Cloud Publications
International Journal of Advanced Remote Sensing and GIS
2014, Volume 3, Issue 1, pp. 544-552, Article ID Tech-237
ISSN 2320 - 0243

Case Study | Open Access

Urban Growth Using Shannon's Entropy: a Case Study of Rohtak City

Bijender Singh

Department of Geography, I.G. University, Meerpur, Rewari, Haryana, India

Correspondence should be addressed to Bijender Singh, sbijender@gmail.com

Publication Date: 30 April 2014

Article Link: http://technical.cloud-journals.com/index.php/IJARSG/article/view/Tech-237

Abstract With an extensive history dating back to antiquity urban development, human-induced climate change is one of the most important areas of human induced environment transformation. The study makes use of Shannon's Entropy with the help of Geographic Information System (GIS) and Remote Sensing technique. Rohtak city is located amidst fertile agricultural lands; the city has undergone rapid expansion during the recent past. The study spread over a period 38 years. On the basis of Survey of India Toposheet and satellite images, built up cover of Rohtak was classified for different time periods. Data used in the present study are the Survey of India Toposheet, LANDSAT TM 1989, IRS P6 LISS-IV PAN (mono) 2005, image acquired from Google earth 2011, and Census of India. The growth rate of built-up area was around three times more than population growth rate during 1989-2002. The growth rate in built-up area was 24.14 percent and population growth rate was 14.47 percent during 2002-2005. On the basis of these data urban growth are examined with the help of Shannon's Entropy and found the sprawl direction.
Keywords *Remote Sensing; Shannon's Entropy; Urban Growth; Rohtak City*

1. Introduction

In the Report of the United Nations (2003) it is estimated that in the next thirty years, almost all global population will be concentrated in urban areas. Such as Europe and North America in the more developed parts of the world, the level of urbanization is very high, and almost 50 percent at the global population lives in urban areas. This percentage, according to several estimates is expected to rise yet further in future decades. In 1800, only 3 percent of the world population lived in urban areas. By 1900, i.e. over next hundred years this figure went up to almost 14 percent only. Further, there were only 12 cities with 1 million or more inhabitants at the onset of last century. However, by 1950, 30 percent of the world population lives in urban centers, and the number of cities with more than 1 million people were 83. The world has experienced fast urban growth in recent decades. In 2000, nearly 47 percent of the world population lived in urban areas. Now, with over 1 million population cities are as many as 411. Less developed countries, 40 percent of residents live in urban areas, while more developed

countries, about 76 percent are urban. Rapid urbanization in many developing countries is low even today. It is expected that 60 percent of the world population will be urban by 2030, and that most urban growth will occur in less developed countries (Population Research Bureau, 2005:19).

In developing countries, urbanization is a phenomenon that has become increasingly intense in the past decade. India has most of the features of urbanization like developing countries. Total number of towns has grown from 1827 to 5161 during 1901 to 2001. The total size of urban population has increased from 2.58 crores 1901 to 28.53 crore in 2001. During 1921-31 to until 1951 an annual growth rate of urban population in India has a faster pace. After that a sharp decreased in growth of urban population in the decade 1951-61. During the 1961-71 and 1971-81 urban growth rate reached up to the current level of 2.7 percent. During the decade 1951-61 the growth rate of urban area decrease because a large number of cities declassification as a result of sticker definition of urban centers at the time of 1961 Census. In India, the number of million cities has increased to 5 million in 1951 to 23 in 1991 and 35 in 2001. At the time of 2001 Census, 37 percent of total urban population resides in these million plus cities.

Haryana, after its formation as a separate state in 1966, and particularly since the 1970s has experienced a marked acceleration in its urbanization process. The number of Class-I urban centers in the state has increased from just 4 in 1971 to as many as 19 in 2001. In 2001, 66.69 percent of the urban population in the state lived in Class- I towns.

