

Rajkot is one of the fastest developing cities located on the western part of India (Figure 1). It was founded by the ruler of Sardhar 1608 A. D. on the west bank of the river Aji as a small fortified town .which has now grown into a one of the major cities of Gujarat. City of Rajkot has Madhapar and Manharpur out growth in the north-west of Rajkot city. There is outgrowth of Bedi in north east direction of the city. More growth is observed in western region which has Munjka and Mota Mava outgrowth. And in the south we can see Vavdi and Kotharia outgrowth (Gazetteer, Rajkot, GOI).

The study has been conducted using LISS IV data acquired from RESOURCESAT- 2 satellite image of Rajkot city. Image for November 2011 of the 150 Path and 44 Row has been downloaded for this study. Thematic Maps of Ward boundary was collected from Rajkot Municipal Corporation in shape file format. City Development

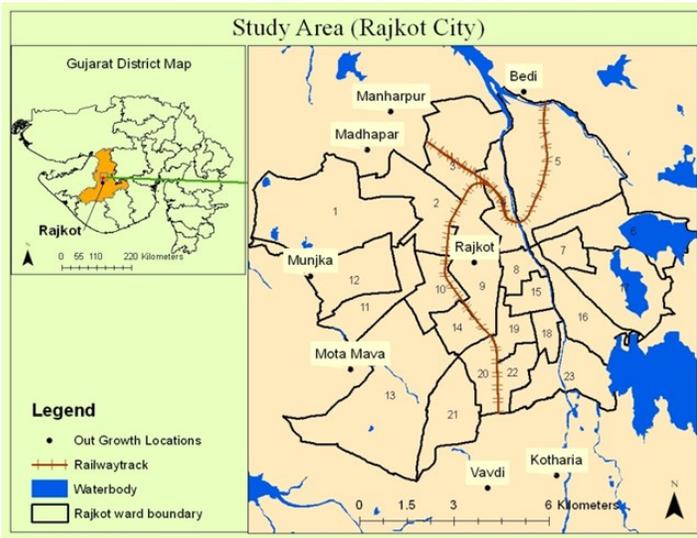


Figure 1: Rajkot City

Plan with land used details was obtained from Rajkot Urban Development Authority Web site in PDF format. Population data at ward level was taken from Census of India 2001 (Figure 2) and 2011 (Figure 3).

2. Methodology

The methodology consists of several steps: data collection from multiple sources, data processing such as image fusion and digitizing, temporal mapping, evaluation based on spatial indicators and comparisons. The main quantitative analysis includes morphology analysis and spatial pattern analysis.

For this study multi date satellite data have been collected and georeferenced. Visual image interpretation has been performed on this remote sensing data to obtain the urban area from the satellite image. Ward boundaries were superimposed on the urban layer. Land use layer was created from the PDF first step was to convert the PDF into image. Then this image was georeferenced with the satellite data and the Land use layer was digitized from this image. This layer gives information about the land use according to the government rules. Population data from Census of India was integrated with the ward boundaries. Grid of different size were created using fishnet tool. Population data was then integrated with grids and a micro level analysis is done for different indices are calculated for the understanding the characterization and dimension of urban sprawl namely density, continuity, concentration, clustering, centrality, mixed use. These indexes have been modified according to the demographic data. The study area is divided into square grids of 500m×500m. On these grids all the urban sprawling index are calculated using field calculator.

2.1 Indices Calculation

Urban sprawl quantification is done using the indices. These indices can be used to understand the characteristics of urban sprawl. The methodology used to measures urban sprawl will be identified and procedures will be developed to compute these indicators in GIS

Table 1: Measures of Sprawl

Dimension	Indicators
Density	Development density: Residential units and
Continuity	Developed area divided by total metropoli-
Concentration	Percentage of very high density grids among
	Coefficient of variation in the density of
Clustering	Delta Index
	Calculating density of each one square mile block of the grid and of each of the 1/4th square mile blocks within it. The standard deviation of each 1/4th mile square block density are then averaged and standardized using the average density of all one square
Centrality	Average distance of housing units or em-
Mixed Use	Average density of one land use in the area of a separate land use

environment. The following Table 1 shows the indicators of sprawl defined by (Galster et al ,2001).

