URBAN SPRAWL OF BHUBANESWAR CITY USING GIS APPLICATIONS AND ENTROPY

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Civil Engineering

By
Milan Naik

109CE0053

UNDER THE GUIDANCE OF

PROF RAMAKAR JHA

Department of Civil Engineering National Institute of Technology, Rourkela May, 2013

URBAN SPRAWL OF BHUBANESWAR CITY USING GIS APPLICATIONS AND ENTROPY

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Civil Engineering

By

Milan Naik
109CE0053

UNDER THE GUIDANCE OF

PROF RAMAKAR JHA

Department of Civil Engineering National Institute of Technology, Rourkela May, 2013

National Institute of Technology, Rourkela

CERTIFICATE

This is to certify that the project entitled, "Urban Sprawl of Bhubaneswar city Using GIS Applications" submitted by "Milan Naik" in partial fulfillments for the requirements for the award of Bachelor of Technology Degree in Civil Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the report has not been submitted to any other University/ Institute for the award of any Degree or Diploma.

Date: (Prof. Ramakar Jha)

ACKNOWLEDGEMENT

I express my gratitude and very thankful to Prof. Ramakar Jha for his guidance and constant encouragement and support during the course of my work. I truly appreciate the value and his esteemed guidance and encouragement from beginning to the end of the thesis, his company and knowledge at the time of crisis would be remembered lifelong.

My earnest thanks to Prof Nagendra Roy, Head of the Civil Engineering Department, National Institute of Technology, Rourkela for giving all kinds of support and help. I am also thankful to all the professors of Civil Engineering Department.

I express my special thanks to Mr. Ray Sing Meena and Mr. Janaki Ballav Swain of NIT Rourkela for extending help when I needed the most. I would also like to thank my friends, Kunal and Lopamudra Priyadarshini in particular, who have directly and indirectly helped me in the successful completion of my project work.

Lastly I want to thank my parents for constantly supporting and encouraging me at the time of failure and they are always at my back. They are my constant source of inspiration for these four years. These four years though being separated has brought me closer to them. I want to dedicate this piece of work of mine to my parents.

MILAN NAIK

(109CE0053)

Department of Civil Engineering,

National Institute of Technology, Rourkela

CONTENTS

List Of Figures

List Of Figures Page No.

ABSTRACT

Urbanization is the index of the transformation of the rural areas to the developed new industries. The aim of the study is to find out the land cover change caused due to different activities in Bhubaneswar City and its surroundings. For this purpose, 3 digital images are used for the years 2000, 2005 and 2011. These images are analyzed using the data processing techniques in ILWIS-GIS 3.3. The main trajectories of land use change are based on nine types of land use data derived from the remotely sensed images. The buffer analysis is done to interpret urban growth. It carried out in linear way along the railway line and from the center of the city. Entropy approach was also used to find the degree of randomness in the sprawl pattern. The process was used to calculate the mean relative and distributed entropy in the both buffer types. The compaction or the dispersal pattern of the urban sprawl was represented satisfactorily. According to the results, a decrease of 66.6% in agricultural areas; an increase of 310% in the residential areas has been found. The growth of urban has been more prone in the left side of the railway line. This could be attributed to the rapid urbanization and better education facilities. Entropy approach shows that the urban development of Bhubaneswar city is going on unplanned manner and it is random in nature. The study is potentially useful for administrators and planner in Bhubaneswar and as case study, of value and interest to a broader community.

Chapter I

Introduction

INTRODUCTION

The world is going through the largest speed of urban growth today. During the course of 2008, more than half of the world's population was dwelling in towns. In 2012 this number has crossed the 7 billion mark. Almost most of this population will be concentrated in Africa and Asia. The megacities were the cynosure for the high growth potential. Up to the mid time of twentieth century, land use change has resulted into a big issue around the whole world (Lambin, 2001). With the growth of our economics and social upliftment, the extensity and intensity of land cover change tended to be severer. The prediction and simulation of urbanization is very important among the studies of land use. Modeling is essential for analyzing, especially for the prediction of the dynamics of the urban growth (Clarke & Silva, 2002). Some failures occurs for modelling the use of land but later on there was rebirth in the two-three decades due to better availability of data. High computing ability also gives impetus for modelling use. Numerous models emerged in this time; these models included cellular automata type, simulation type or some part of it related to agent based type. Cellular automata are extremely capable to predict land use change (Dietzel & Clarke, 2006). During the course of time, some models were developed to forecast the future land use condition to evaluate and assess different land use policies.

Remote sensing and GIS are furnishing new tools for advanced management of ecosystem. The remotely sensed data facilitates the critical synopsis of earth's function patterning and their changes throughout locally, regionally and globally (Mishra and Subudhi, 2006). The marvelous growth in geographical information science has provided us the availability of different types of land use models. They differ in terms of data collection, spatial modelling. The data can provide a crucial connection between ecological, national and regional conservation and management diversity (Willkie and Finn, 1996). GIS technology is integral part of the all the land use models. The spatial and temporal process can be easily handled by the capability of the GIS technology. The remote sensed images give a lot of data which can be beneficial for the development of special resolution in remote sensing for a time series.

Existing land use models rage from rule-based programs that provide information and guidance on the process of allocating growth to different sub areas, to sophisticated models that incorporate economic theories and market mechanisms. The models employ a wide range of approaches, such as spatial interaction, spatial input-output, and rule-based (Waddell 2004).

Spatial interaction, spatial input-output, and linear programming models were used in the early operational models of the 1960's and 1970's. Micro simulation was not into practice until 1980's although it was developed during the 1960's (wargon, 2010). The 1980's saw discrete choice models and cellular automata becoming the newest modeling approaches. In the 1990's, several land use models implemented a rule-based set of procedures to apportion population, employment and land use on the GIS (Geographic Information System) platform.

Shannon (1948) did the conception of entropy. The second law of thermodynamics states that thermodynamic degradation is unalterable over time, e.g., a burnt log cannot be un-burnt and lukewarm water cannot be separated distinctly into hot water and cold water (Jha and Singh, 2008). The disorder, disorganization or randomness of organization of a system is known as its entropy (Miller, 1969). The entropy value can be taken as the measurement of uncertainty. A random variable's entropy is specified in terms of its probability distribution and is a good measure of randomness or uncertainty (Aggarwal and Rahman, 2011). Urbanization has become one of the main factors of land degradation, mainly due to the quality of the agricultural lands that have been urbanized (Santibanez & Royo, 2002). Urban growth without proper planning has resulted in serious problems in environment. This leads to inadequate infrastructure facilities, water scarcity and traffic congestion. Recent land use changes will be helpful to alternate infrastructure and services such as proper zoning conveyance, medical facilities, and designing of schools. Further land use studies can be corroborated to geology, mapping of soils, and other hydrologic features. The purpose of this study is to analyze land use change in the Bhubaneswar City area and to find its urban sprawl direction. The intent is to assess the land use change and to use the entropy approach to find the degree of randomness.

Software Used

ILWIS is a PC based GIS & Remote sensing Package. It has been developed by ITC. It can be effective tool for spatial analysis, image processing and digital mapping. It can take data as input and by through process management it does the digital processing and three dimensional interpretations. The data analysis mainly caters to the raster analysis. It can be used by easily by both from the specialists and novices. The spatial and temporal patterns can be produced from the input data.

Chapter II

Literature Review

Literature Review

Now days, there have been a lot of interest in land use change and urban sprawl in the researchers. As is testified by the voluminous literature, containing urban growth has become a world focus in planning, although reservations about the necessity for rural preservation are expressed by some commentators (Evans, 1991) on socio-political grounds. In most countries spatial control strategies aimed at curbing city growth have pragmatically been replaced by strategies to manage growth, since growth is inevitable anyway (Urban Foundation 1993, p. 4).Mapping urban sprawl helps to identify areas where environmental and natural resources are critically threatened and to suggest likely future directions and patterns of sprawling growth(Simmons, 2007). Numerous researchers have addressed the problem of accurately monitoring land-cover and land-use change in a wide variety of environments (Muchoney and Haack, 1994; Singh, 1989; Shalaby and Tateishi, 2007). Different types of models are used to predict the urban sprawl in periods of time. Brett Hazen (1996) used a model called LUCAS to asses land use change in Little Tennesse River Basin of western North Carolina. Robert Johnston (2000) used another model called UPLAN to help in future urban scenario of the city Espanola in New Mexico. While John Landis (2001) came across with a model called Curba which incorporated bio diversity factor in urban development pattern. Patterson (2008) projected urban sprawl by using URBANSIM model in Brussels.

Some Researchers used different GIS software and algorithms to assess the land cover changes. Merwe (1997) used IDRISI GIS package to calculate development for land use types with an emphasis on their measured and weighted criteria. H P Samant (1998) took multi date data of topographical maps and Landsat TM data to find the land Use change in Navi Mumbai. Silva et. Al predicted urban growth in European cities using Sleuth model. Carlson (2002) used Sleuth model coupled with Landsat Tm imagery to predict future changes in surface runoff resulting from the urbanization. Liu (2003) et. al used cellular automata algorithm with conjunction with fuzzy set technique to model urban development and found realistic and viable scenarios. Liu (2005) et. al used the integration of remote sensing, geographical systems and multivariate mathematical models to predict urban growth. Hu and lo (2006) applied the logistic regression for modeling urban growth in Atlanta for better understanding the factors affecting it. Andrew Manu et. al used remote sensing technologies to study the urban growth of three major

Sahelian cities. Their objective was also to correlate the urban expansion with long term population growth and add to any existing remote sensing database for future planning of these cities. Rienzo (2009) used a 3D geological and geotechnical model to predict urban developments in Italy. Zhang (2011) et. al combined markov chain analysis and cellular automata to understand the sprawl intensity of Shanghai. Yang and Lo used the SLEUTH model to predict urban sprawl in Atlanta Metropolitan Area.

Jansen et. al provided a spatially explicit land-cover/use change dynamics in the period 1991–2001 using the UNEP Land Cover Classification System for classes with object-oriented geo-database approach to handle changes in the evolution of land-cover objects, i.e. polygons, with time to withstand change dynamics analysis. Haack and Rafter (2006) used KVGIS layer to find the urban growth in Kathmandu. Much of this growth has occurred without effective planning causing serious problems including environmental pollution, using unemployment, inadequate infrastructure facilities and conflicting land use demands. But recent land use change information is useful for provision of various infrastructures and services such as transportation, utilities, medical facilities and schools. Henriquez and Azocar (2006) found the land cover change in Chillan and Los Angeles through the digital interpretation of aerial photographs from different time sets. Their study explored the main driving forces that explain the growth of these mid-sized cities using model for land use and the spatial analyses as predictive tools. Jha and Singh (2008) used entropy approach for analysis of urban development in Haridwar which is an important city along the banks of River Ganga, to develop future plan for urbanization promotion areas and urbanization control areas. Rahmann and Aggarwal used the Shannon’s entropy to model the urban expansion of Hyderabad city, India. They found remarkable sprawl or urbanization in the city. Mohajeri developed urban street patterns behavior using the entropy and found good correlation among them. Remote sensing, GIS and entropy approaches were integrated to fulfill the objectives of the present work. Taubenbock applied multi temporal remote sensing and time series of Landsat data for monitoring and understanding of urban sprawl process in India. Ibrahim and Sarvestani (2009) used different satellite images between 1976-2005 and population census of Shiraz city in Iran to show urban sprawl pattern. Four main land use types such as constructed areas ,water, vegetation and bare land areas were classified from satellite images of Shiraz city. From their work it is urged that the succeeding planning will be more focused on protection of available vegetation and compensation of destroyed coverage.

Peijun et. al used multi temporal Landsat TM images and further improved the accuracy using post processing approach.

Belal and Moghanm (2011) found the urban sprawl in two major districts in the Egypt. Landsat images like Multispectral Scanner (MSS) in the 1972 and Enhanced Thematic Mapped (ETM) in the 2005 were used to assess the changes of urban encroachment, agricultural lands and water areas during this period with integration by GIS. The main objective of their study was to interpret sprawling of urbanization and its impact on agricultural land using integrating remote sensing and GIS. Rahman and Aggarwal (2011) used the Shannon's entropy model to find urban sprawl using IRS P-6 data (Rahman, 2011) and topographic sheet in GIS environment for Hyderabad and its Surrounding Area. This study is quite relevant in the sense that with the fast city expansion the urban ecosystem is changing and it has a negative impact on the flora and fauna as well as on human health in this region. Jing and Jianzhoung (2011) used multi-temporal TM/ETM+ images to predict the urban expansion in Lianyungang City between 1987 to 2009. The analysis to the model of urban expansion indicated that the urban expansion was obviously bicentric, and takes traffic roads as development axis.