2. Study Area

Rohtak city is located on the intersection of 28°54′ N latitude and 76°35′ E longitude, at a distance of 75 kilometers to the north-west of Delhi, the National Capital of India. Rohtak is the administrative headquarters of a district and a tehsil by the same name. The national capital of India has the only Metropolis city in the northern region of the country. Rohtak city is situated in the National Capital Region (NCR). According to The Regional Plan 2021 of NCR, Rohtak city has identifies the regional centre with the population of ranging from 3 lakh to 10 lakh.

Due to its location in the close vicinity of the National Capital, the urban landscape of Rohtak has undergone change from time to time. According to the Census of India 2011, Rohtak city is the third largest city of Haryana state. Rohtak is a Class–I city with a population of 3, 73, 133 at the time of 2011 census. In 2010, Municipal Committee of Rohtak was up-graded to Municipal Corporation (MC). According to the MC limit the total area of the city was 11039.15 hectares in 2010.

3. Data Based and Methodology

The present study is spread over a period of 38 years (1973 to 2011). The study is based on remote sensing and GIS techniques in conjunction with secondary data have been adopted in the study. The data related to remote sensing are handled with the help of Erdas Imagine 10 and related to GIS with the help ArcGIS Desktop 10.0 respectively. The lists of data used in the study are the Survey of India Toposheet No. H 53 D/9 and H 43 W9 at the scale of 1:50,000, LANDSAT TM 1989 (Landsat TM: path 158, row 40, 18/5/1989) downloaded from the Global Land Cover Facility (http://glcf.umiacs.umd.edu/), IRS ID LISS-III 2002 (IRS LISS III: path 95, row 51, 15/02/2002), IRS P6 (Resourcesat–1) LISS-IV PAN (mono) 2005, Image acquired from Google earth, 2011 (20/09/2011) and Census of India.