In this paper the study area is divided into small grids of 500m×500m and bigger grids are of 1000m×1000m. The above mentioned measures are calculated grids level.

3. Results and Discussions

3.1 Density

Density is calculated to show the population in a particular area. In this paper micro level analysis is done for each index which gives a better result. Density is calculated using the following formula.

$$\text{Gross Density} = (\text{Total population Grid} / \text{Built up Area of Grid})$$

Where Grid Size = 500×500 meters, and 1 dot = 1,000 person

It is observed from Figure 2 and Figure 3 Population has decreased from 9292 persons per grid in 2001 to 7394 persons per grid in 2011. People have moved out in the new developed areas in all directions from the center. Wards in the central Rajkot are densely populated in 2001 where as the density has reduced over a period of time and has spread in the new built up areas. New development in Ward 1, 2, 3, 5, 6, 17, 21, 12, 11, 13, 12 have changed the population density of the central wards, people have migrated to outer areas where new housing

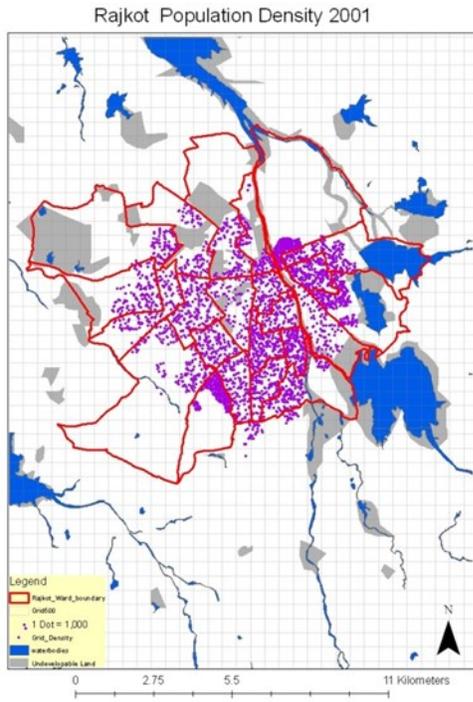


Figure 2: Rajkot Population Density 2001

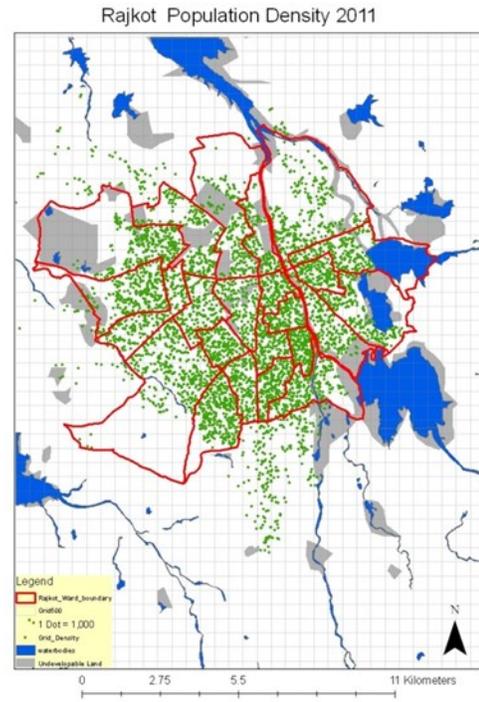


Figure 3: Rajkot Population Density 2011

development is taking place and land price is lower compared to central zone more over new industrial development is also attracting people to move away from CBD.

3.2 Continuity

Continuity is the degree to which developable land has been built upon at urban density in an unbroken manner (Ewing, 1997; Harvey & William, 1965).

Following formula is used to calculate continuity:

$$\text{Continuity} = \text{Developed area} / \text{total metropolitan area}$$

According to Figure 4 and Figure 5 given above continuity for 2001 is 0.34 and for 2011 is 0.66. Hence, it is observed that continuous development has taken place over a period of time. A ribbon development pattern has been observed in North West direction and in the south direction. There is a smooth and continuous development which indicates extent of scattered development. Most of the growth has happened along the fringes of urban area. Water bodies, protected wetlands, forest, parks, other public reservation are not considered as interruptions of continuous development pattern.

