

ANALYSIS OF THE URBAN SPRAWL DYNAMICS USING SHANNON'S ENTROPY IN ROORKEE PLANNING AREA

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ABSTRACT:

This study is an attempt to analyse the urban growth patterns using Shannon's entropy in Roorkee, Uttarakhand, a growing urban agglomerate in India due to its locational and functional attribute. It has three major national highways that connect to Delhi, Dehradun, and Haridwar. This study utilises the integration of the Remote sensing data and Arc GIS to perform a preliminary identification and mapping of the change detection using the classified data and important driving factors of growth in the city. These factors need to be calibrated using quantifiable indices-like Shannon's entropy which can evaluate the simulated growth pattern in terms of the degree of dispersion and concentration of built-up areas in the different zones around the major driving factors. This index helps in establishing the likely patterns of growth based on the index values obtained. The results and conclusions can serve as a planning paradigm for any further smart and sustainable development in the city.

Keywords: *Shannon's Entropy, Urban Sprawl, Growth pattern, Sustainable development*

1. INTRODUCTION

The globe has experienced fundamental changes in land cover and landscape pattern due to rapid process of urbanization, which causes the expansion of an urban areas into the surrounding agricultural lands and forested areas. Thus analysing urban growth processes and patterns is crucial to monitor urbanization and its impact on environment over time. Urban planners and policy makers, require advanced and rapid techniques to acquire quantitative and qualitative information on urban growth processes and patterns. These studies will help in analysing growth patterns and ensuring a more systematic and sustainable growth in future (J.Huang et al.,2007; Van de Voorde et al.,2009).

An attempt has been made in present study, to analyse the urban growth patterns using the remote sensing data and Shannon's entropy, to statistically establish the type of growth in the study area and its implications on the future growth and environment. Shannon's entropy is a measure of spatial concentration and dispersion performed statistically to understand the urban sprawl patterns

2 . STUDY AREA AND THE DATA USED

The study area was Roorkee city and its environs. Roorkee is located in the state of Uttarakhand and; its geographical coordinates are 29.87° N-77.88°E, with an average elevation of 268 meters. The city has developed on the banks of Ganga canal, which flows from north to south through the city. It is spread over a flat terrain with the Himalayas to the east and north-east. LISS IV sensor data of year 2009 and 2013 was used in the study.

3. METHODOLOGY

3.1 Image processing

Two multi temporal high resolution Liss IV imagery of year 2009 and 2013 were acquired and geo rectified to

UTM projection. Digitisation of the base layers was done using the two datasets. Band extraction and was performed overlaid with the vector layer and false color composites were prepared.

3.2 Preparation of land cover (LC) maps

The land cover-(LC) maps were prepared using object based classification. The following four (4) classes were extracted: Agriculture, Built-up, Water Bodies, and Vegetation

3.3 Preparation of the built-up-non-built-up maps from the LC maps

The study involves the analysis of urban growth, hence it becomes necessary to focus on the built-up areas only. So, a built up-non built up map was prepared by reclassifying the LC map into two classes, i.e., built-up and non built up.

3.4 Preparation of the change/growth maps

Post classification comparison of the multi temporal classified datasets was used to produce growth map using different spatial analyst tools like image differencing, Principal Component Analysis(PCA), change vector analysis, image ratioing, The growth map indicates the different classes(i.e., agriculture, vegetation, water bodies and strategic lands) that changed to built up.

3.5 Identification of the driving forces of the urban growth and their mapping

The causative factors of urban growth were identified based on extensive literature review. Secondly, ground truthing of the study area and the discussion with the local experts, revealed the driving forces of the growth .It was found that land use conversion was dependant upon a series of spatial variables, i.e., accessibility, proximity, and physical nature of the land as it exists. The vector data of the features associated with the urban environment of Roorkee city was prepared in Arc GIS 10.3, like mapping of major roads, arterial roads. In this study, the major driving forces taken into consideration are:

1. Distance of the cell to major existing roads.
2. Distance of the cell to the arterial roads.
3. Distance from the cell to closest existing built-up.(in 2009 and 2013)
4. Amount of built-up in the neighbourhood of the cell.(in 2009 and 2013)

In this study, the probability of a land to convert from non-urban to urban land is considered as a function of the identified predictor variables. The Shannon's entropy analysis is then performed to better understand the equation between the urban growth patterns and the driving forces.

3.6 Analysis of the growth maps using Shannon's entropy

Claude Shannon gave a statistical character to entropy in a new scientific domain: the information theory. Shannon defines entropy as an absolute limit of best possible lossless encoding of a digital message. In 1972, Henry Theil gave Shannon's entropy a broader interpretation as a measure of dividedness and spatial dispersion in his relative entropy concept. (Pedro Cabral, et al.,2013). The Relative entropy concept defines the proportion of the maximum possible dispersion in which a variable is spread between categories or spatial zones. The value varies from 0 to 1. It will be 1 if the variable is evenly spread among all zones, and will approach 0 if the variable is concentrated in a small number of zones. In the complex and interrelated processes involved in urban growth and sprawl, entropy must be kept within a range defined by the minimum value, below which the system becomes vulnerable and unstable, and the maximum value, above which the system becomes unsustainable. The parameterization of those thresholds may be very useful for urban administrations, thus providing valuable insights into the functioning of urban systems (Pedro Cabral et al,2013).

Shannon's entropy is an effective indicator of whether urban growth is dispersed or compact with respect to a particular driving factor. In this study, Shannon's entropy has been used for evaluating the simulated growth pattern with respect to road network- major and minor roads. For this zones along the major and minor roads are formed and then entropy analysis done.

3.7 Calculation of Shannon's Entropy

Shannon's entropy was measured with respect to major and minor roads. So, the first requirement is to create buffer zones along the major roads and minor roads. Ten buffer zones of 300 m are created along the major road and 5 buffer

zones of 300m along the minor roads. Then, no of growth pixels in each zone are calculated. These growth pixels in each zone are used to find the proportion of urban growth (ρ_i) occurring in the i^{th} zone and it is defined as:

$$\rho_i = \frac{G_i}{\sum_{i=1}^n G_i}$$

Then this proportion of growth in each zone with respect to all zones is used to calculate the Shannon's entropy defined by:

$$SE = -\sum_{i=1}^n \rho_i \log(\rho_i)$$

Where, i = zone number and n = total number of zones.

The value of SE ranges from 0 to $\log(n)$.