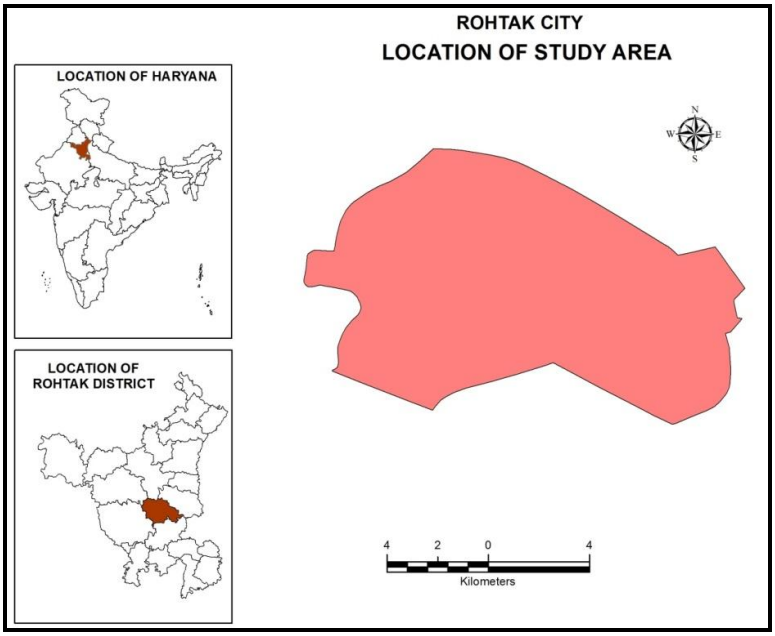

Figure 1: *Location Map of Study Area*

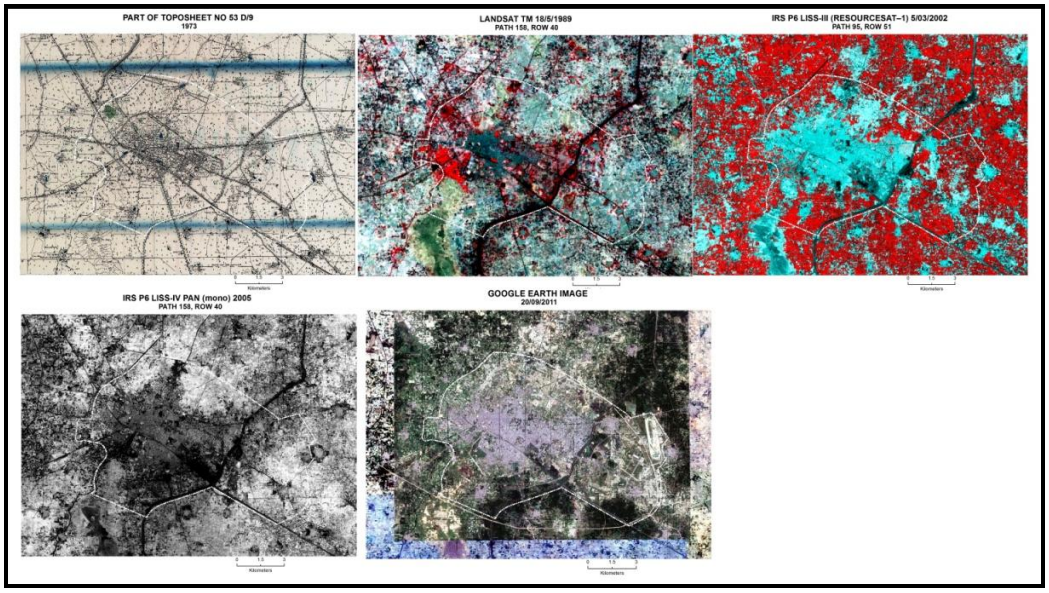

Figure 2: *Topographical Map and Satellite Images of the Study Area*

Toposheet no. H 53 D/9 (Survey of India) at the scale of 1:50,000 have been used as a reference to perform geometric correction using Erdas Imagine 10.0 software. Approximately, 60 ground control points (GCPs) were selected in order to register the images to the Universal Transverse Mercator (UTM) coordinate system in 43 North Zone and WGS 84 Datum. The Toposheet used as a reference to perform reference to four times satellite data i.e. for Landsat TM, IRS LISS III, IRS PAN, and acquired from Google earth. The both toposheet and Google earth image have been classified by the visual interpretation. The Municipal committee of Rohtak became Municipal Corporation in 2010. Therefore, the latest MC limit of Rohtak, 2010 has been used to analyze the growth of the city.

Shannon's Entropy

One of the measures commonly used due to its toughness in urban sprawl measurement is *Shannon's entropy* (Yeh and Li, 2001). It measures the patterns of built-up area either dispersed or concentrated over time (Yeh and Li, 2001). Entropy calculation is based on computation of area. It is measured with the help of a combination of remote sensing (RS), geographic information system (GIS) and photogrammetric techniques (Sudhira et al., 2004)

The Entropy (E) value could be calculated using following formula.

$$\sum_{i}^{n} \mathrm{Pi} \cdot \log\left(\frac{1}{\mathrm{Pi}}\right) \qquad (1)$$

Pi Xi/$\sum_{i}^{n} xi$ is the observed value in the i^{th} zone in a total of n zones.

n represents total number of zones/wards

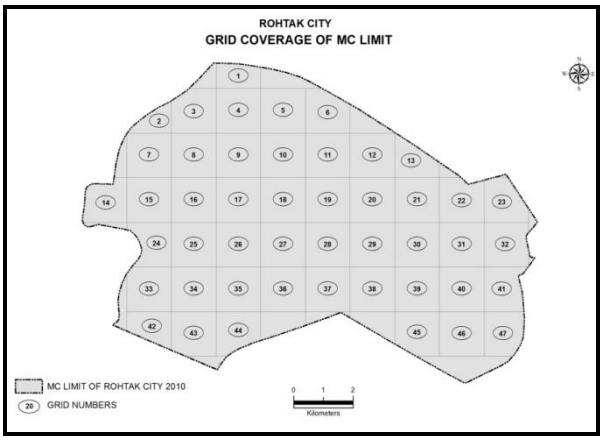

Figure 3: *MC limit of Rohtak Divide into Grids*

Entropy value ranges from 0 to log (n). In the present case, log (n) is 1.672. Entropy value closer to zero represents compact distribution of urban growth, while values closer to 'log n' represent dispersed distribution of sprawl. Values of entropy near to 'log n' reveal the dispersion of built -up area, which indicates the occurrence of urban growth and heterogeneity of land uses (Punia and Singh, 2012). In this study, Shannon's entropy has been used to quantify the patterns of urban growth. Shannon's entropy is used to measure the degree of spatial concentration or dispersion (homogeneity) of a geophysical variable (built-up area) among 'n' spatial units/ wards (Jat et al., 2008).