3.3 Concentration

Concentration is the degree to which development is located disproportionately in relative to 500m x 500m of the total urban area rather than spreading evenly throughout.

Following formula is used to calculate concentration as proposed by Galster et al. (2001), where:

$D(i)u$ = Density of land use over the developable land area in urban area

$$\left(\sum_{m=1}^M \frac{[D(i)m - D(i)u]^2}{M} \right)^{0.5} / \sum_{m=1}^M \frac{D(i)m}{M}$$

$D(i)m$ = Density of land use over the developable land area in 500m x 500m grid

As observed from figures 6 and figures 7 urban areas here are continuously growing but all urban areas are not evenly developed. Here in 2001 concentration is 0.56 and in 2011 concentration is 0.23. Due to high concentration in 2001, the development is evenly distributed. Whereas in 2011 there is high concentration in the central wards and a few other areas high concentration are observed in the North West direction. Low concentration is observed in the outgrowth of ward 1, 2, 5, 12 and 13; hence development pattern is sprawl like in the wards mentioned here.

3.4 Clustering

Clustering is the degree to which development has been tightly bunched to minimize the amount of land in each 1000m x 1000m grid of developable land occupied by residential or non-residential uses.

Following formula is used for calculating the clustering (Galster, 2001).

$$\frac{\left(\sum_{m=1}^M \sum_{s=1}^4 \frac{(D(i)s - D(i)m)^2}{4} \right)^{0.5}}{\sum_{m=1}^M D(i)m / M}$$

$D(i)s$ = Density of land use over the developable land area in 500m x 500m grid

$D(i)m$ = Density of land use over the developable land area in 1000m x 1000m grid