Chapter III

The Study Area

THE STUDY AREA

3.1 The CITY

Bhubaneswar city is located in the Khurda District of Odisha. It is the capital of Odisha and also known as the temple city for its numerous temples. The study area has an area of 270 Sq.Km. It is situated on the Howrah -Chennai main south Eastern Railway line at 435km from Howrah and 1215km from Chennai and the NH.5 connecting Chennai and Kolkata goes across urban center. The city is in the west part of the “Mahanadi Delta” on the bank of the river Kuakhai and the South west of Cuttack city. The river Daya which has cut off from Kuakhai moves along the south eastern part of the city. After the independence, Bhubaneswar region has gone through a lot of expansion and growth. Administrative and institutional activities have contributed to the increase in the volume of trade and commerce activity. The city lies in between 21° 15' north latitude 85° 15’ longitudes. The average temperature in winter is 12 degree Celsius and the maximum temperature is 43 degree Celsius (Figures 1 and 2). The south-west monsoon appears in June. Bhubaneswar has the good climate. The city has three different seasons. They are summer (from March to June), Monsoon (July to October) and winter (From November to February). According to Kopppen classification the city comes under savanna (ISDR Report, 2002). The average annual rainfall of the city is 1498 mm (Bhubaneswar main report). The mean annual temperature of bbsr lies between 27^0C to 41^0C. The climate remains humid for the month of June to month of October. The population of Bhubaneswar has been increased from 16,512 in 1951 to 881,988 in 2011 (census of India, 2011). A proper look at its demographic and socio-cultural activities reveals that this state is one of the least urbanized among the major states of India (13.5 % of the state population resides in urban areas). 69 percent of the state population is involved in agribusiness. Nevertheless, the state has the third lowest population growth rate in the country. The literacy rate is marginally lower than the national mark. Modern Bhubaneswar is a well-planned city with wide roads and many parks and gardens. The framework was made by Otto H. Koenigsberger. Though part of the city has remained as planned, it has developed speedily over the decades and has made the planning process clumsy.

3.2 Ground Level Data

Ground water level of data of Bhubaneswar is compiled from year 2006-2010. The data are shown in Table 1.

Table 1: Ground water level (in m) during 2006-2010

major areas	2006 water level	2010 water level	Change
Unit-Viii	7.12	8.25	1.13
unit-ix	6.9	7.2	0.3
unit-iv	4.58	5.25	0.67
nayapalli	7.28	8.1	0.82
Tankapani Road	3.75	5.5	1.75
OUAT	2.65	3.5	0.85
BJB Nagar	3.15	4.6	1.45
Niladri Bihar	2.88	3.45	0.57
Jharpada	4.51	5.2	0.69

Source: Telegraph India, Central ground Water Board of India

3.3 Demographic Summary

Initially during 1948, the city is designed for the 40000 people .But later on the it undergoes high growth due to effect of the small industries and manufacturing industries. Availability of education and better health care facilities also propel more force for urbanization in the city. During 1961-71, it has the highest growth rate of 176.07% in the country. But after that the growth rate has taken the downward tendency. As per census of India 2011, the city has urban population of 881788 which has male 468,302and female 413,686 respectively. The literacy count of the city is 93.15 percent .The future urban population in 2021, 2031 and 2041 are projected as 920328, 1067525 and 1214722 respectively.

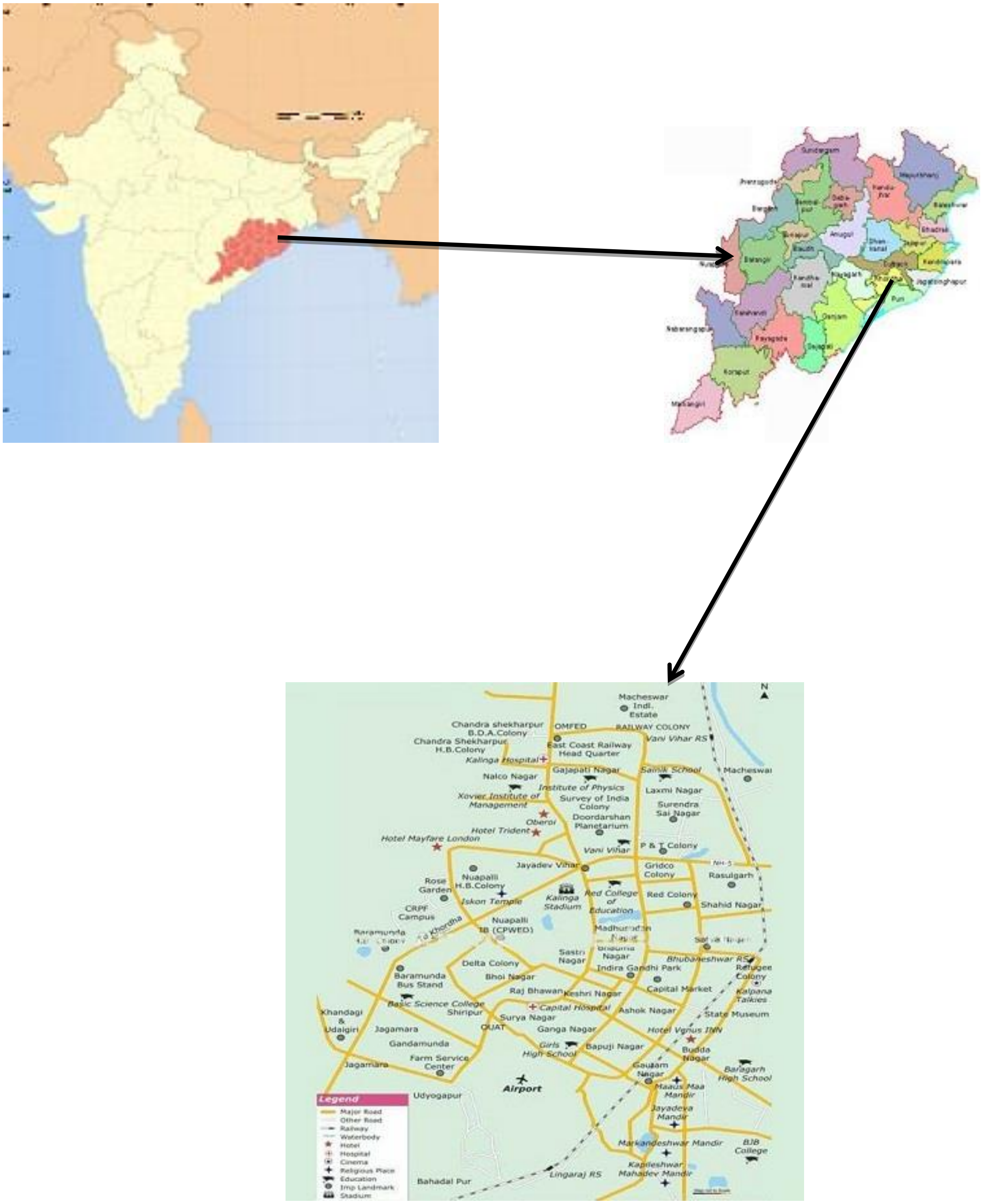

Figure 1: Map of Bhubaneswar

Source: http://www.mapsofindia.com/maps/orissa/bhubaneshwar.htm

Figure 2: Aerial Map of Bhubaneswar (Source: Google Earth)

Chapter IV

Methodology

Methodology

4.1 Creation of Segment Map

At first base map is selected for the three year data. The three year used in this study are 2000, 2005 and 2011.Using the ILWIS-GIS software segment map is created. ILWIS-GIS Academic 3.3 Version is used for this purpose. Segment Map is an object which stores mainly data (all the data sets). The data are comprised of the spatial geographic information which consists of roads, contour related lines. The segment has to be codified by different means. That includes by IDs, class names or height parameters. The segments in a segment map and the earth relative position of the object in that scenario will be represented by a coordinate system. The coordinate system will correspond to the map the system is analyzing for that purpose. Segment has different features .It can be edited by the segment editor and can be effectively displayed in map windows. To create a segment map, at first the map is imported in the ILWIS. The Geo-referencing of the map is done. Geo-referencing can be done by various methods. In this work, Geo-referencing is done by coordinate system. After this process, segment map can be created.

4.2 Creation of Polygon Map

Polygon Maps are used to spatial geographic information that mainly consists of polygons. It also incorporates closed areas which can be source of area. The polygon has to be codified by different means. That includes by IDs, class names. The polygons in a polygon map and the earth relative position of the object in that scenario will be represented by a coordinate system. The coordinate system will correspond to the map the system is analyzing for that purpose. Polygon has different features. It can be edited by the Polygon editor and can be effectively displayed in map windows. They are main used a foundation stone to raster maps. Initially segment maps to be created before we create polygon maps. The point map is created in which polygon maps are digitized using names or IDs as the label points. Different checks are too carried out. The check includes self-overlap, intersections and dead ends. After that it has been digitized to a polygon map. Ten types of land classification have been used. This classification is assigned to the respective type in the polygon maps.

4.3 Raster Maps

Raster maps are normally plain paper type map. All the information's in the map are only available all together. In other words, a raster map is a picture of something. It can be in .bmp or .jpeg format. But vector maps have other types of functionality and diversity. They are available in certain groups (streets, house, and landscape). An advantage of raster maps in opposite to vector maps is, that they are usually a lot "prettier" and contain more information (Source: maptrails.com).

4.4 Georeference

A georeference is a relation between coordinate axes and the columns, rows in a raster map. The pixels' location can be defined by a suitable georeference. Same georefenceing relates to raster maps of same area. Georeferencing can be via corners, tie points, direct linear, orthophoto, 3D.

4.5 Coordinate System

A coordinate system has the data about the coordinates we are using in the maps. The possible coordinates can be defined by either XY or Latlon techniques. Segment, polygon and point map always have a coordinate system. A map which has a georeference always uses a coordinate system. The coordinate systems can be of five types. So it may be via boundary only, projection, Latlon, formula, tie points.

4.6 Domain

A domain stores the information which can be in form of map or a column. A domain has basically a set of colors, IDs or values. The use of domains is very important in a land use maps. A table generally needs a domain when the records in the table contain information on units in a map. There are four types of domains in ILWIS-GIS. They are ID, class, value and Image.

4.7 Land Use Types

In this study, a detailed analysis of the land use types is done. These are done using maps of high resolution. The classification has been successfully applied to the polygon maps of Bhubaneswar. The different types are

1. Agricultural
2. Commercial
3. Industrial
4. Others
5. Public Utility
6. Residential
7. Transport
8. Vacant land
9. Waste Land
10. Water

Agricultural: Agricultural areas mainly comprises of land used for the growing of food and other fiber type items. It also includes trees and other woods. It may also incorporate plantation, gardens.

Commercial: Commercial areas are the land which is used for marketing and business purpose. Different types of trade Centre, marketing complexes and different commercial activities. They have mutual relationships between themselves.

Industrial: Industrial areas are land which has been used for plants. The plants will include from small to heavy industries.

Others: Others include the land which has been restricted for public purpose, Brick furnaces, land where the crops are not planted

Public Utility: This classification includes land used for construction of the public buildings which has both government and private offices. Educational Institutions are also part of this category. It also includes recreational areas such as public parks and gardens.

Residential: These are the built up areas which is mainly used for the dwelling purpose. According to the needs of the families, there are different types of buildings. The residential has both parts which are residential urban and residential rural.

Transport: The area used is for the commutation purpose. Bus station, railway station, roads are part of this category. The roads are also different types.

Vacant land: These are the land which are not occupied and not used for any other purpose.

Waste land: The Land which has potential for developing vegetative cover and is not used for due to some constraints.

Water: The land which has the water bodies which it has tanks, small streams, ponds and rivers.

Data Exportation and Buffer Analysis

From the polygon maps created for the base maps, areas are calculated with the help of the histogram operation in ILWIS-GIS 3.3. Three types of land use are taken with due importance which are the agricultural, water and residential areas. After the completion of areas calculation, buffer analysis is done. Buffer zone is taken in two ways.

- Firstly, Growth pattern along the railway line of Bhubaneswar is taken. From the railway, buffer zone of 1 km is taken on both sides. The areas on each buffer zone are calculated. 6 buffer areas on each side have been taken. The areas are A1, A2, A3, A4, A5 and A6.

- Secondly, a center point is chosen at Acharya Vihar area. From that circle of multiple of 1 km is taken into account. So in this case growth pattern in a circular pattern is analyzed. 5 types of land use classification are taken into account for this. The land use classes are

a) Agricultural

b) Residential_Urban

c) Commercial

d) Barren Land

e) Industrial

4.8 Entropy Approach

Initially Shannon (1948) has developed the concept of entropy and proposed a theory regarding that. He used a mathematical equation related to the thermodynamics. As we can know that entropy is the second law of thermodynamics. It represents degree of randomness. Numerous applications of entropy in environmental and water resources have been shown by Singh (2000).

The disorder, disorganization or randomness of an organization of a system is known as its entropy (Miller, 1969). Entropy is degree of randomness and disorganization. When a system changes from a lower to a higher state, the entropy also changes accordingly. This can be measured by a set of probabilities. As an alternative to conventional nearest neighbor technique Medvedkov (1966) has related this notion to the problem of settlement pattern analysis. In information theory, entropy has been a part for measurement of noise and as a measure of disorder in spatial distributions. Medvedkov (1966) suggests that a settlement pattern is a composite of two superimposed sub-patterns, one random and the other uniform. Every sub patterns has its own type of points which represent density. For uniform pattern, entropy will be zero. Entropy is an effective tool to measure the randomness as it has been not affected by other parameters like size, shape of the entity.