4. Urban Sprawl Analysis

It is important to note that comparison of an area in a time series data required a same spatial unit. Also, it is useful in the case of Rohtak using *entropies* for different time period data. The boundary of municipal wards and limits in Rohtak City has undergone change over time. To resolve this problem the latest MC boundary of Rohtak city has been taken as base for different time data in the present study. Therefore, the MC boundary has been divided into 1.5 kilometres by 1.5 kilometres grids (as shown in Figure 2). Forty seven grids cover the entire MC area of Rohtak city.

Generally, it is suggested that the urban sprawl is affected by access to road network and distance from city centre. In the present case entropy calculated based on the distance decay properties of urban sprawl. The influences of these location factors were measured with the help of buffer in GIS.

The aim of the present study is to depict pattern of urban sprawl in Rohtak city. Therefore, this study of trends of urban built-up area is required to get temporary data. In this work, Survey of India (SOI) Toposheet published in 1973 and Landsat TM 1989, IRS-1D LISS -III 2002, IRS P6 (RESOURCESAT 1), LISS -IV Pan (mono) 2005 and Google Earth 2011 image acquired from Google Earth has been used to detect changes in urban built-up areas. Using these data of built up area over a period of time shows the changing trend in the pattern.

Table 1: *Built-up Area and Population Change in Rohtak City (1973-2011)*

Years	Built-up Area (in Hectares)	Change in Built-up Area from Previous Year	Percent Change over the Previous Year	Estimated/Census Population	Percent Change over the Previous Year	
1973	399.82	-	-	128956	-	-
1989	649.07	249.25	62.34	206230	77274	59.92
2002	1409	759.93	117.08	302425	96194.9	46.64
2005	1609.67	200.67	14.24	325969	23544.3	7.79
2011	1998.2	388.53	24.14	373133*	47163.6	14.47

Census population for the year 2011

Source: i) Based on SOI toposheet for the year of 1973 and satellite data 1989, 2002, 2005, 2011 respectively

Table 1 presents data on built-up area and total population of Rohtak city for the year 1973 to 2011. Built-up area is calculated from SOI for 1973 and Satellite data for 1989, 2002, 2005 and 2011. Total built-up area of Rohtak city was 399.82 hectare in 1973. At that time the estimated population of the city was 1, 28,956.

Built-up area became 649.07 hectare at the time of 1989 and recording a growth rate more than 60 percent as compared to 1973. In the same time the growth of population increased at the rate of 59.92 percent. This implied that growth in built-up area was in commensurate with growth in population of the city as the gap between the two rates was not that large. During the period between 1973 and 1989 Tilyar Lake was developed for tourism purpose in the eastern side of the city on the highway connecting Rohtak with Delhi. The lake is spread over an area of 132 acres (0.53 km^2) area and forms an integral part of the tourist setup, making it one of the greenest stretches in the adjoining area.

The growth rate of built-up area and population worked out to be 117.08 and 46.64 percent respectively at the time of 2002. Growth rate of built-up area was around three times more than population growth rate during 1989-2002. It shows that the city grew more in the form of horizontal expansion than vertical one. Lots of new residential areas have come into existence during this time. Although, the city has expanded in all direction, the main growth was along the eastern parts of the city along National Highway No. 10 (Singh, 2013).