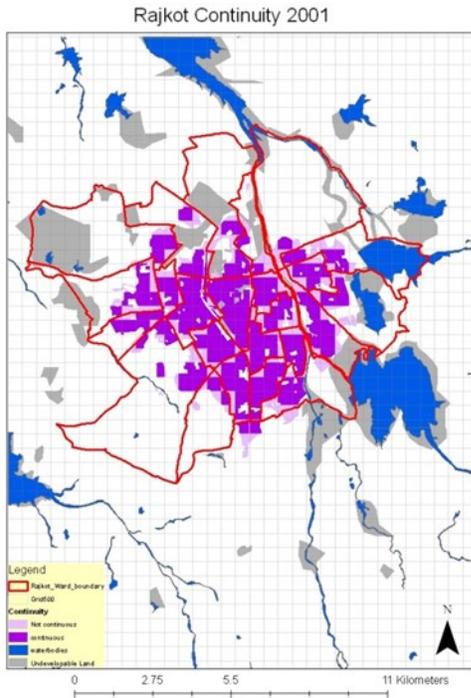


Figure 4: Rajkot Continuity in 2001

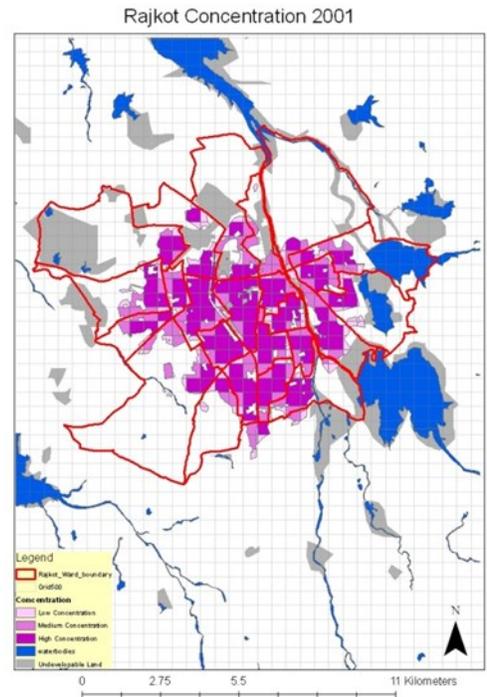


Figure 6: Rajkot Concentration in 2001

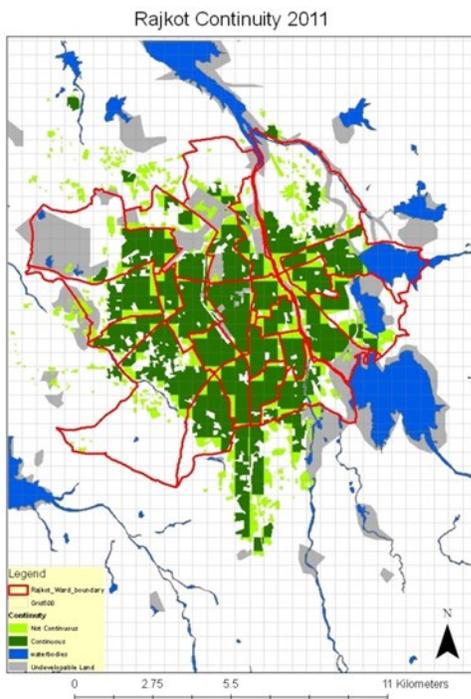


Figure 5: Rajkot Continuity in 2011

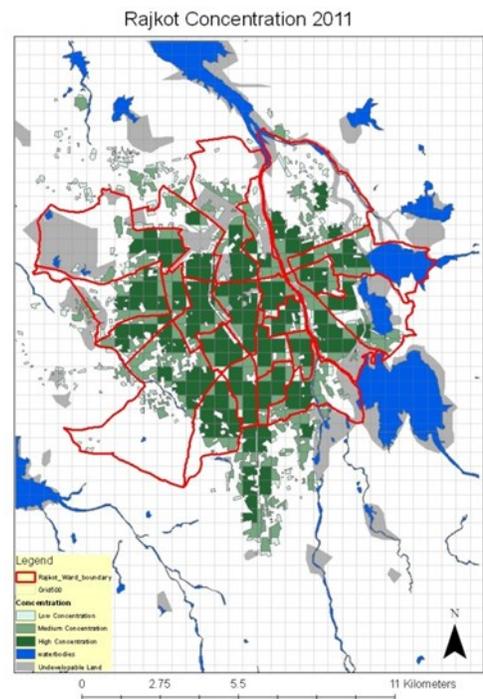


Figure 7: Rajkot Concentration in 2011

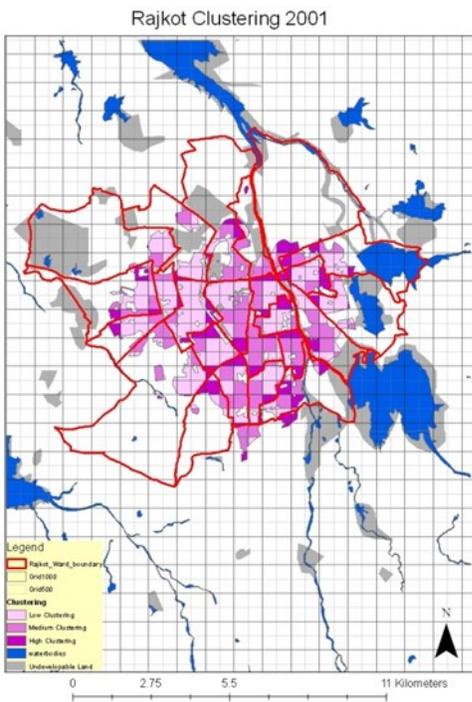


Figure 8: Rajkot Clustering in 2001

As observed from Figure 8 and Figure 9 Clustering value for 2001 is 0.58 and for 2011 it is 0.52. The change observed is very insignificant. Clustering is concerned with the development pattern within the grids. In some grids development is dense and concentrated but not very clustered. The central ward represents high clustering during observation periods.