4.8.1 Mathematical Formulae

Here the urban area has been divided into n zones and m represents the variable in a particular zone. The degree of spatial concentration can be measured by Shannon's Entropy E (Thiel, 1967; Thomas, 1981). The formula is

$$E=\sum P_i \log(1/p_i) \qquad (1)$$

Where $P_i = m_i/\sum m_i$ is the probability of occurring of the variable in the i^{th} zone, m_i is the observed value of the variable in the i^{th} zone, and n is the number of zones. The value of entropy ranges from o to log (n). Lowest value of the entropy will be zero and maximum will corresponds to log (n). We can also calculate the relative entropy. The relative entropy E_r is (Thomas, 1981):

$$Er = \sum P_i \log(1/p_i)/\log(n) \qquad (2)$$

If the probability is concentrated in one region, then the Equation (2) would give the lowest value of zero. Otherwise, it would give a maximum value of 1 for an evenly distribution. Eq. (2) is used for the analysis here. Entropy can be used to measure the distribution of a geographical variable and the difference in entropy between time (t+1) and (t) can be used to indicate the change in the degree of dispersal of land development or urban sprawl (Thomas, 1981). It can be written as:

$$\Delta E = E(t+1) - E(t) \qquad (3)$$

In which ΔE is the change in the entropy between time (t+1) and (t). Change of entropy will clearly depict the land development pattern which can be a scattered or concentrated type. Eq. (2) has been used to calculate entropy in 2000, 2005 and 2011 years.

Chapter V

Results and Discussion

Results and Discussion

5.1 Land Use Areas

Segment map and polygon map for three years (2000, 2005 and 2011) are created with the help of ILWIS-GIS. They are shown in the Fig. 3 and 4.

Segment Map of 2000

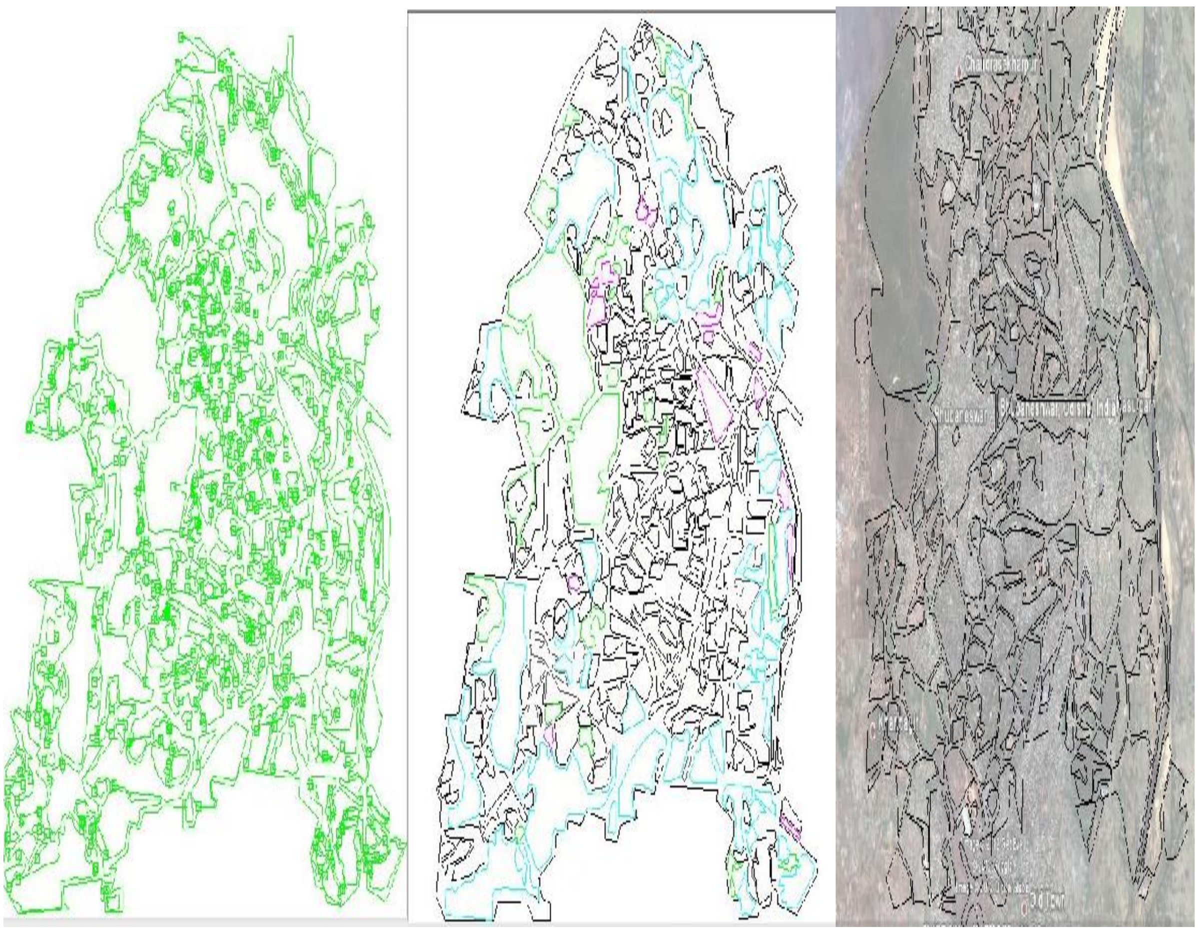

Figure 3: Segment Map for year 2000, 2005 and 2011

Polygon Map of 2000

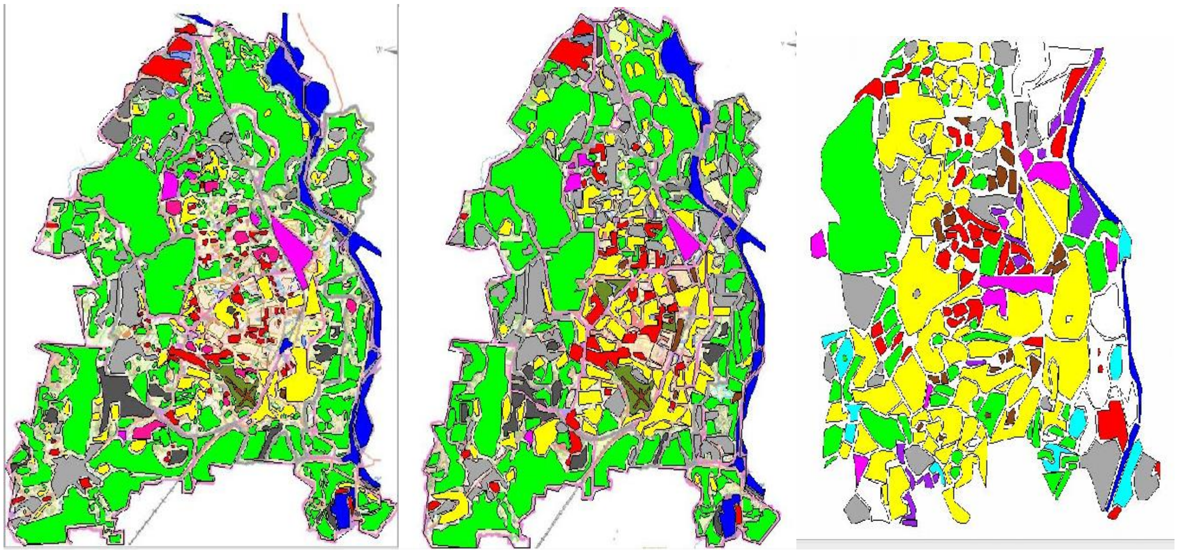

Figure 4: Polygon Map for year 2000, 2005 and 2011

For the year 2000, 2005 and 2011 the land use areas are calculated from the respective polygon maps and put into the table in 2, 3, and 4. Further percentage of land use variable is tabulated.

Table 2: Different areas of Year 2000

Land Type	Area in 2000(in hectare)	% of total
Agricultural	16266.98	60.25
Commercial	81.3	0.3
Industrial	652.23	2.42
Other	578.57	2.14
Public Utility	1361.66	5.04
Residential	2557.06	9.47
Transport	274.54	1.02
Vacant land	2257.9	8.36
Waste Land	1006.16	3.73
Water	1963.6	7.27
Total	27000	100

Area of land use in 2000 is shown below in Fig. 5. As we can see that agricultural areas contributed the highest areas during this period. Vacant land and residential areas contribute the same areas.

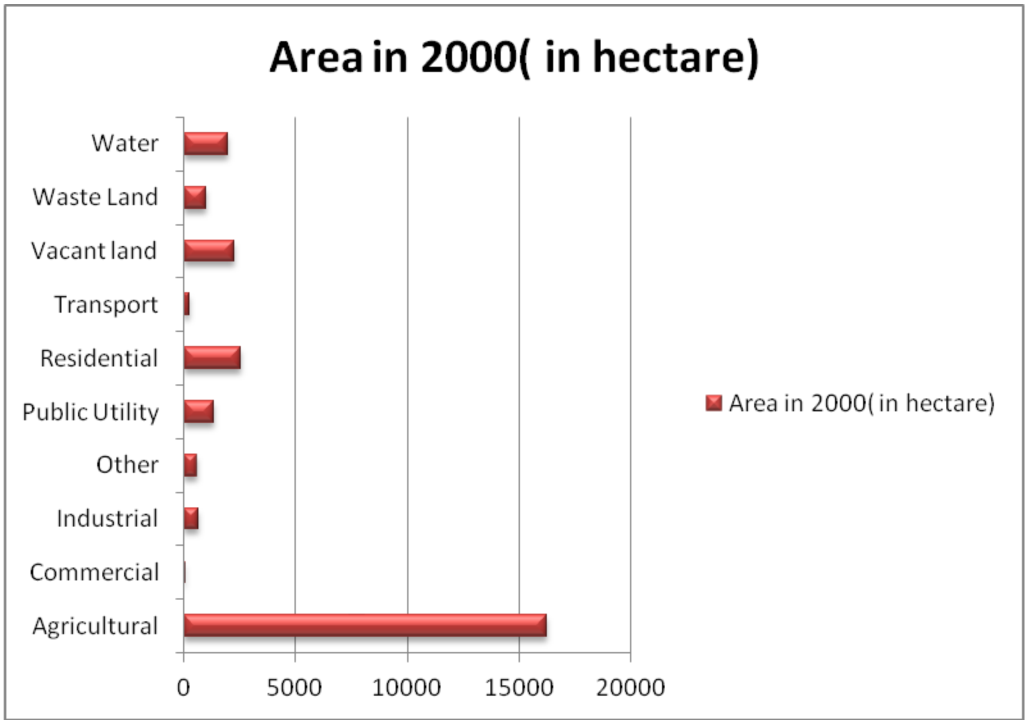

Figure 5: Variation of land use areas for year 2000

Table 3: Different areas of Year 2005

Land Type	Area in 2005(in hectare)	% of total
Agricultural	11812.38	43.75
Commercial	207.1	0.77
Industrial	345.7	1.28
Other	2942.5	10.9
Public Utility	1538.45	5.7
Residential	4292.57	15.9
Transport	427.84	1.58
Vacant land	3443.43	12.75
Waste Land	775.43	2.87
Water	1214.6	4.5
Total	27000	100

During year 2005, the trend changes in the land use areas. Agricultural areas have a downward trend while there is increase in residential and public utilities. The variation has been shown in Fig. 6.

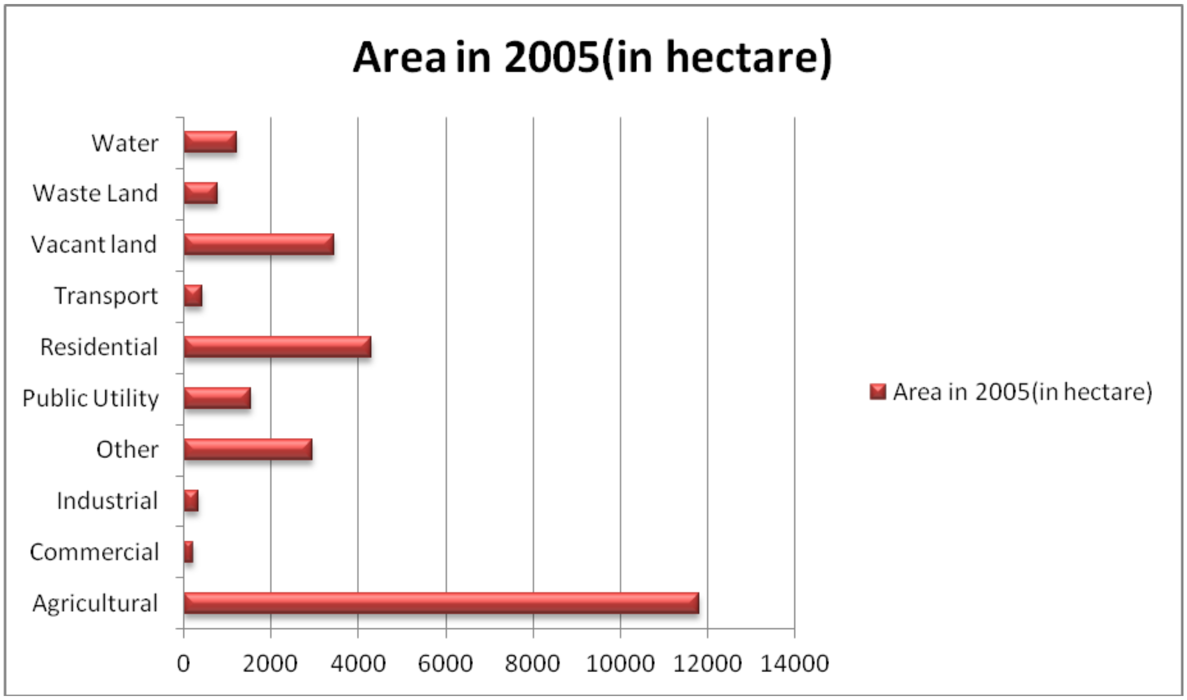

Figure 6: Variation of land use areas for year 2005

Table 4: Different areas of Year 2011

Land Type	Area in 2011 (in hectare)	% of total
Agricultural	5458.4	20.22
Commercial	585.15	2.17
Industrial	1024.52	3.79
Other	1922.44	7.12
Public Utility	2298.07	8.51
Residential	10729.98	39.74
Transport	785.5	2.91
Vacant land	2748.2	10.18
Waste Land	955.54	3.54
Water	492.2	1.82
Total	27000	100