3.8 Calculation of Relative Entropy

Relative entropy is used for scaling the entropy values from 0 to 1. These are calculated using the following equation:

$$RE = \frac{SE}{\log(n)}$$

The values of relative entropy can then be interpreted as: if the growth is concentrated in one zone, then relative entropy will be 0. And if the growth is evenly dispersed in each zone, the value of the relative entropy is 1. Hence, the variation of entropy from 0 to 1 suggests the concentration or dispersed nature of growth.

4. RESULTS AND DISCUSSIONS

The imagery of Roorkee is obtained from LISS IV is as shown below:

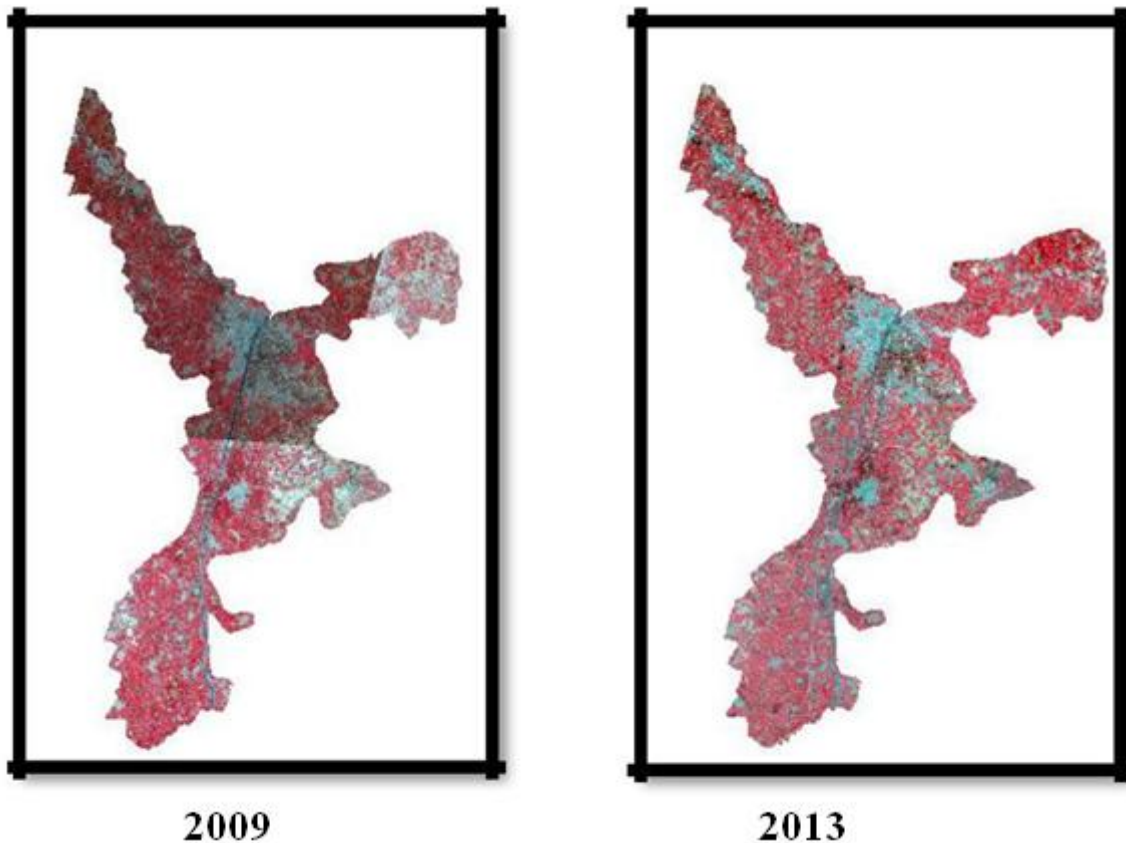


Fig 1: LISS-IV IMAGES COVERING THE STUDY AREA IN 2009, 2013

The object based classification done in Ecognition software and four land cover classes were extracted : Agriculture, built-up, water bodies, vegetation, these classes were then reclassified into two major classes i.e. built-up and non-built-up (Fig 3).