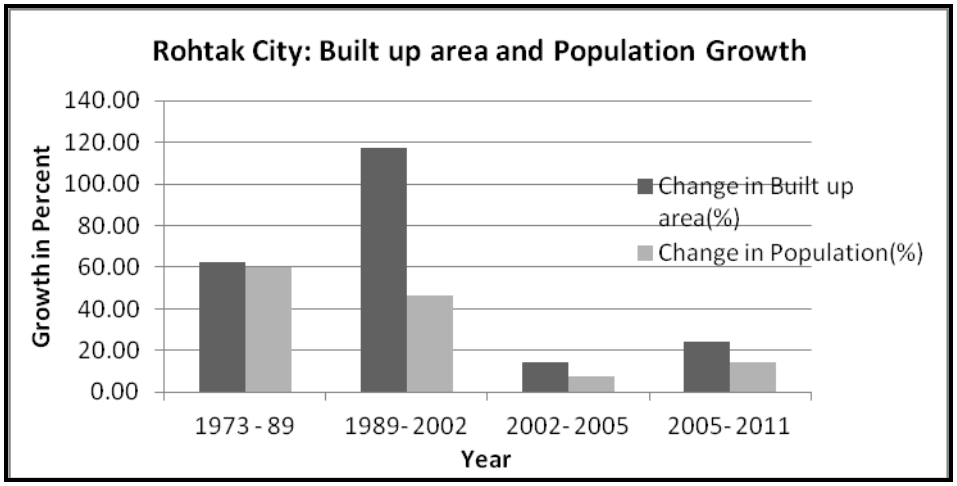

Figure 4: *Build up Area and Population Growth*

In this direction an industrial area was developed by the Haryana State Industrial and Infrastructure Development Corporation Limited (HSIIDC). During 2002-2005 a growth rate of 14 percent was recorded in the built-up area while population grew at the rate of only 7.79 percent only. This indicates that the growth of the city is more of horizontal expansion continued to exist. The built-up area of the city has become 1998.2 hectares and population 3, 73,133 at the time of 2011. Thus, growth rate in built-up area was 24.14 percent and population growth rate was 14.47 percent during the period of 2005-2011. During this period, several residential, institutional, industrial areas have been developed in the city. During the same time HSIIDC has developed an Industrial Model Township (IMT) on the eastern side of the city. Several industries/companies are developing its units in Industrial Model Township (IMT) area, for instance, Asian Paints Limited, Maruti Suzuki's Research and Development Plant, Hitech Plastics Limited and Footwear Design and Development Institute. In the northern side of the city many institutions have come up like Institute of Fashion Design, Film & TV, Fine Arts and Communication, Industrial Training Institute. The Haryana Urban Development Authority (HUDA) is developing the Rajiv Gandhi Sports Complex in Sector-6 also on the northern side of the city.

The city has experienced a growth of built-up area by almost five times while the population of the city has barely trebled during the 1973 to 2011. The growth rate of built-up area has doubled than the growth rate of population in nearly four decades i.e. 1973 to 2011. It showed that growth of the city is mainly horizontal at the cost of surrounding fertile agricultural land. Also, the growth of built-up area in the city shows that it is not demand driven. It is striking to note that as much as 37 percent of the addition in the geographical area of city during the period has occurred over less than a decade between 2002 and 2011.

The entropy used for measure the sprawl of the city and was calculated for the 47 grids that cover the municipal limit of the city. The upper limit for the value of Shannon's entropy in the present case could be 1.672 i.e. equal to log n ('n' is the number of grids i.e. 47). During the study period, relatively lower value of Shannon's entropy (0.921) in the year 1973 and largest value of Shannon's entropy (1.319) in the year 2011. It indicates that at the time of 1973 the built-up area was distributed compact and homogeneous in the core. Also, it is noted that the entropy values have continuously increased during the study period (1973 to 2011). Entropy values 0.921 in 1973, 1,031 in 1989, 1,230 in 2002, 1,278 in 2005 and 1,319 in 2011 are reached. Be close to the upper limit of log n, 1.672 i.e. show the degree of dispersion of the built-up area. This increase in entropy increase in the built-up area indicates the scattered distribution.