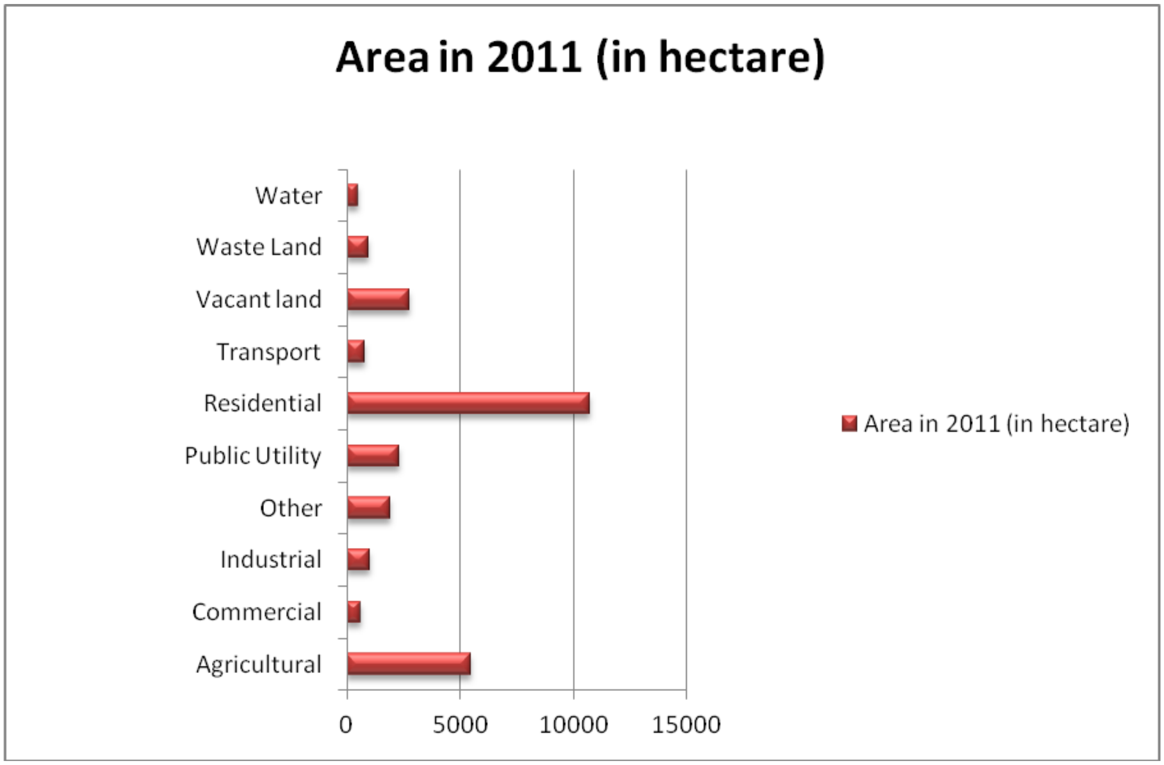

Figure 7: Variation of land use areas for year 2011

5.1.1 Comparison Of different Years

Further land use change has been calculated from 2000 to 2005 and also from 2005 to 2011.There is negative increase in the agricultural areas while the residential areas bear the testimony of high growth. The change percent is shown in Table 5.

Table 5: Change percent of land use in 3 years

Land Type	From 2000 to 2005 (% change)	From 2005 to 2011(% change)
Agricultural	-27.38	-53.79
Commercial	154.74	182.54
Industrial	-47	196.36
Other	408.58	-34.67
Public Utility	12.98	49.38
Residential	67.87	149.97
Transport	55.84	83.6
Vacant land	52.51	-20.19
Waste Land	-22.93	23.23
Water	-38.14	-59.48

Land usage of different land types are compared and represented in the bar graph in Fig. 8. From the graph it has been clear that residential, public utility has the upward growth while agricultural, water has downward movement. In 2011, residential areas have outnumbered the agricultural areas.

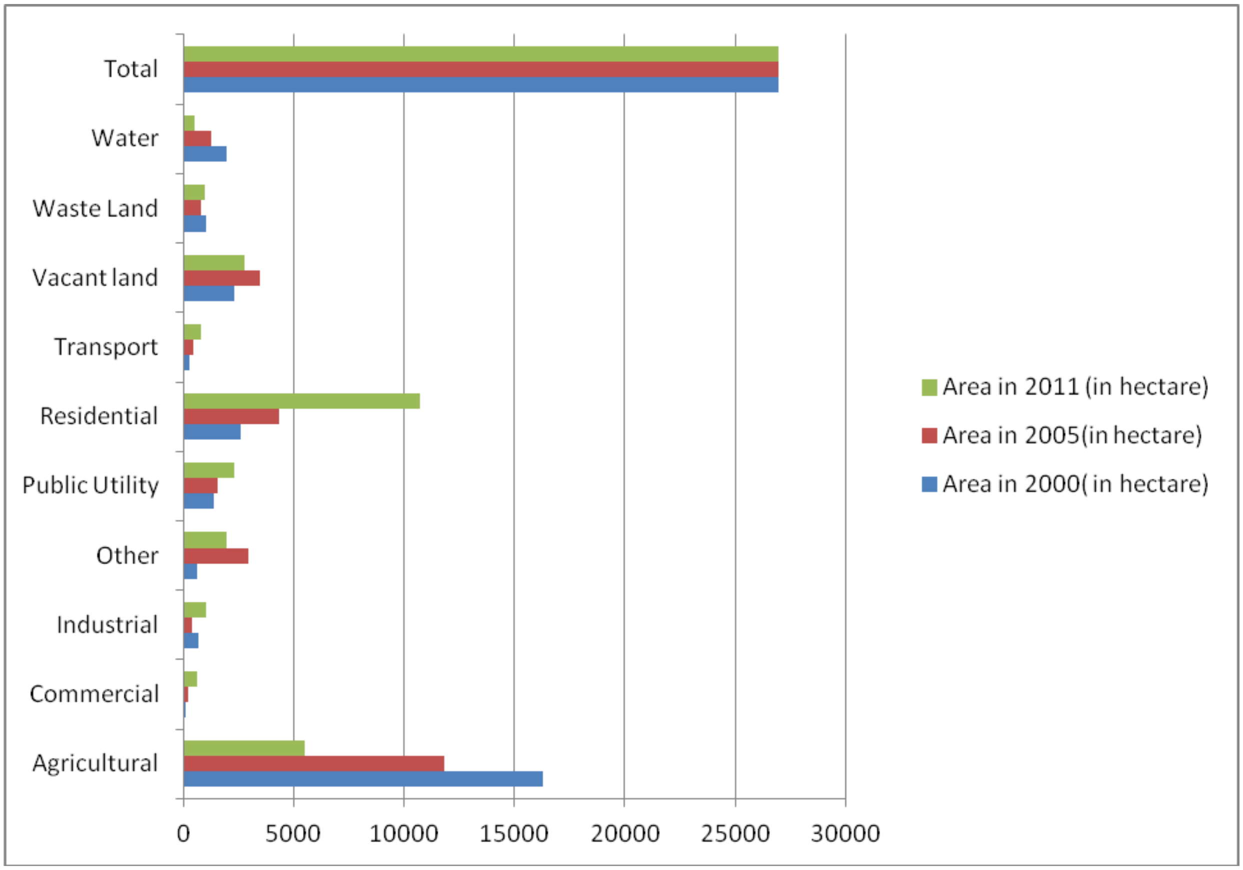

Figure 8: Land use in three different years

5.2 Buffer Analysis

5.2.1 Along the Railway line

Detailed analysis of buffer zones is done for agricultural and residential areas. The left side of the railway line corresponds to the saheed nagar, chadrasekharpur region and the right part has state museum and macheswar areas. Table 5, 6, 7 will show about the contribution of different land use types in 2000, 2005 and 2011 respectively. Pie charts also show clearly the contribution of other type land use areas in both left and right side of railway line. A1, A2, A3, A4, A5, A6 are different buffer zones as mentioned in 4.4.

Table 6: Land Areas (Hectares) in buffer regions in 2000

Land Use Type	A1	A2	A3	A4	A5	A6
agricultural	2216.12	2090.77	1996.57	1555.58	1548.03	1635.53
commercial	30.84	0	0	0	0	0
industrial	285.89	1301.01	327.38	38.78	82.97	0
other	22.83	0	0	105.28	112.57	98.65
public utility	354.24	557.75	503.31	179.83	113.45	47.59
residential	761.53	692.53	350.77	270.13	188.3	167.26
transport	52.83	182.15	0	0	0	0
vacant land	153.4	85.81	195.12	417.96	558.63	241.3
wasteland	287.03	276.65	77.81	261.23	93.29	33.46
water	31.61	5.29	287.57	711.67	626.03	299.81
total	4196.32	5191.96	3738.53	3540.46	3323.27	2523.6

Table 7: Land Areas (Hectares) in buffer regions in 2005

Land Use Type	A1	A2	A3	A4	A5	A6
agricultural	1414.59	1557.02	1619.12	1104.59	830.45	983.52
commercial	287.13			51.11	48.82	0
industrial	475.43	45.32	354.86	31.59	86.04	62.71
other	104.92			0	0	53.69
public utility	117.43	1278.44	539.47	271.48	236.45	116.58
residential	923.19	913.35	669.19	643.84	424.03	252.36
transport	93.64	12698.29		39.11	110.81	0
vacant land	535.98	730.6	113.29	652.88	681.41	216.94
wasteland		258.71	75.03	33.65	807.26	478.95
water	244.01	156.99	277.97	712.21	98	358.85
total	4196.32	5191.96	3738.53	3540.46	3323.27	2523.6

Table 8: Land Areas (Hectares) in buffer regions in 2011

Land Use Type	A1	A2	A3	A4	A5	A6
agricultural	517.36	260.14	383.71	352.96	791.16	929.42
commercial	267.86	91.1	224.46	55.05	191.81	126.27
industrial	169.67		258.01	92.49	37.44	0
other	10.96	231.97	0	590.29	489.36	142.46
public utility	71.9	150.39	222.19	174.07	523.91	632.96
residential	2271.4	3490.42	2300.4	1966.76	471.9	383.59
transport	262.59	395.32	216.52	122.24	20.3	0
vacant land	624.58	572.62	133.24		299.56	227.79
wasteland					265.79	0
water				186.6	232.04	81.11
total	4196.32	5191.96	3738.53	3540.46	3323.27	2523.6

For a complete analysis of agricultural areas in the buffer region, bar graph is shown in Fig. 9. Initially in 2000, agricultural areas has downward trend from A1 to A5. In A6 there is an increase due to presence of forest in the outer 6 km periphery. In 2005, A1 region has lesser area. Then there is increment of areas from A1 to A3 region. Decrease in A4 region is the presence of water. Further addition in the 5 km and 6 km periphery is the presence of forest land type. During 2011, A2 has the minimum areas due to high urbanization in that place. Further there is increase in areas to the outer periphery.

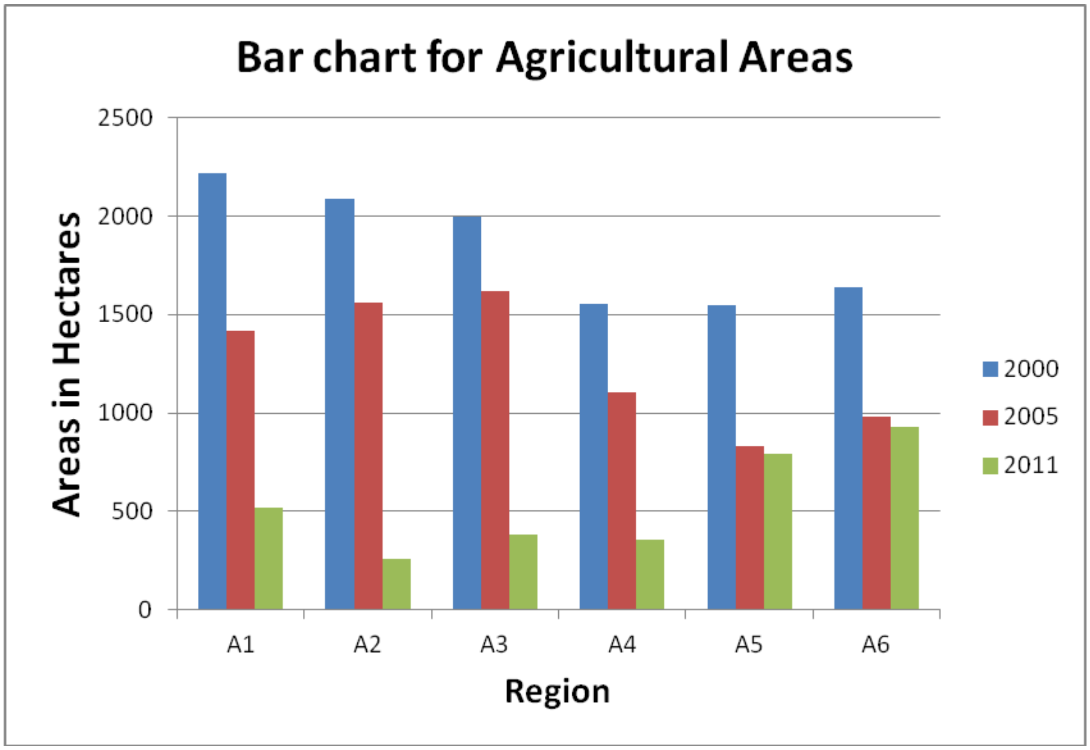

Figure 9: Variation of Agricultural areas in buffer zones in different years

The variation of residential areas in the buffer regions has been demonstrated in Fig.10. In 2000, A1 region has highest area and after that there is a decrease in areas from A1 to A6. During 2005, similar urban growth pattern is found up to 2 km periphery. After that the residential areas has the downward trend. In 2011, A2 region has the maximum areas. The lesser area in the center part or A1 region can indicate less availability of land in that part of the City. Further, there is a decrease in area of built up lands from A2 to A6 periphery.