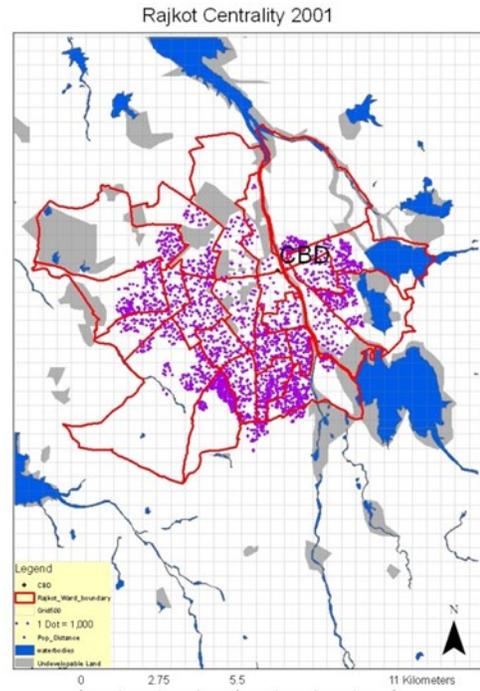


Figure 10: Rajkot Centrality in 2001

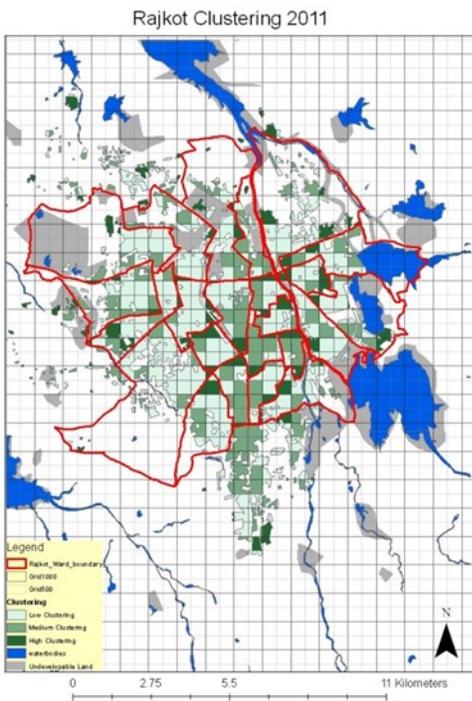


Figure 9: Rajkot Clustering in 2011

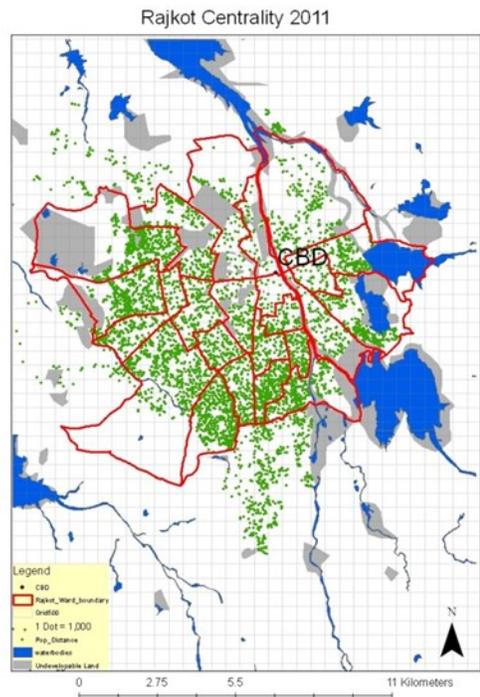


Figure 11: Rajkot Centrality in 2011

3.5 Centrality

Centrality is the degree to which residential or non-residential development is located close to the central business district (CBD) of urban area has been studied.

The following equation is used to calculate centrality (Galster et al., 2001):

$$\frac{T_{(i)u}A^{0.5}}{\sum_{m=1}^M F_{(k,m)}T_{(i)m}}$$

$T_{(i)u}$ = total number of observations of land use in Urban Area

A = Total Area

$F_{(k,m)}$ = distance from CBD

$T_{(i)m}$ = total number of observations of land use in 500×500 grid

As observed from figures 10 and figures 11 Centrality for 2001 is 3.7 where as it has become higher for 2011 to 7.6. Increase in centrality, is one of the most common elements of sprawl. Highly decentralized area as residential and non-residential are spread over a larger region. Decentralization of Sprawl in urban area is often cited as a cause for longer travel distances and consumption of more time reflects inefficiencies in land use. The result reveals the pattern is poly nuclear, represents more than one commercial and industrial area. Hence it results in shortening employee's journey to work. Employees are distributed all over the urban region.