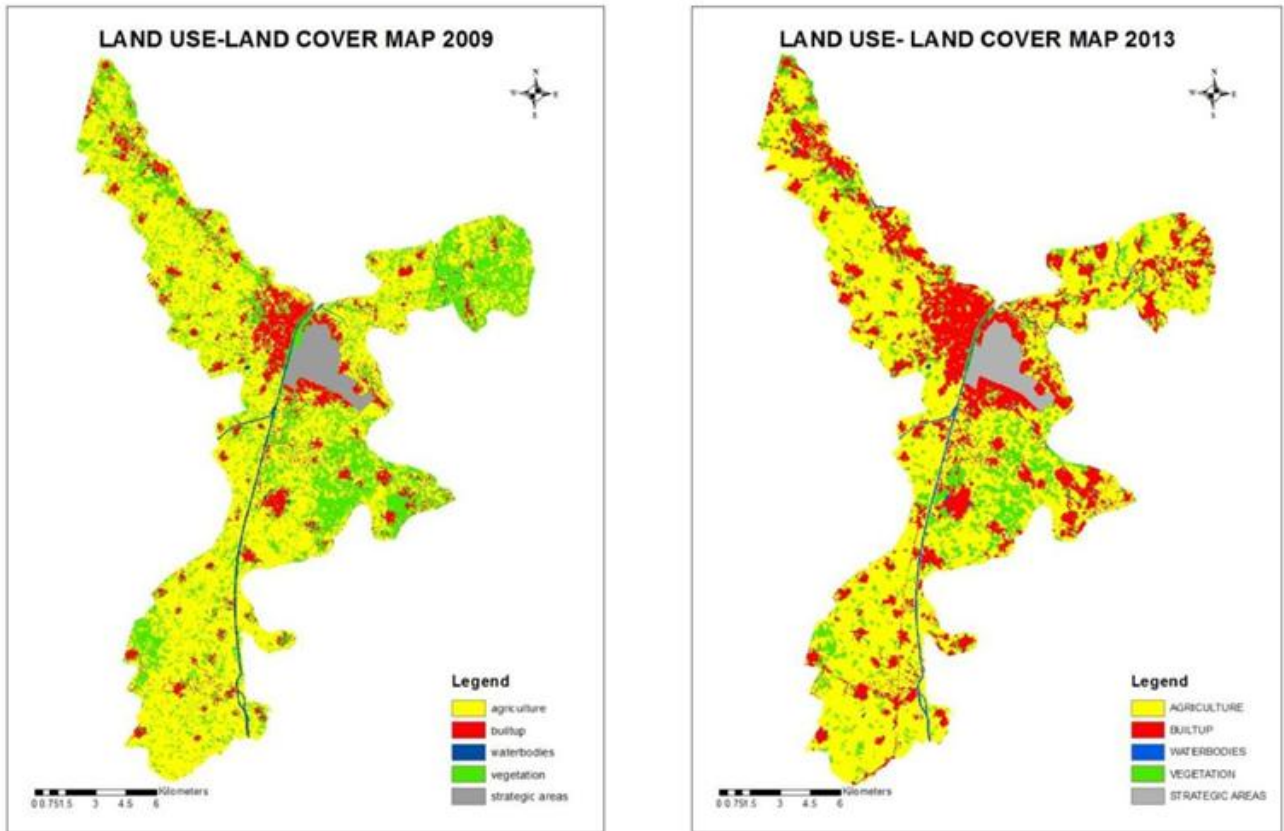


Fig 2: LAND USE AND LAND COVER MAPS OF THE STUDY AREA IN 2009, 2013

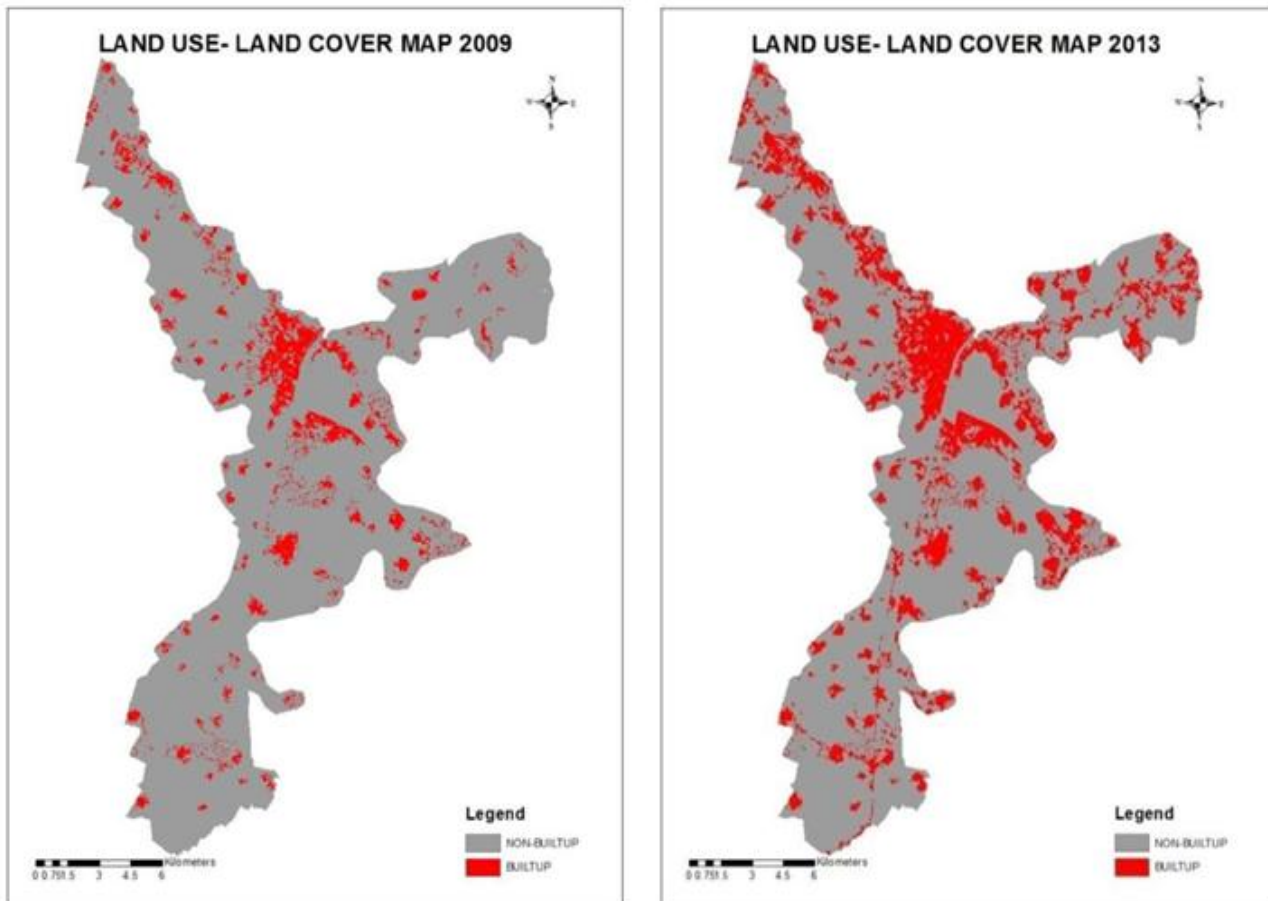


Fig 3: BUILT-UP AND NON BUILT UP MAPS OF THE STUDY AREA IN 2009, 2013

The growth of the built-up from 2009 to 2013 was analysed as shown in (Fig 4).

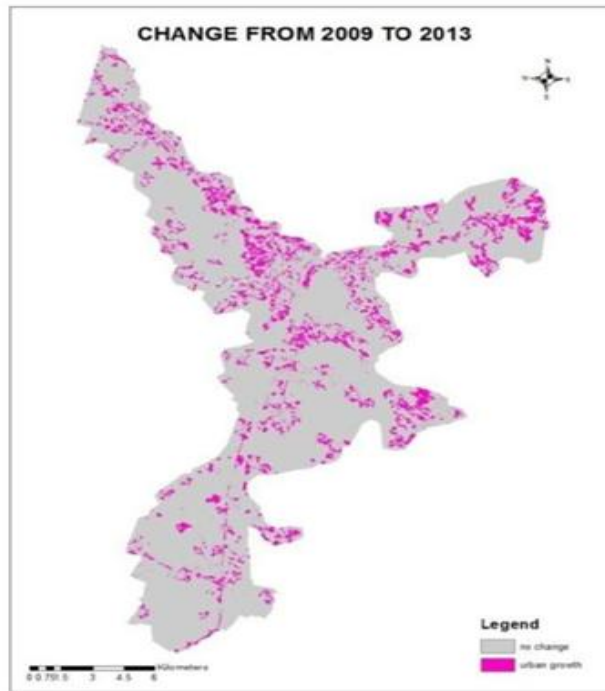


Fig 4: URBAN GROWTH MAP

The area estimate of the amount of growth in built-up from 2009 to 2013 is shown in table below–

Class name	Original area 2009	Original area in 2013	Growth area
Built-up	24.33km ²	56.28km ²	31.9 km ²

In the study, after the various literature reviews, and the ground truthing, major growth factors were identified in Roorkee planning area. The growth was more prominent along the major highways and the arterial roads connecting the cities and villages. The growth also depends upon the accessibility, proximity and physical nature of the land as it exists. Since the roads are majorly the centre of attraction for the growth of urban areas, hence, the vector data of the major roads and arterial roads of Roorkee city was generated (Fig 5).