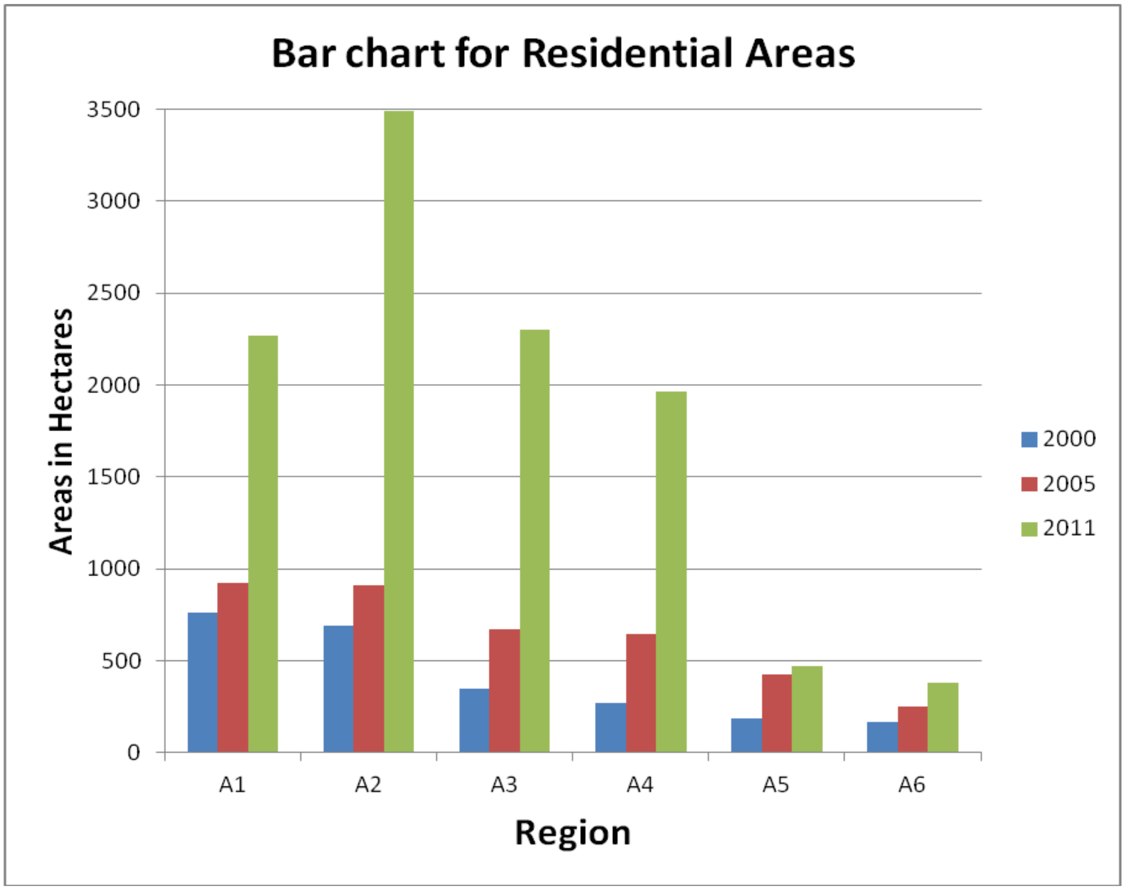

Figure 10: Variation of Residential areas in buffer zones in different years

In the buffer analysis, land use areas in left and right part of the City are taken into account. The left part shows area of Chandra sekharpur, saheed nagar, vanivihar and the right part has area like kalpana talkies, gautam nagar, buddh nagar. In Table 9, the land use areas from spatial analysis and in Fig.11 pie chart for the land use are shown. From the pie chart it can be found that residential areas has same share in both part (left and right) of Bhubaneswar. The contribution stands at 11%. The land use areas in right part are shown in figure 12 and Table 10 in year 2000.

Table 9: Different Areas (Hectares) in Left buffer regions in 2000

Land Use Type	A1-left	A2-left	A3-left	A4-left	A5-left	A6-left
agricultural	1083.1	1129.2	809.77	815.99	1018.45	1251.85
commercial	30.84					
industrial	20.59	1301.01	315.51	38.78	82.97	
other	22.83				112.57	98.65
public utility	275.51	550.83	503.31	179.83	113.45	47.59
residential	241.82	273.38	318.59	223.43	188.3	148.35
transport	52.83	126.98				
vacant land	153.4	85.81	195.12	321.57	393.04	241.3
wasteland	244.82	72.18		261.23	93.29	
water	31.61	5.29				
total	2157.35	3544.68	2142.3	1840.83	2002.07	1787.74

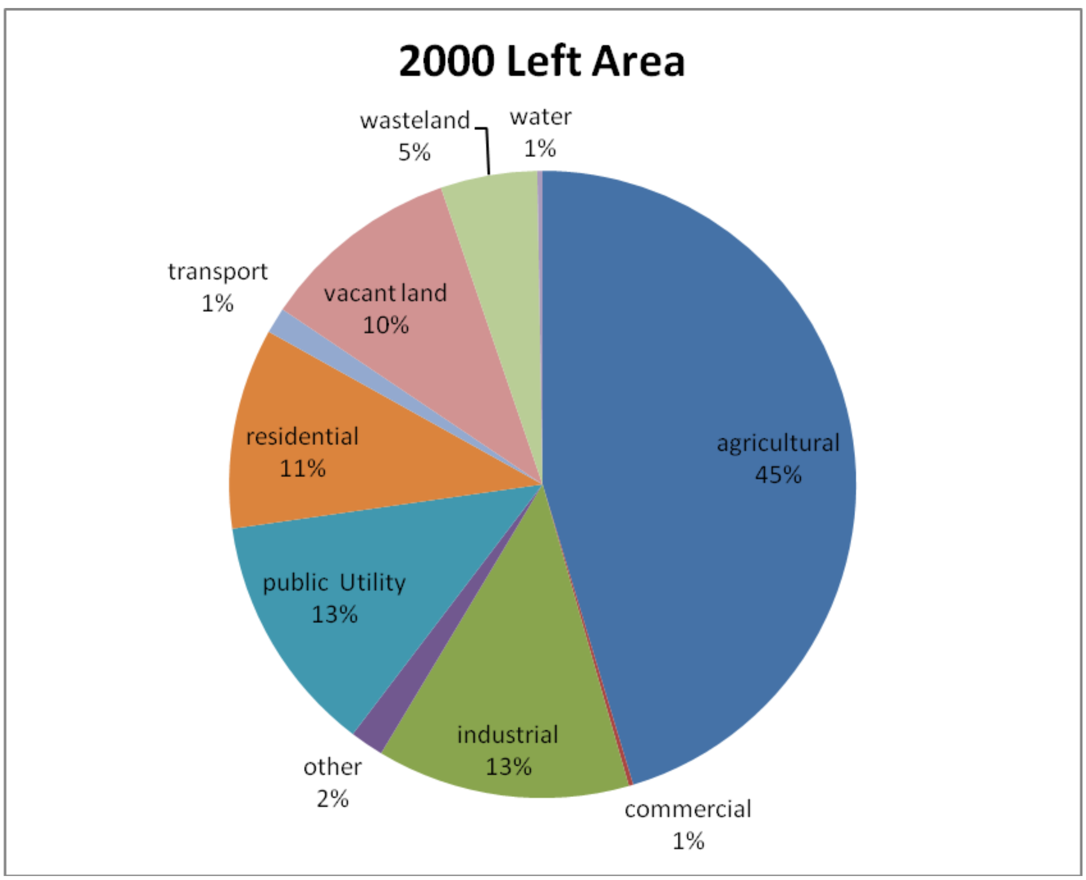

Figure 11: Total left side break-ups of land use in the year 2000

Table 10: Different Areas (Hectares) in Right buffer regions in 2000

Land Use Type	A1- right	A2-right	A3-right	A4-right	A5-right	A6-right
agricultural	1133.02	961.57	1186.8	739.59	529.58	383.68
commercial						
industrial	265.3		11.87			
other				105.28		
public utility	78.73	6.92				
residential	519.71	419.15	32.18	46.7	0	18.91
transport		55.17				
vacant land				96.39	165.59	
wasteland	42.21	204.47	77.81			33.46
water			287.57	711.67	626.03	299.81
total	2038.97	1647.28	1596.23	1699.63	1321.2	735.86

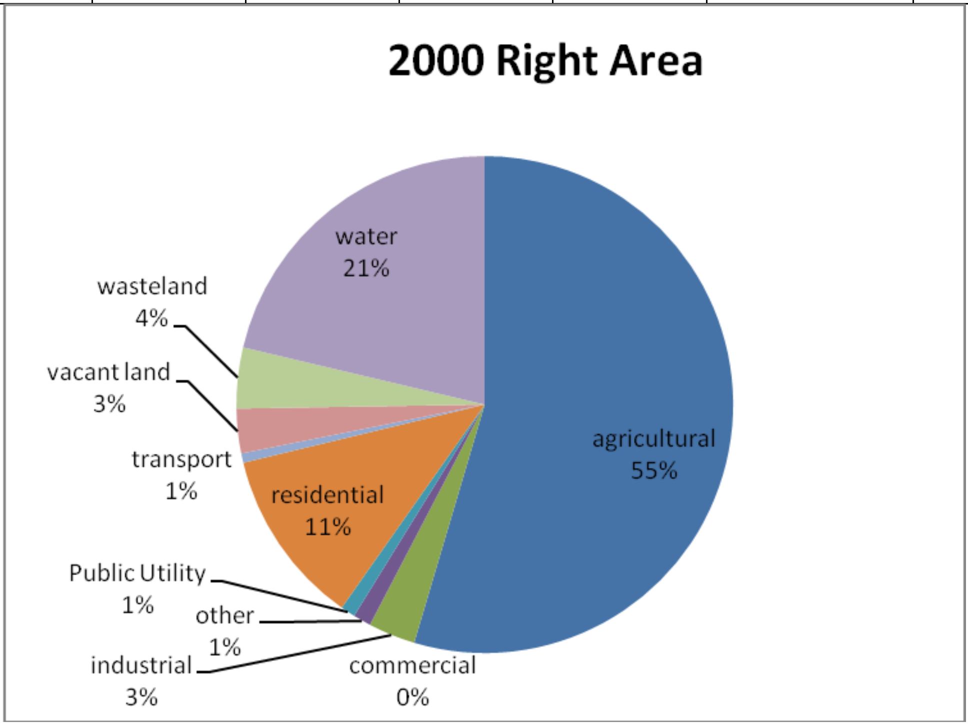

Figure 12: Total Right side break-ups of land use in the year 2000

In 2005 the left part has more urbanization which can be understood from the pie chart shown in Figure 13, 14. The left has urbanization of 23% and of the right part has 16%. The break ups for different land use are shown in Table 11, 12.