Table 2: *Rohtak City: Shannon's Entropy Value*

Years	Value of Shannon's entropy
1970	0.921
1989	1.031
2002	1.230
2005	1.278
2011	1.319

Source: Computed by Author from SOI Toposheet and Satellite Data

It is found that in the early years of 1970s the almost built up area was exit in the first 20 grids. In these grids, 10 grids account around 96 percent of the total built up area of the city. With the passage of time the share of built-up area in 10 grids gradually decline from 96 percent in 1973, 92 percent in 1989, 78 percent in 2002, 73 percent and 2005 and finally 66 percent in 2011. Obviously the spread was more conspicuous during the last decade. In other words, while for the year 1973, there were as many as 31 grids without any built-up area, the corresponding figure for 2011 is only 10. The number of such grids for the years 1989, 2002 and 2005 was 20, 29 and 33 respectively. This is indicative of the pace of dispersal of built-up area in the city during the recent past.

In the present study, grid-wise area has been considered as the geophysical variable, which enables determination of urban growth. Shannon's entropy analysis results for 5 time-points (1973, 1989, 2002, 2005 and 2011) are presented in Table 2.

5. Spatial Pattern of Urban Sprawl

Shannon's entropy has been determined to understand the spatial pattern of urban growth of the city. Shannon's entropy has been calculated for all the grids taking each grid as an individual spatial unit. Built-up area has been used as a variable of Shannon's entropy to find out that the pattern of land development in these grids whether compact built-up dominated or it is dispersed/ homogenous. The temporal change of spatial patterns of urban development can be easily measured from the change in entropy. The increase in the value of the entropy indicates that there is an increase in urban sprawl and development tends to be more dispersed. As already mention earlier, the city has been divided into 47 grids. After that Shannon's Entropy has been calculated for each grid. Shannon's entropy values were assigned to the respective central point of the grid. Shannon Entropy interpolation methods have been used to show the smooth pattern of urban sprawl. It is used with the help of centriods of each grid using ArcGIS (ESRI product) software extension Spatial Analyst Tools. Interpolation method has applied for Shannon's entropy values for all five sets of data time period (i.e. 1973, 1989, 2002, 2005 and 2011).

Based on the interpolation of Entropy value the shape of city shown in Figure 5 like an ellipse in year 1973. The major axes of ellipse are mainly following the major road transport routes of the city. Major axis follows the National Highway No. 10 which connects Delhi to Hisar and passes through the heart of the city. Similarly minor axis follows the National Highway Nos. 71 and 71A. Figure 5 also shows that the value of Shannon's entropy index decreases towards the outskirts of the city. The central parts of the city which contain higher Entropy values are enclosed by circles of higher values of entropy, and as one move away from the centre the values tend to decline towards the outer part of the city.