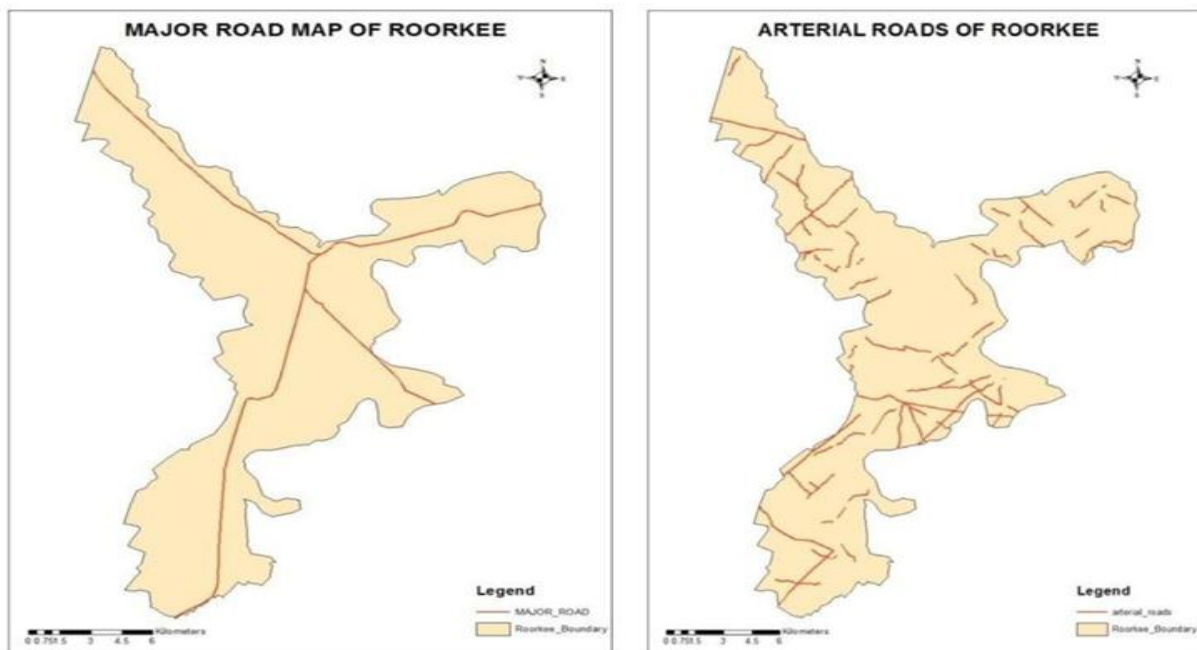
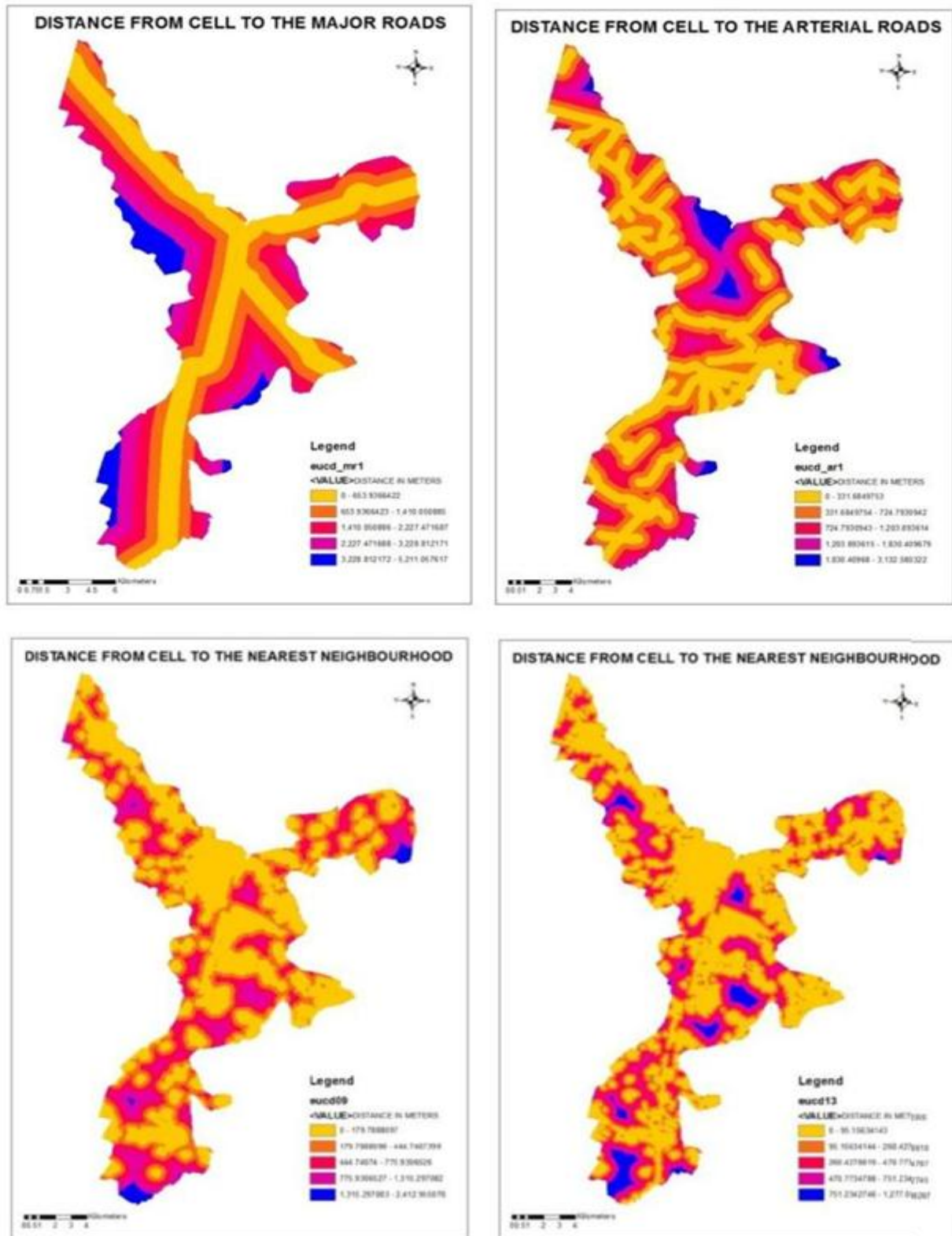


Fig 5: VECTOR LAYER MAP OF THE ROADS OF ROORKEE AREA

These vector layer maps are converted into raster maps of the driving factors. There are six variables identified that can possibly have bearing on the pattern of urban growth in Roorkee city: Distance from cell to the closest major road, Distance from cell to the closest arterial road, Distance from cell to the nearest neighbourhood built-up in 2009 map, Distance from cell to the nearest neighbourhood built-up in 2013 map, The amount of built-up in the neighbourhood from the cell in 2009 map, the amount of built-up in the neighbourhood from the cell in 2013 map (Fig 6).