Table 11: Different Areas (Hectares) in Left buffer regions in 2005

Land Use Type	A1- right	A2-right	A3-right	A4-right	A5-right	A6-right
agricultural	1133.02	961.57	1186.8	739.59	529.58	383.68
commercial						
industrial	265.3		11.87			
other				105.28		
public utility	78.73	6.92				
residential	519.71	419.15	32.18	46.7	0	18.91
transport		55.17				
vacant land				96.39	165.59	
wasteland	42.21	204.47	77.81			33.46
water			287.57	711.67	626.03	299.81
total	2038.97	1647.28	1596.23	1699.63	1321.2	735.86

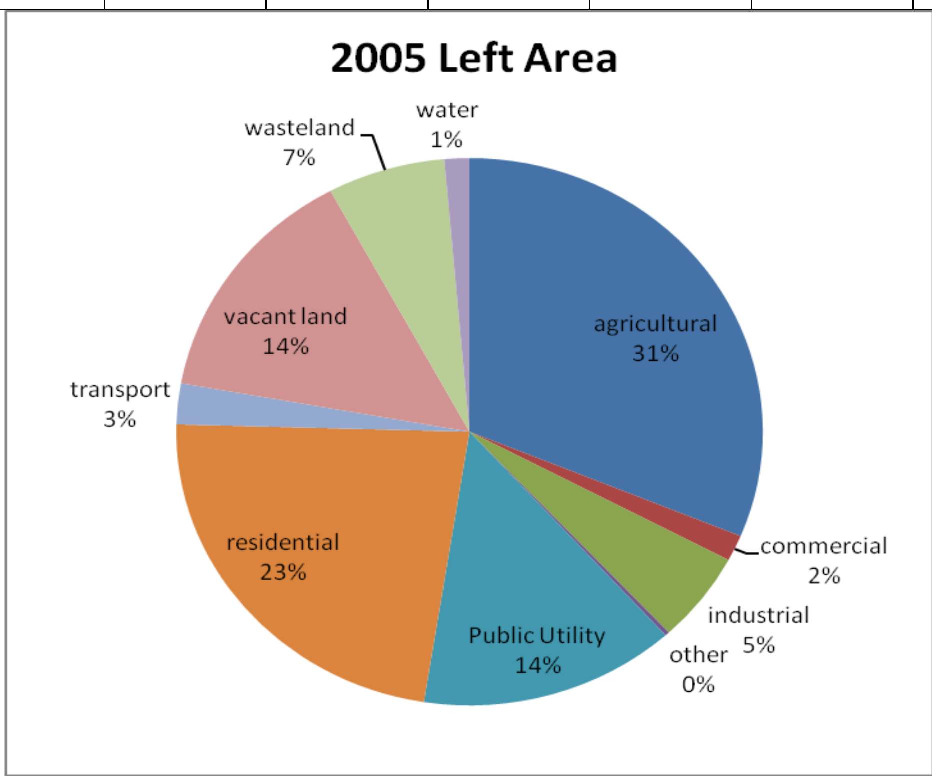

Figure 13: Total Left side break-ups of land use in the year 2005

Table 12: Different Areas (Hectares) in Right buffer regions in 2005

Land Use Type	A1- right	A2-right	A3-right	A4-right	A5-right	A6-right
agricultural	898.51	645.18	905.2	442.14	406.52	112.01
commercial	46.46		0	22.27	48.82	0
industrial	247.57	45.32	13.28	0	0	0
other	104.92	28.13	57.85	0	0	0
public utility	53.56	327.73	32.79	0	0	64.75
residential	574.87	263.12	146.19	121.06	18.94	47.11
transport		147.11	0	0	0	0
vacant land	113.08		87.92	401.95	146.01	96.32
wasteland		89.81	75.03	0	602.91	56.82
water		100.88	277.97	712.21	98	358.85
total	2038.97	1647.28	1596.23	1699.63	1321.2	735.86

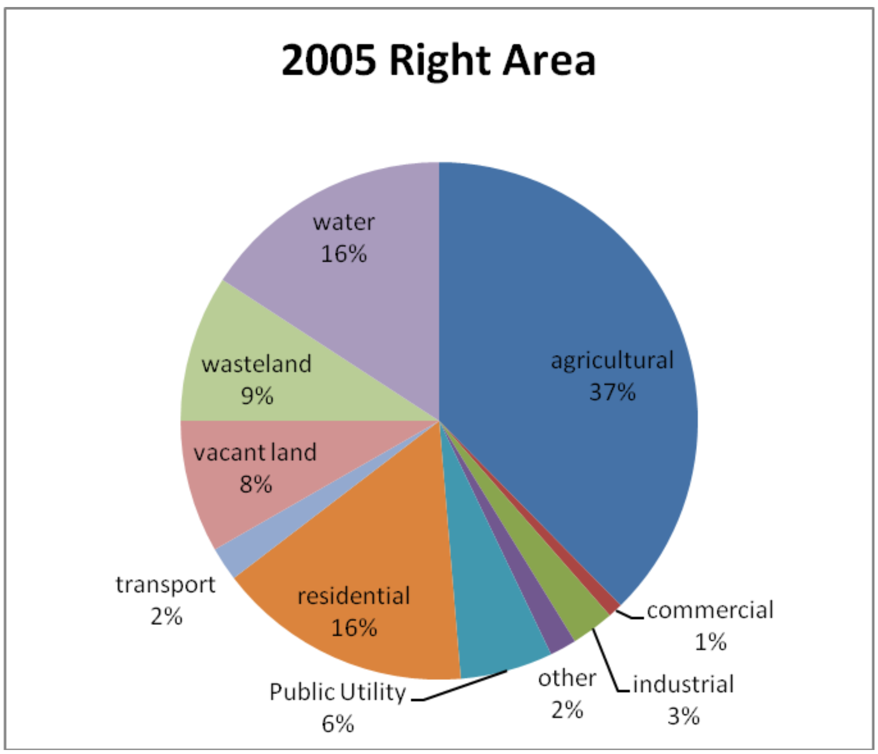

Figure 14: Total Right side break-ups of land use in the year 2005

During 2011 the urbanization is more clearly represented. The left part has urbanization of 60% while the right part has 26%. The break ups of land are shown in Table 13, 14 and pie charts are shown in Fig. 15, 16.

Table 13: Different Areas (Hectares) in Left buffer regions in 2011

Land Use Type	A1-left	A2-left	A3-left	A4-left	A5-left	A6-left
agricultural	372.82	200.02	209.55	148.17	695.96	811.87
commercial	95.92	27.09	130.18	55.05	191.81	126.27
industrial	152.05	0	151.88	23.67	0	0
other	10.96	0		0	0	0
public utility	71.9	150.39	129.2	125.13	493.84	367.43
residential	1292.33	2457.48	1311.69	1440.83	320.9	364.32
transport	123.08	249.49	126.42	47.98	0	0
vacant land	38.29	460.21	83.38		299.56	117.85
wasteland						
water						
total	2157.35	3544.68	2142.3	1840.83	2002.07	1787.74

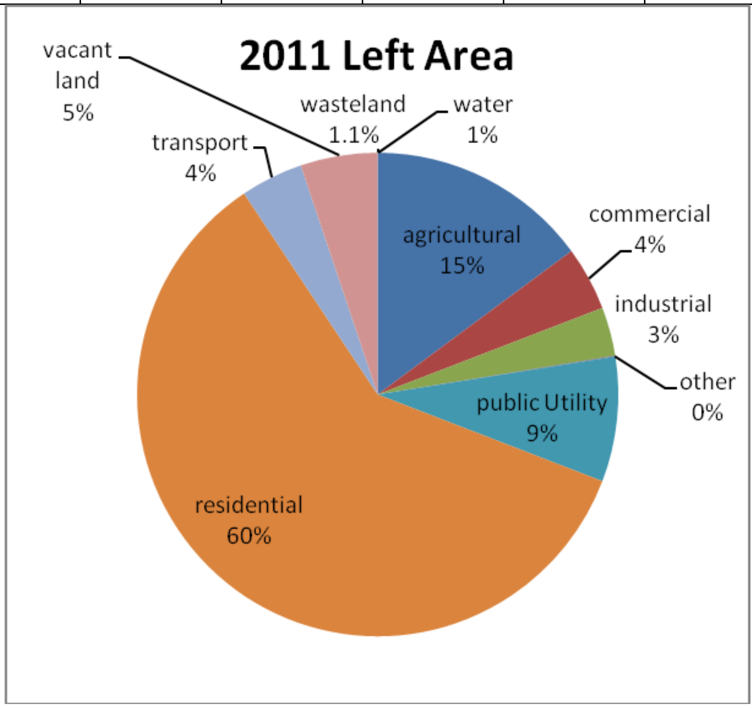

Figure 15: Total Left side break-ups of land use in the year 2011

Table 14: Different Areas (Hectares) in Right buffer regions in 2011

Land Use Type	A1- right	A2-right	A3-right	A4-right	A5-right	A6-right
agricultural	144.54	60.12	174.16	204.79	95.2	117.55
commercial	171.94	64.01	94.28	0	0	0
industrial	17.62	0	106.13	68.82	37.44	0
other	0	231.97	0	590.29	489.36	142.46
public utility	0	0	92.99	48.94	30.07	265.53
residential	979.07	1032.94	988.71	525.93	151	19.27
transport	139.51	145.83	90.1	74.26	20.3	0
vacant land	586.29	112.41	49.86	0	0	109.94
wasteland				0	265.79	0
water				186.6	232.04	81.11
total	2038.97	1647.28	1596.23	1699.63	1321.2	735.86

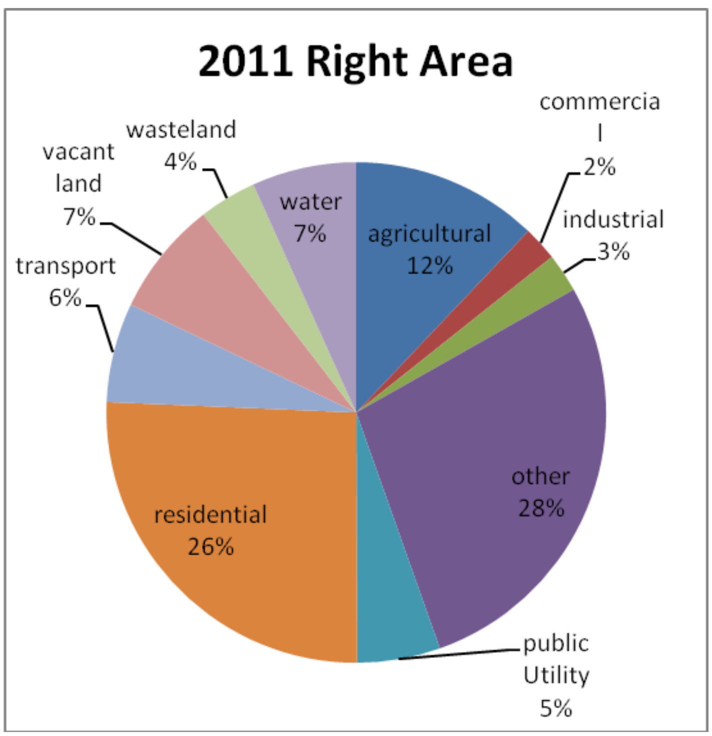

Figure 16: Total Right side break-ups of land use in the year 2011

5.2.2 along center of the City

The center of the town is taken at the Acharya Vihar Area. From that portion Circle of 1km radius taken up to 8km radius and urban sprawl is found out with ILWIS-GIS. For the year 2000, 2005, 2011 the built up areas are shown in figure 17, 18, 19 respectively. The Land use classification are taken as

From Fig. 18 initially there is urbanization growth is towards south and south east part of Bhubaneswar City. The urbanization has been found to grow towards buddha nagar and old town area. During 2005, The sprawl can be properly represented by Fig. 19. The growth of city's built up area has also moves towards south west direction from khandagiri to patrapada. The development in south west part is due to the proximity of NH-5. In the south-east part, the outgrowth can be attributed to NH-203's presence. The growth picture of 2011 is shown in Fig. 20. During this period, the growth has also added another movement in North direction from chandrashekarpur to raghunathpur. In the west part of the city , the growth is hindered by presence of chandaka forest area. So the total development of Bhubaneswar city is in South-east (potential to increase upto Uttara), south-west(can increase upto Janla, Retang) and in north direction.