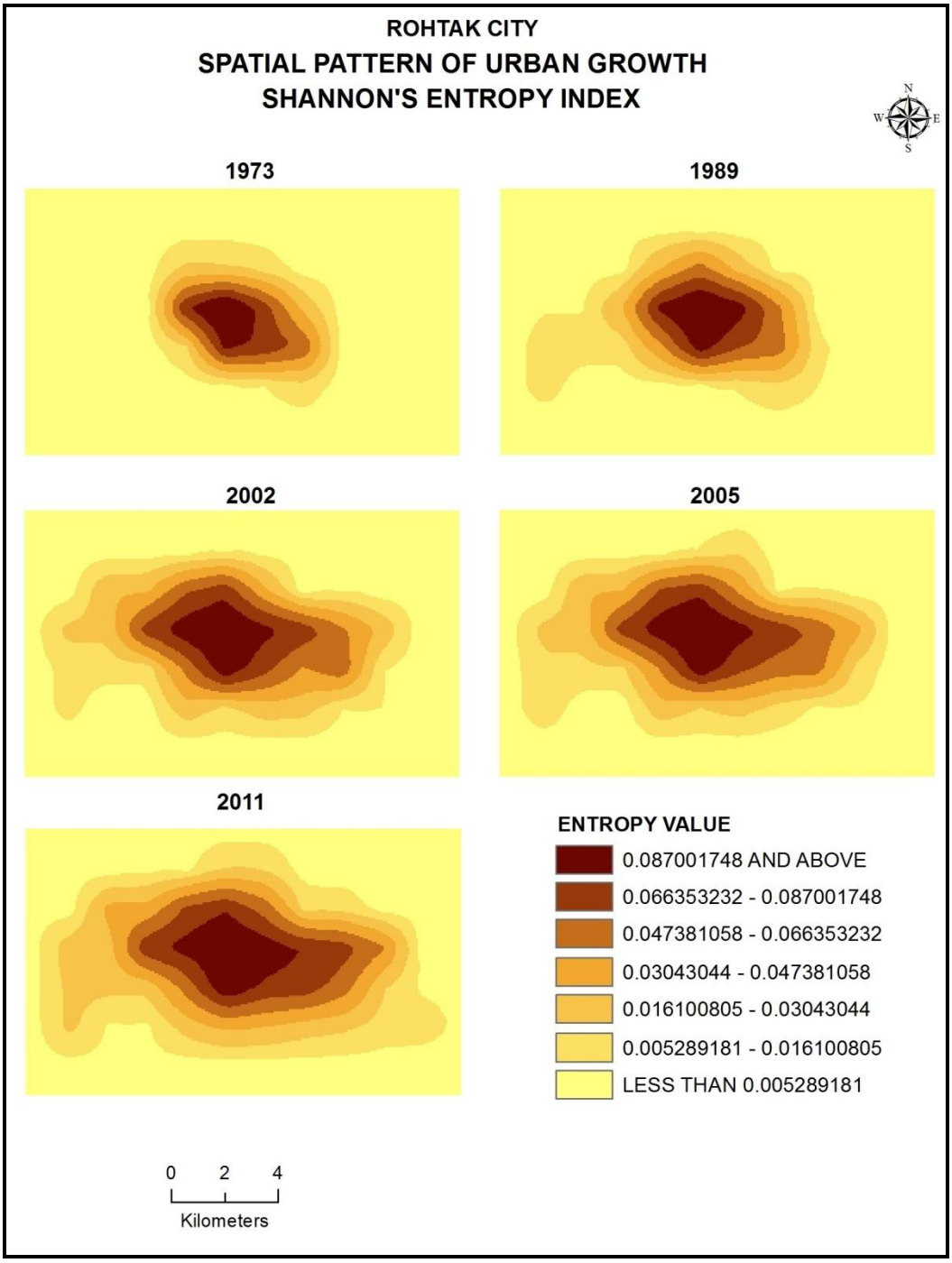

Figure 5: *Spatial Pattern of Urban Sprawl*

The outer parts of the city are enclosed by circles of gradually declining value of Shannon's Entropy. This shape has persisted up to the year 1989. In the year 2002 some notches in the outer part of the city come up, and continue up to 2011. The shape of the city based on Entropy value in year 1973 is very similar to the one that emerges from the Rohtak Development Plan 2025 developed by Department of Town and Country Planning, Haryana. During the periods under study it is found that the major direction of the expansion of the city is towards the eastern parts. It is the impact of National Capital Territory of Delhi. As already mention earlier, the major extension of the city is in the eastern side mainly because planned residential sectors developed by HUDA have come up in this side. Moreover, the growth directions are more prominent in eastern and northern side after the year 2005.

The growth in MC limits of the city that has extended much faster than before because of political factor. The growth of the city become faster and beyond the Jawahar Lal Nehru Feeder Canal in the year 2005. At the same time Industrial Model Township (IMT) has been developed between National Highway No. 10 (towards Delhi) and State Highway No. 18 (towards Sonipat).

6. Conclusion

The method of Shannon's Entropy with the help of Geographic Information System (GIS) and Remote Sensing technique is very useful tool for measuring urban sprawl. The measurement of urban sprawl is very useful for future urban planning at local and global level. The calculated Shannon's entropy for built up area of the study area confirms that the development is highly dispersed as the entropy for 2011 is 1.319. It shows that rate of urban growth of Rohtak city is quite high and needs proper management to attain sustainable development. It also showed that the horizontal growth is very high than the population growth of the city. The city is located in the fertile agricultural land so the government should monitor the growth of the city for proper management of land in a particular use of a category.

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