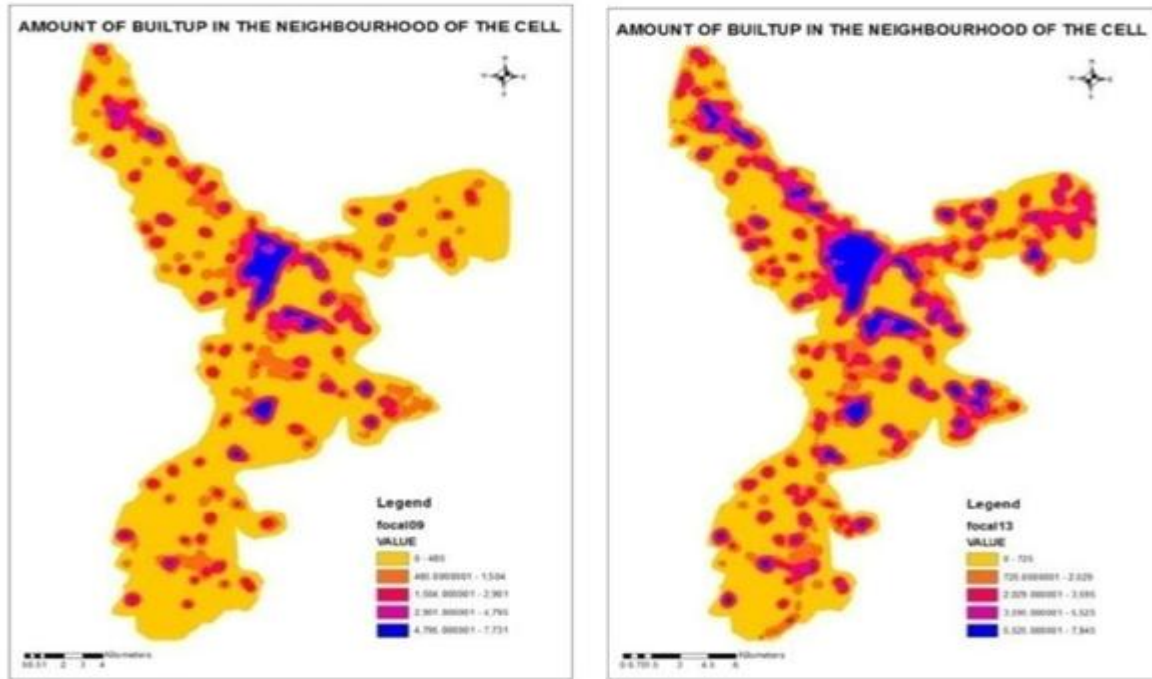


Fig 6: EUCLIDEAN DISTANCE MAPS OF THE CAUSATIVE FACTORS OF URBAN GROWTH IN ROORKEE AREA

The analysis of the Euclidean distance measurement of the major driving factors of urban growth shows that roads are the main factors of growth along which major urban growth occurs. Hence, an analysis of the growth maps is done using Shannon's entropy along the roads. In order to make the measurement of the sprawl for temporal dataset, the urban growth map was employed. Buffers along the: major roads and the arterial roads cover the whole Roorkee planning area. The major road was divided into four major parts (Fig 7):

1. The highway from Roorkee to Dehradun.(towards west)
2. The highway from Roorkee to Haridwar.(towards east)
3. The highway from Roorkee to Delhi.(towards south)
4. The highway from Roorkee towards Landhaura village.(towards south-east)

The ten zones of 300 m were created along each major road, similarly five zones of 300m were created along the minor roads and their Shannon's entropy and relative entropy computed by the equation already discussed. The growth cells along each zone are measured and the proportion of the growth with respect to the total growth is measured. The zone map along the roads can be shown in the following map:

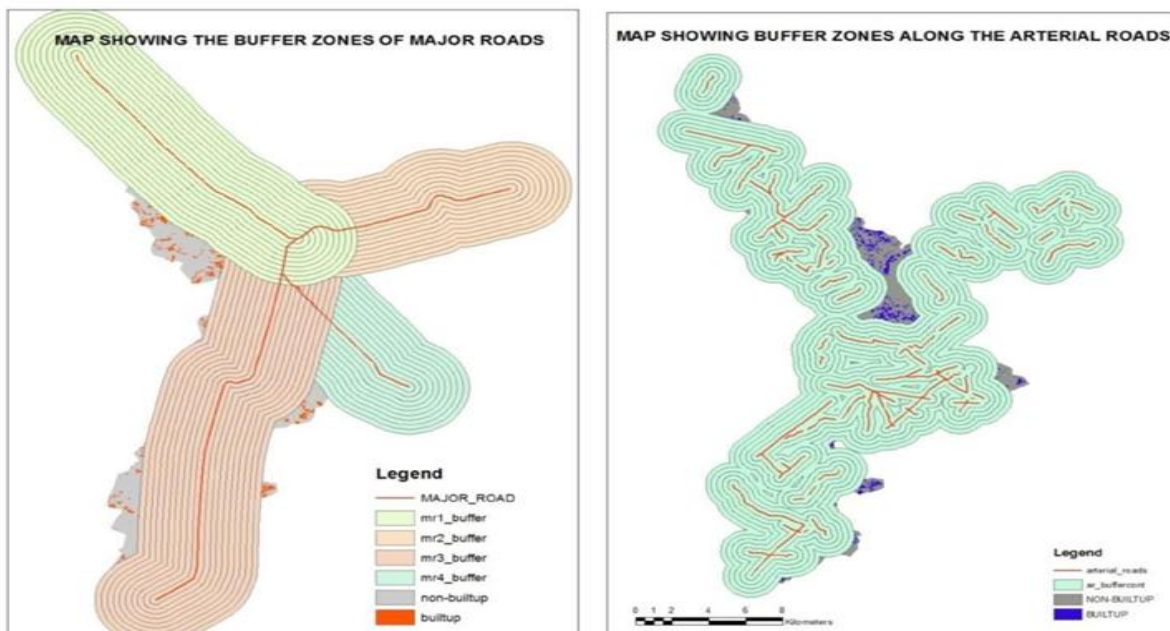
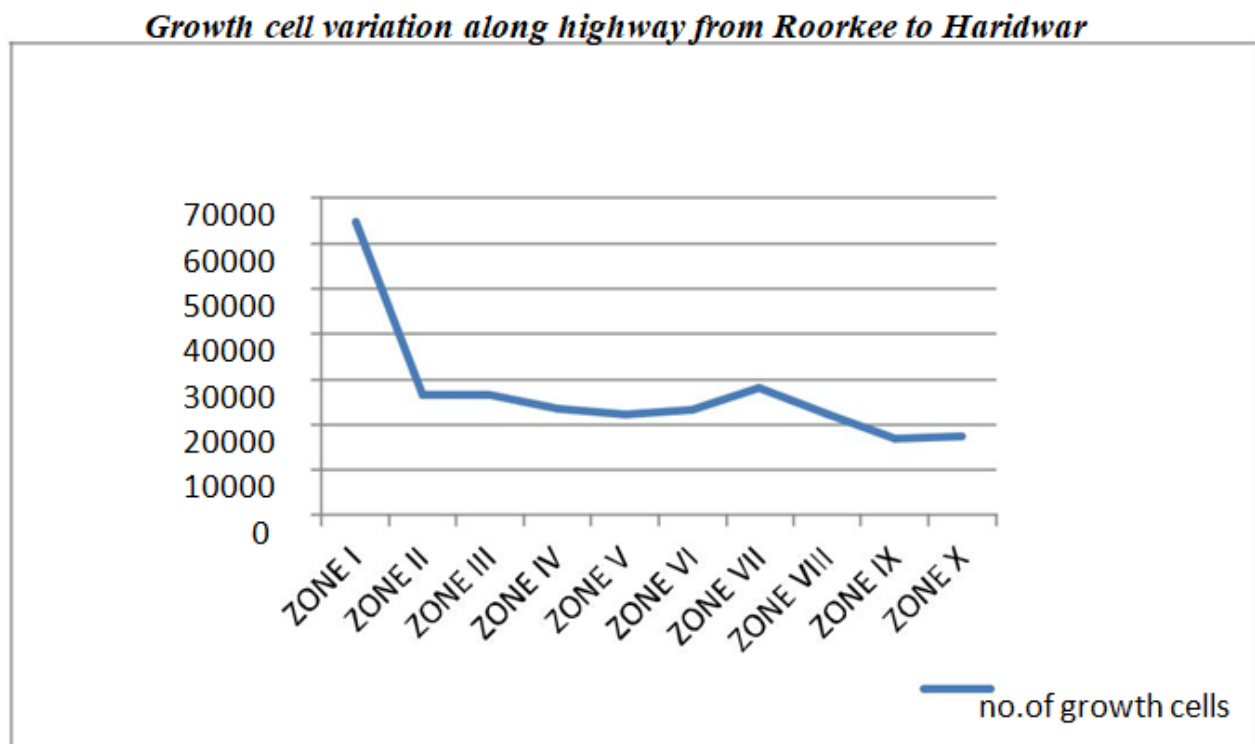
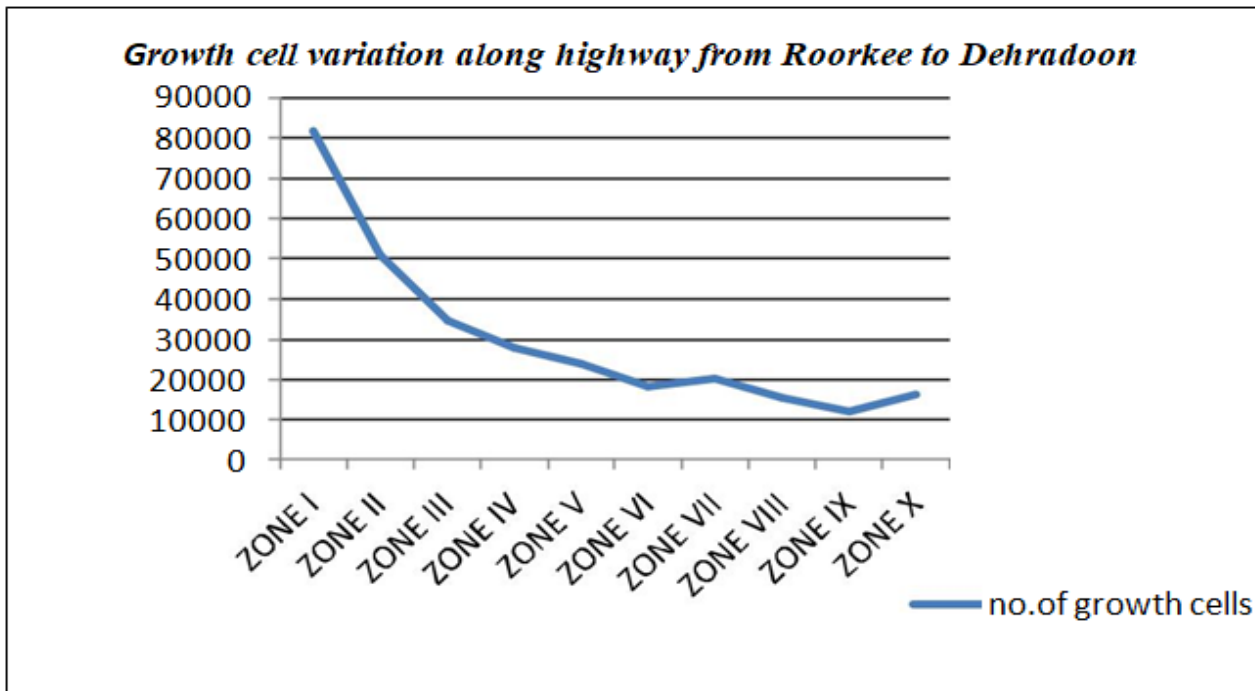


Fig7: MAP SHOWING THE BUFFER ZONES ALONG MAJOR AND MINOR ROADS

The buffer zones are so selected as to cover the whole Roorkee area. The growth cells in each zone can be computed in Arc GIS and can be shown graphically.