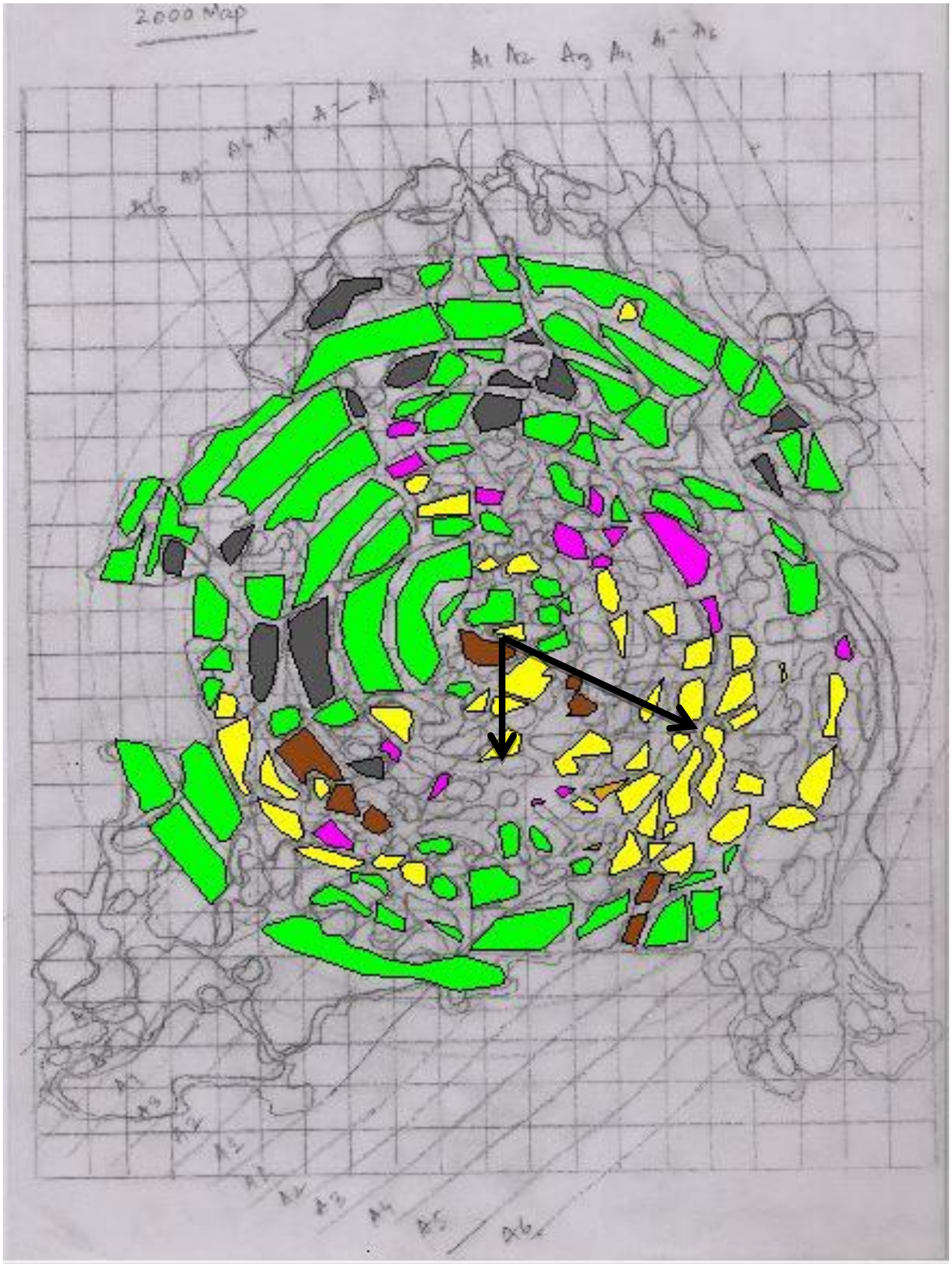

Figure 17: Polygon Map for the year 2000 for Growth along the Center

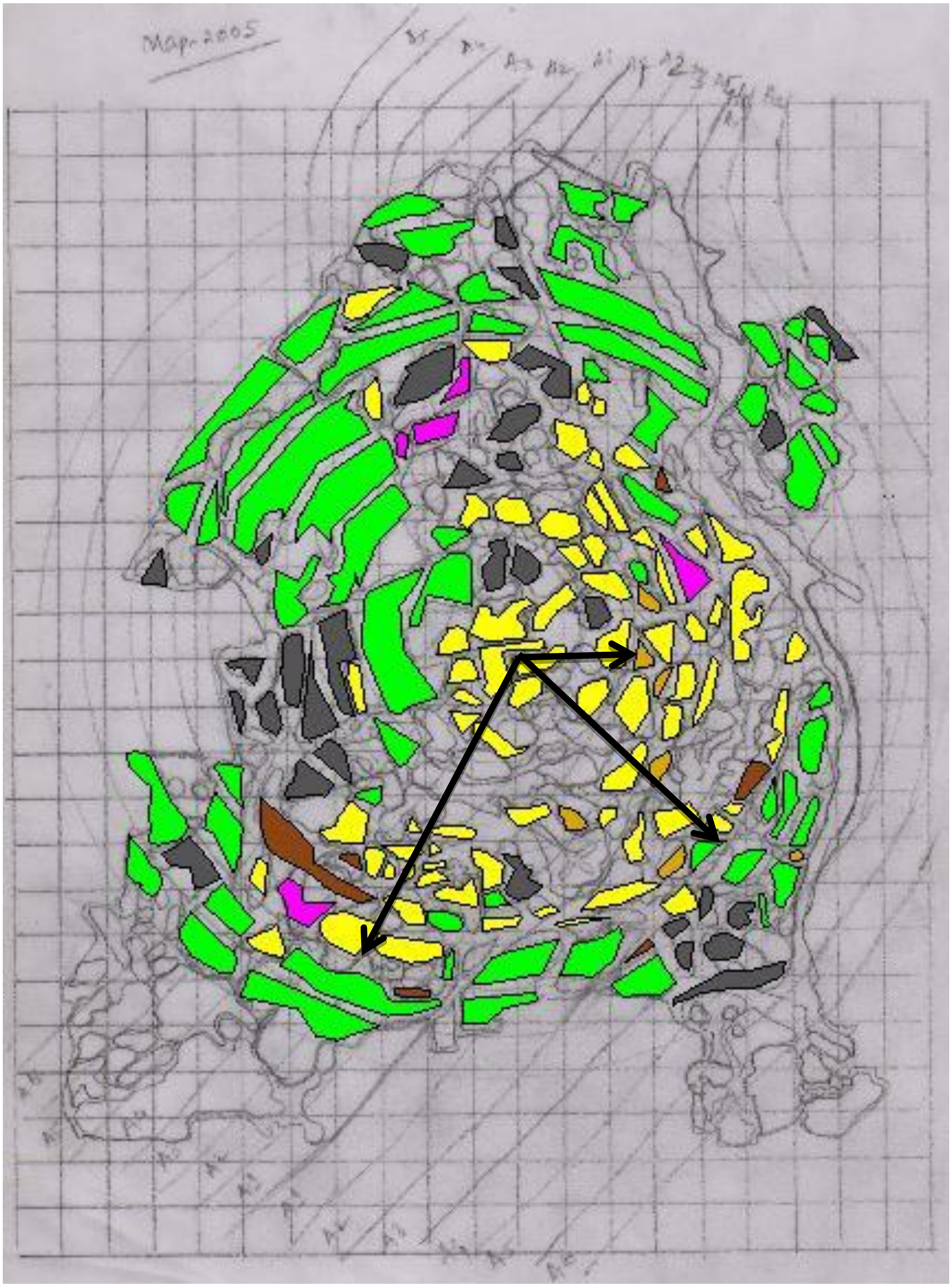

Figure 18: Polygon Map for the year 2005 for Growth along the Center

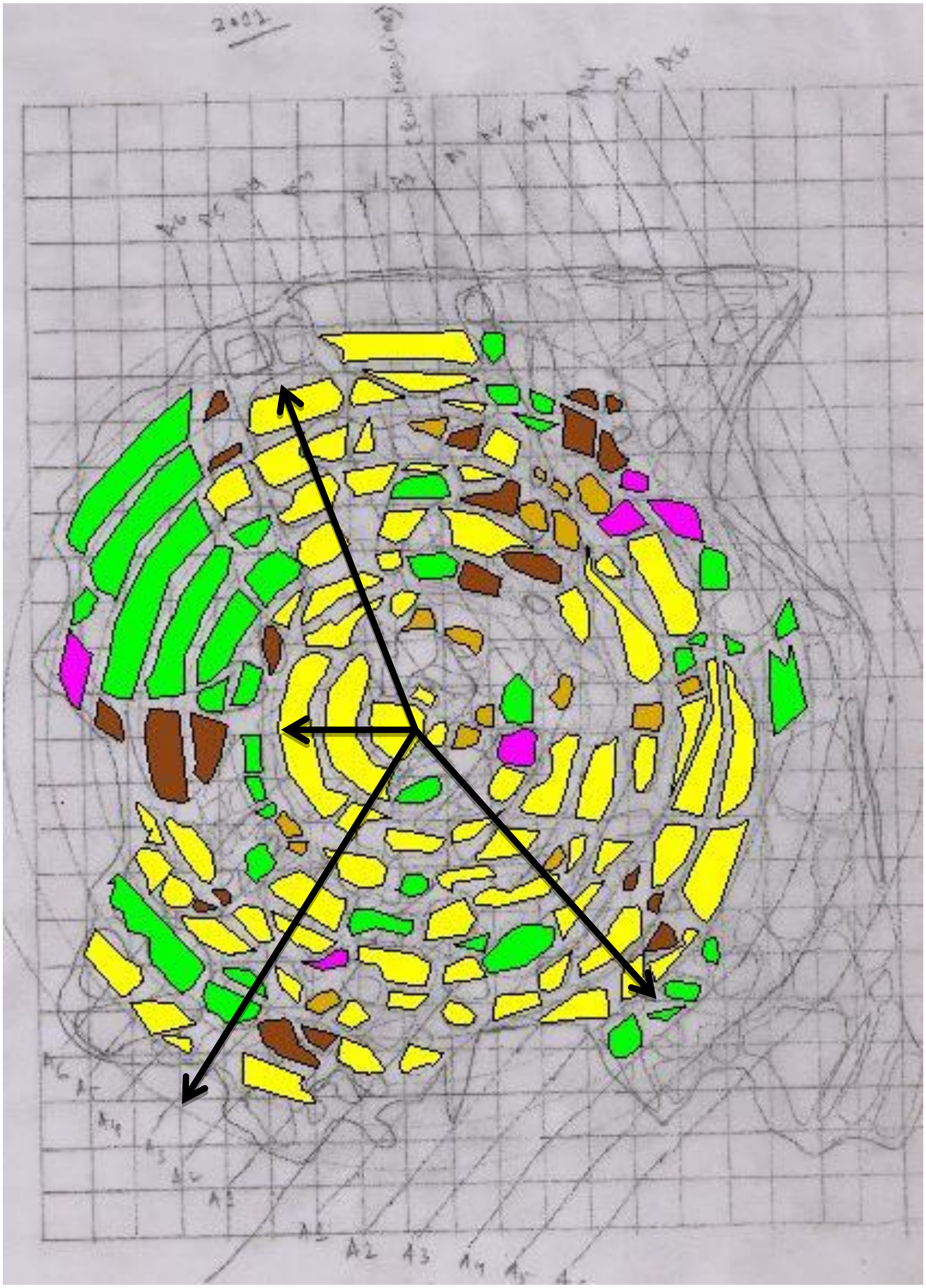

Figure 19: Polygon Map for the year 2011 for Growth along the Center of Bhubaneswar

5.3 Entropy

5.3.1 Along Railway Line (Buffer Type 1)

Mean relative entropy has been calculated for Years 2000, 2005 and 2011 using equation (2) and shown in figure 20. Further change in entropy is done using equation (3) and entropy values are calculated using equation (1) and shown in figures.

Table 15: Mean Relative Entropy for Buffer type 1

year	entropy	change	%change
2000	0.76		
2005	0.96	0.2	26.32
2011	0.99	0.03	3.13

As shown in Fig. 20, the entropy value increases from 0.76 to 0.99 from 2000 to 2011. This indicates that the dispersal of land gradually in Bhubaneswar along the railway line periphery.

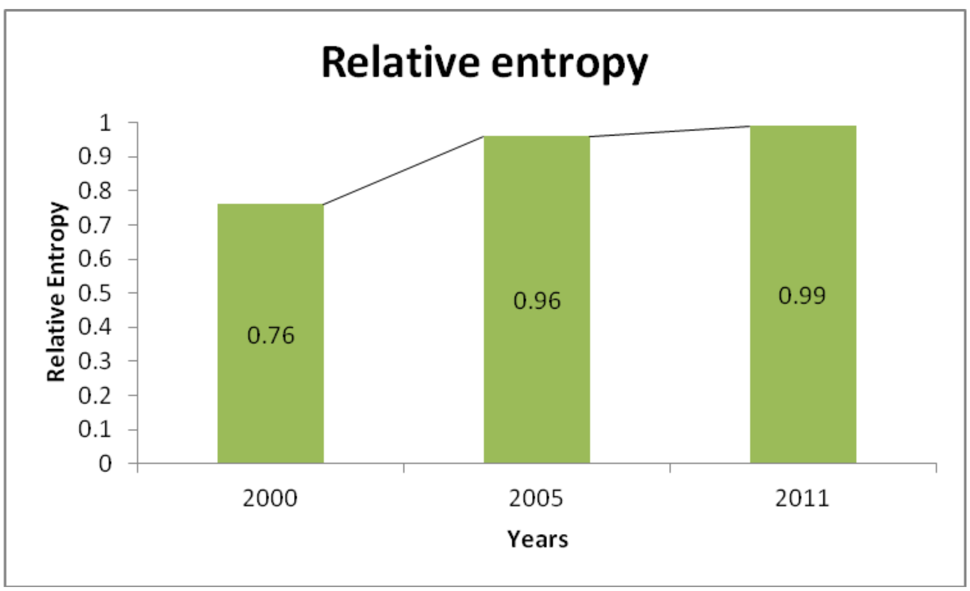

Figure 20: Mean relative entropy value for 2000, 2005 and 2011

.

The relative and distributed entropy value for year 2000 is shown in Fig. 21, 22. We can say from bar graphs that both the entropy values are maximum at the inner region (A1) and it gradually decreases as we move outward. This indicates the less compactness in the outside fringe of Bhubaneswar.

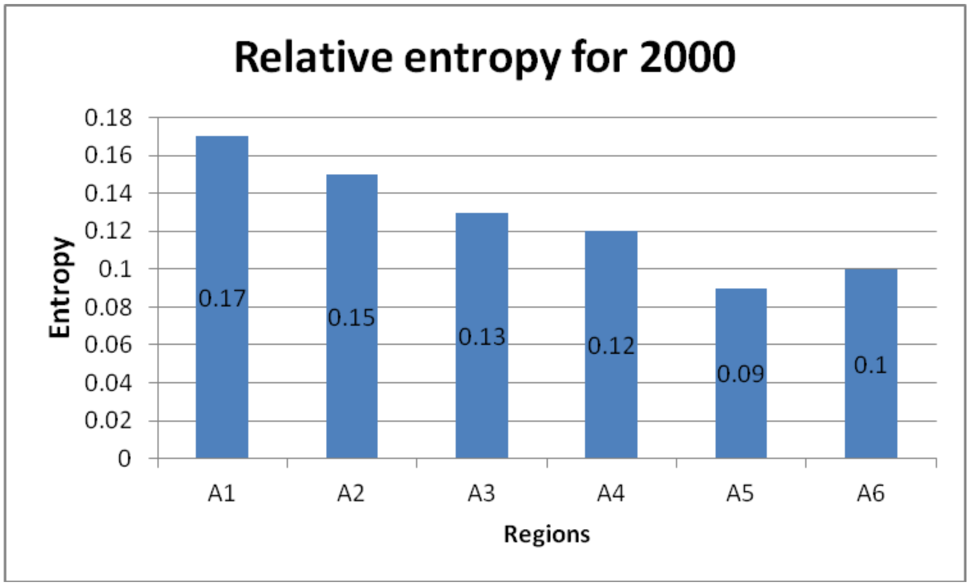

Figure 21: Relative Entropy value for 2000.