3.6 Mixed Use

Mixed land use is the degree to which substantial number of two different land uses exists within the same grid.

Following equation is used for calculating the mixed use:

$$\frac{\text{Total no of Grids of Mixed Use}}{\text{Total no of Grids with Single Use}}$$

Three types of land use are considered: Residential, Commercial and Industrial. Grids which have more than one land use type in them are considered as mixed use.

As observed from figures 12 and figures 13 the value of mixed use is 0.21 for 2001 and 0.24 for 2011 which shows very marginal change in a decade. Mixed land use remained as a part of the urban settlement, with the increase of the sprawl of the area of mixed land use increases. 4.0 Conclusion

All the index derived are being placed together. Density index shows that there is decrease in density representing population are getting scattered. There is a smooth and continuous development. Continuity has increased over a period of time. In 2001 it is observed that there is high concentration throughout hence the development is more evenly distributed. Whereas in 2011 the concentration has been reduced to half the value. Clustering is having similar pattern in both the years. In 2001 it is seen that it is

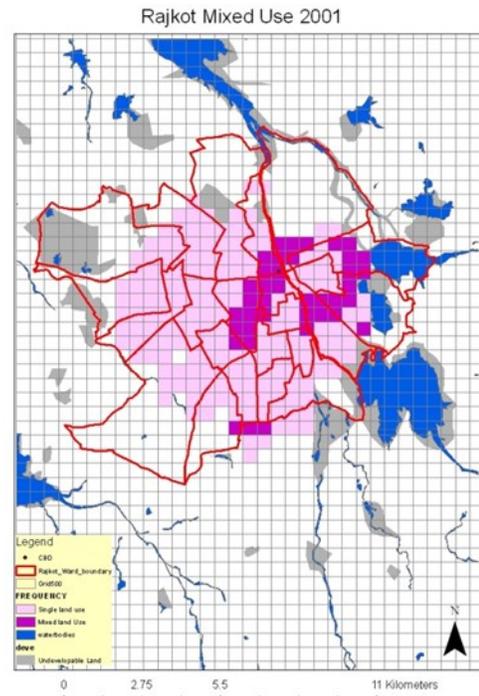


Figure 12: Rajkot Mixed Use in 2001

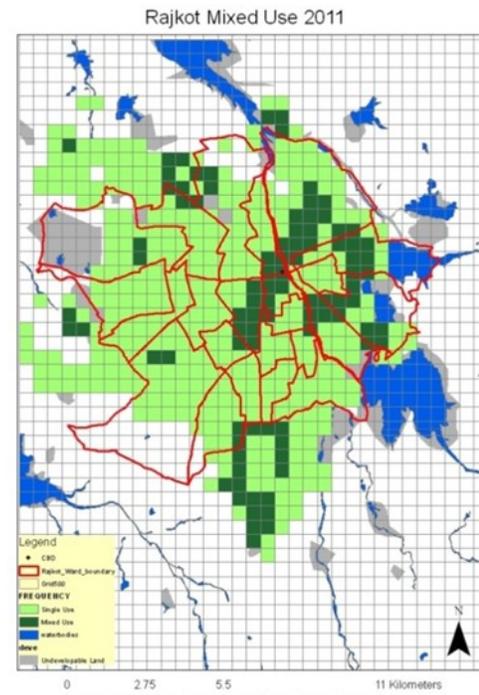


Figure 13: Rajkot Mixed Use in 2011

more centralized as we move towards 2011 centrality is lost and many new poly nuclear pattern of development is seen. Value of mixed use suggest that ratio of mixed use on single land use is showing similar value.

Table 2: Urban Index

Index	2001	2011	Change
Net Density	9292	7394	-
Continuity	0.34	0.66	+
Concentration	0.56	0.23	-
Clustering	0.58	0.52	-
Centrality	3.7	7.6	+
Mixed Use	0.21	0.24	+

These results can be of great use for developing the city plan. According to these results Rajkot Municipal Corporation can take up the issues in each ward and work on the development of the city ward by ward. Each Index has been calculated for a 500 m x 500 m grid which leads to better understanding of the areas which require more attention and areas which are open for new development.

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