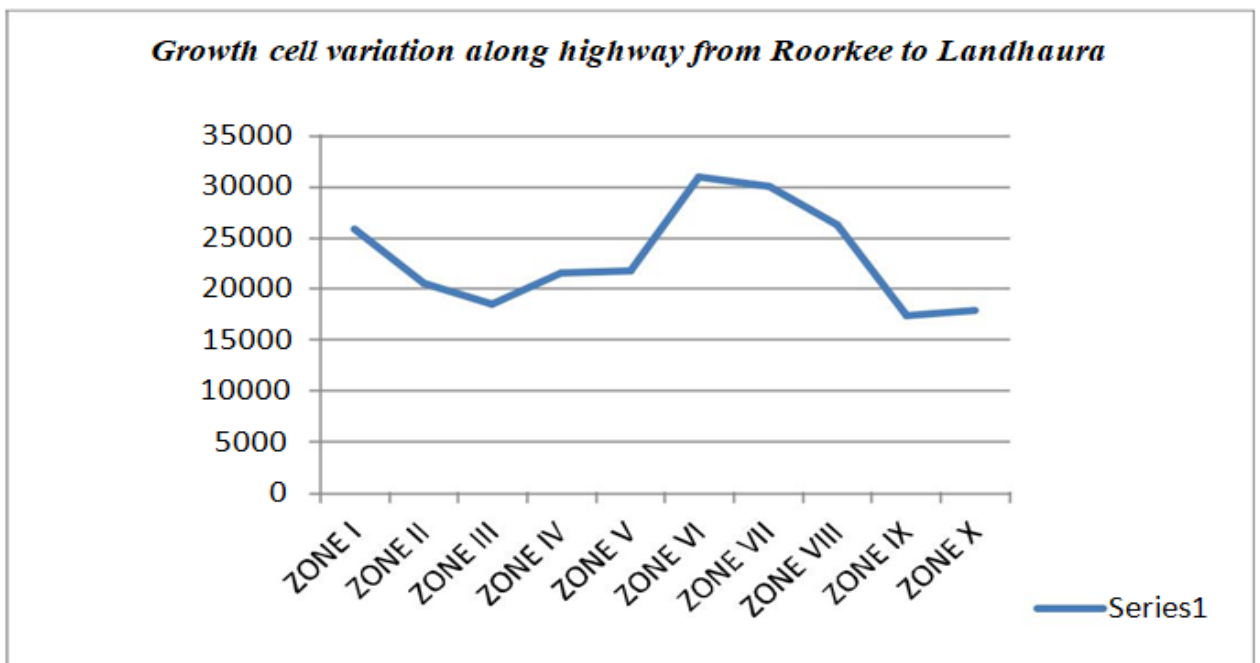
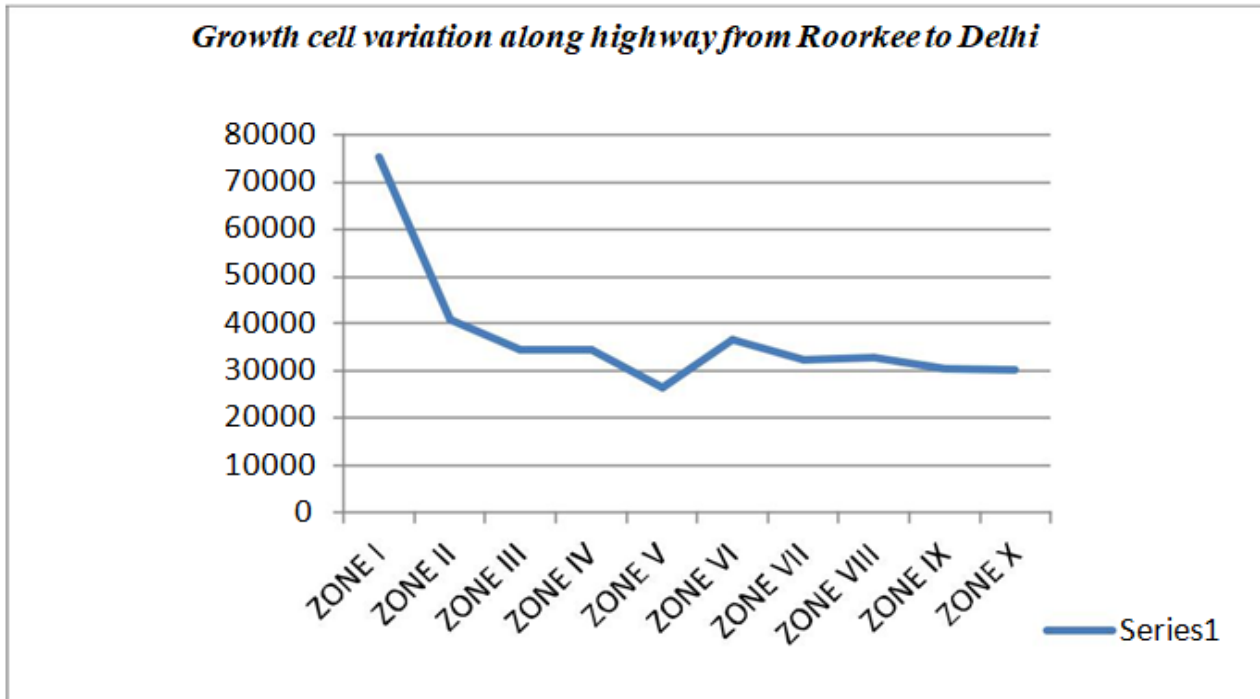


FIG 8: GRAPHS OF THE VARIATION OF GROWTH CELLS ALONG THE MAJOR ROADS

From the graphs (Fig 8) above, it is quiet clear that the growth decreases away from the road.

The Shannon’s entropy and relative entropy computations are done using the formula and the results for the major roads are:

Major road no./index	Shannon’s entropy	Relative entropy
1	0.917944	0.917944
2	0.960524	0.960524
3	0.977937	0.977937
4	0.991211	0.991211

The results show the values of both the entropies very close to 1 which represents that the urban growth is evenly dispersed across all the 10 zones. It shows that the driving factors of growth that were determined initially have been validated using the Shannon’s entropy concept and that the growth is uniform. This helps us in understanding that the growth of various schools, commercial centres, residential and non residential areas is not dependent only on the city centre but depend on the roads as the major source of accessibility. The growth is compact and distributed mostly in the inner zones and as the distance from the road increases the sprawl is seen to shrink. The highways and major roads seem to be the centre of attraction. The growth in these 4 years has been tremendous and can be seen as a very fast growing city. The developments seem to grow uniformly along the sprawl regions even in the near future. Similar computation is done for the Shannon’s entropy for the arterial roads, with five zones and each of 300 m. The zones have been shown in fig 7. The growth pattern along the roads can be graphically represented as follows:

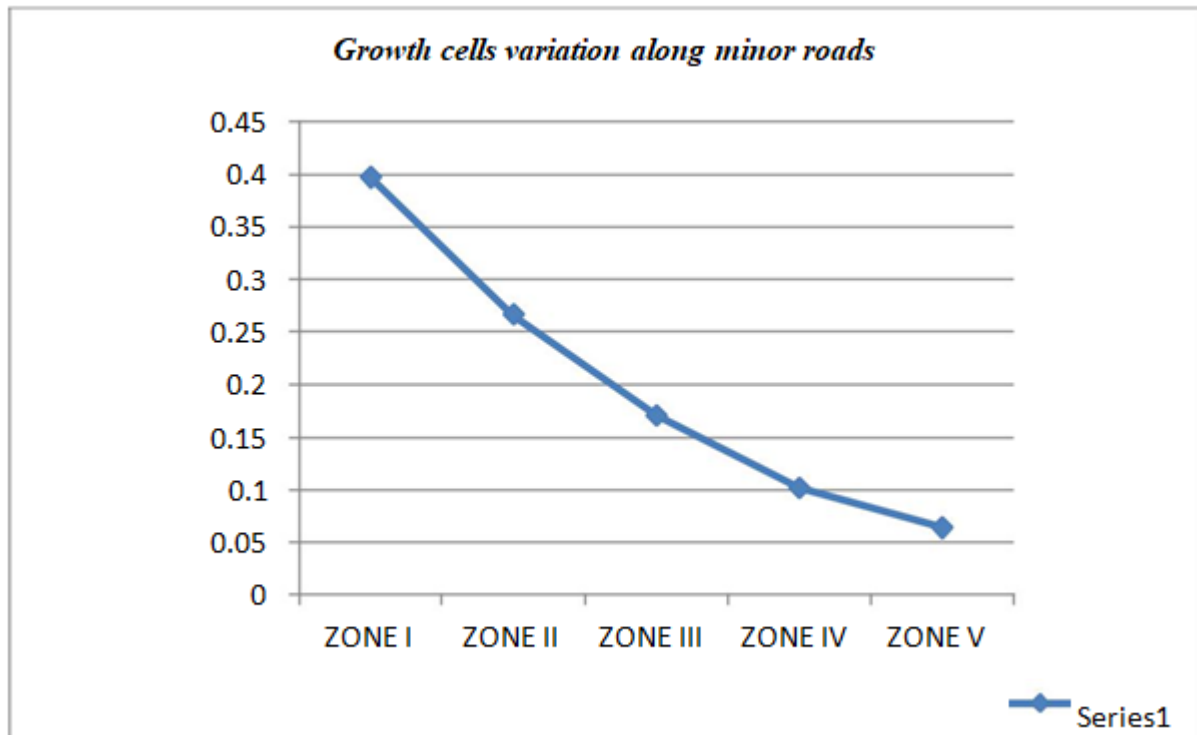


FIG 9: GRAPH OF THE VARIATION OF GROWTH CELLS ALONG THE MINOR ROADS

The urban growth shows a decreasing trend away from the roads. The computation of the Shannon’s entropy and relative entropy along these minor roads is done and the results obtained are:

ROAD/ INDEX	SHANNON’S ENTROPY	RELATIVE ENTROPY
ARTERIAL ROAD	0.620726	0.888057

The results above are similar to the trend the growth along major roads, hence it can be concluded that the urban growth is evenly dispersed across all the five zones as the value of the entropy is close to 1 and here also the development majorly takes place along the roads in a compact manner.

5. CONCLUSIONS

This study shows that the Roorkee city experiences a ribbon sprawl development along the major highways and roads in the city. The determination of the causative factors of growth with the Euclidean distance concept using Arc GIS shows the quantitative representation and determination of factors that are responsible for the growth. The important factor of growth in this study area is the highways and other roads inside the city. Shannon’s entropy further establishes that the growth is compact and evenly distributed along the roads and has a high tendency of developing along these zones only. Hence, it is important to manage the development in a sustainable manner as the growth is tremendous and sprawl patterns need to be dealt in a systematic way. This study also establishes that entropy gives a good measure of the type of pattern in a city which can be used by the analysts and developers for any future development planning. It can also be

used to control any uneven sprawl development that may cause haphazard development and loss of valuable lands. GIS and remote sensing along with the amalgamation of entropy proves to be a useful tool for the study of growth patterns and may be used for future planning in a smart way.

6. REFERENCES

1. Pedro Cabral, Gabriela Augusto, MussieTewelde and Yikalo Araya, Entropy in Urban Systems, 2013.
2. Priya Narayanan, Analysing the Urban sprawl through entropy of Gulbarga city and its spatial promoters of growth through Geoinformatics.
3. Jyotishman Deka, Om Prakash Tripathi, Mohamed Latif Khan, Urban growth trend analysis using Shannon's Entropy approach – A case study in North-East India
4. Uffink, J. Bluff your way in the second law of thermodynamics. Stud. Hist. Philos. Sci. Part B: Stud. Hist. Philos. Mod. Phys. 2001, 32, 305–394.
5. Wilson, A. Entropy in urban and regional modelling: Retrospect and prospect. Geogr. Anal. 2010, 42, 364–394.
6. Hoffhine Wilson, E.; Hurd, J.D.; Civco, D.L.; Prisløe, M.P.; Arnold, C. Development of a geospatial model to quantify, describe and map urban growth. Remote Sens. Environ. 2003, 86, 275–285.
7. Galster G., Hanson R., Wolman H., Coleman S., & Friehage j. (2001). Wrestling sprawl to ground: defining and measuring an elusive concept. Housing policy debate, 12(4), 36.
8. Joshi, P.K., Lele N., and Agarwal, S.P., (2006), Entropy as an indicator of fragmented landscape - Northeast India case study, Current Science, 91(3), pp 276-278.
9. Lata, K.M., Sankar, R.C.H., Krishna, P.V., Badrinath, K.V.S., and Raghavaswamy.,(2001), Measuring urban sprawl: a case study of Hyderabad, GIS Development, 5, pp 8–13.
10. Muthusamy.S, Rosario Arunkumar.X , Naveen Raj. T , Lakshumanan.C ,Jayaprakash.M , (2010), Land Use and Land Cover Changes Detection Using Multi temporal Satellite Data, Cuddalore Coastal Zone, Se-Coast of India, Journal of Geomatics and Geosciences, 1(3), 610-619.
11. Manonmani.I.K., (2010), Spatio-Temporal analysis of Landuse in fringe area using GIS – A case study of Madurai city, Tamilnadu, International Journal of Geomatics and Geosciences, 1(2), pp 264-270.