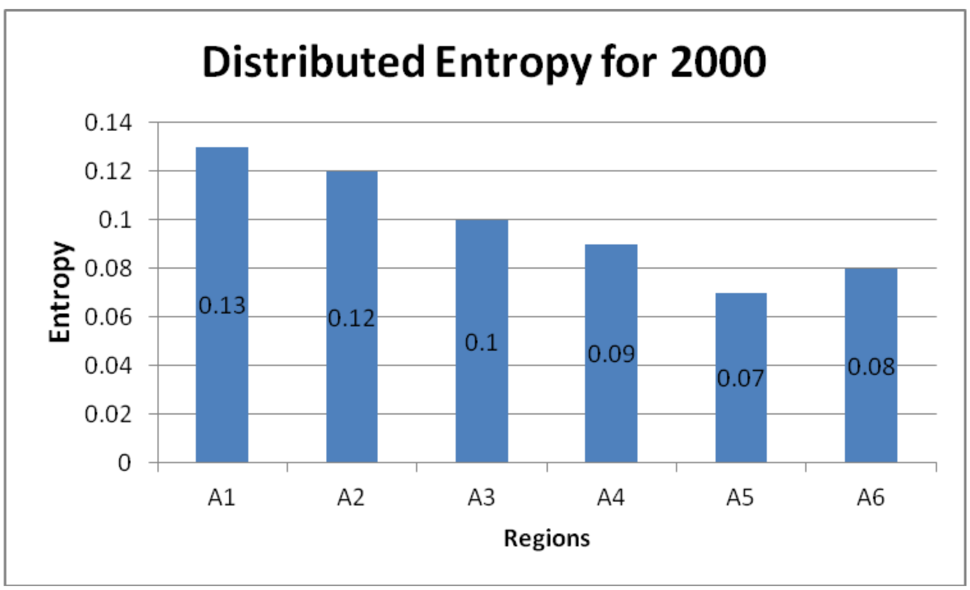

Figure 22: Distributed Entropy value for 2000.

The relative and distributed entropy for year 2005 is shown in Fig. 23 and 24. The entropy values have an increment from the year 2000. This gives the more sprawl in 2005 comparing to 2000.

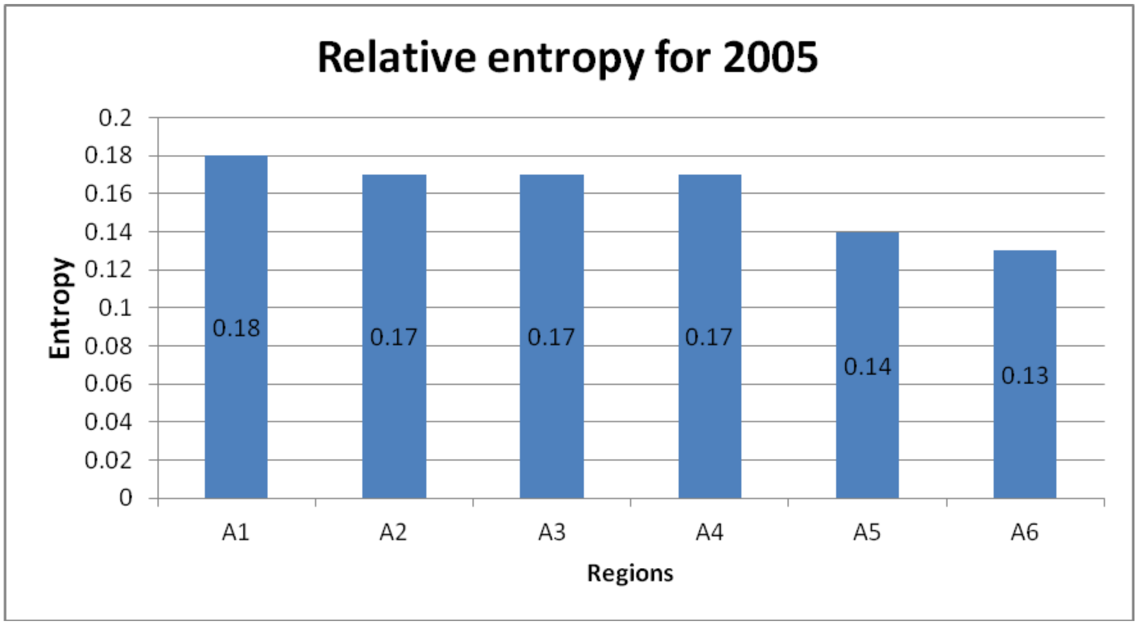

Figure 23: Relative Entropy value for 2005.

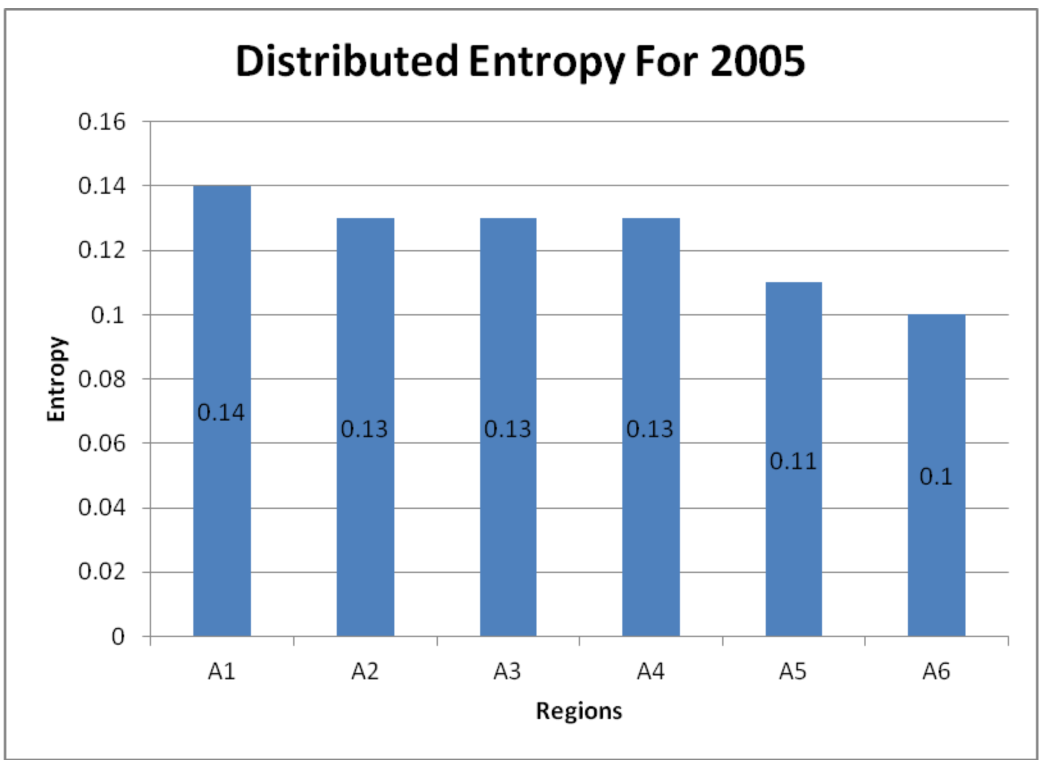

Figure 24: Distributed Entropy value for 2005.

The distributed and relative entropy value for year 2011 has been represented in Fig 25, 26. The entropy values increased from year 2005 which indicates more sprawl and dispersal of land in Bhubaneswar City.

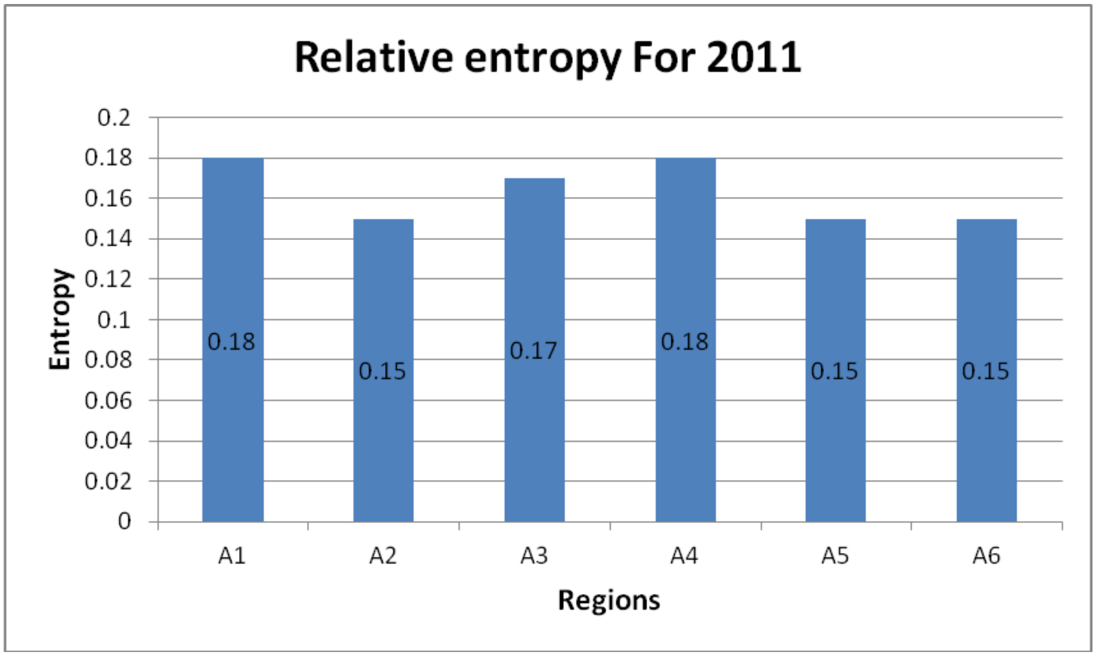

Figure 25: Relative Entropy value for 2011.

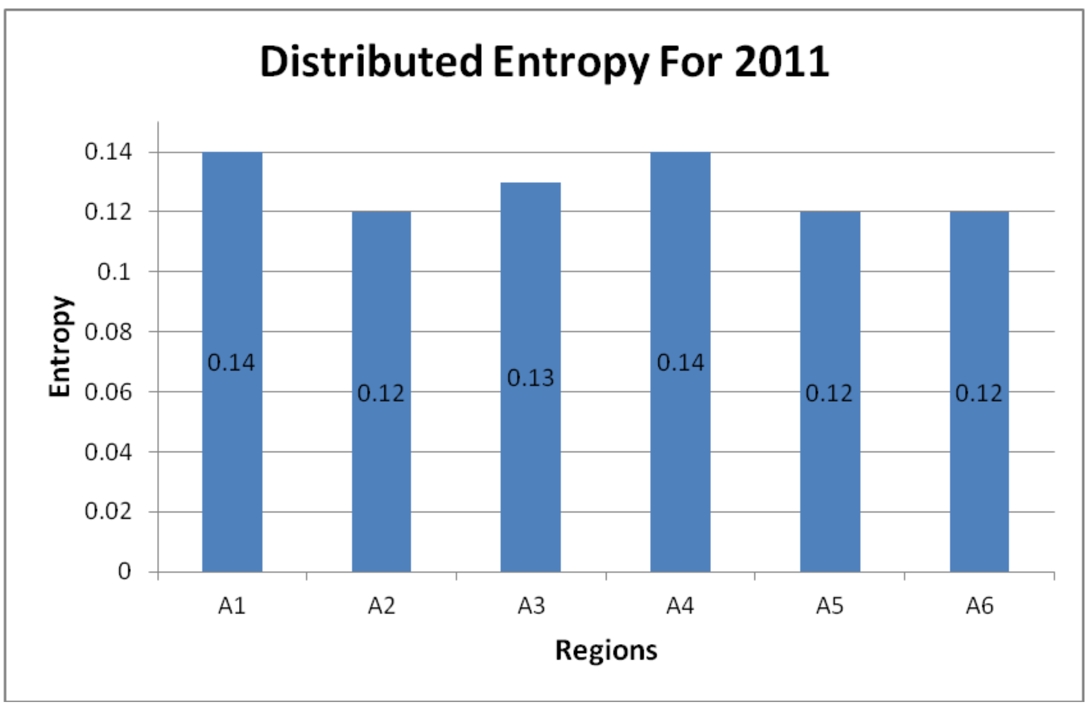

Figure 26: Distributed Entropy value for 2011.

The comparison of entropy valued for year 2000, 2005, and 2011 has been tabulated in Table 16. The bar graph shown below in Fig. 27. From the comparison, we can find that the entropy has an upward trend along the railway line over the years.

Table 16: Comparison of Entropy for different years

Different year entropy	A1	A2	A3	A4	A5	A6
entropy for 2000	0.13	0.12	0.1	0.09	0.07	0.08
entropy for 2005	0.14	0.13	0.13	0.13	0.11	0.10
entropy for 2011	0.14	0.12	0.13	0.14	0.12	0.12

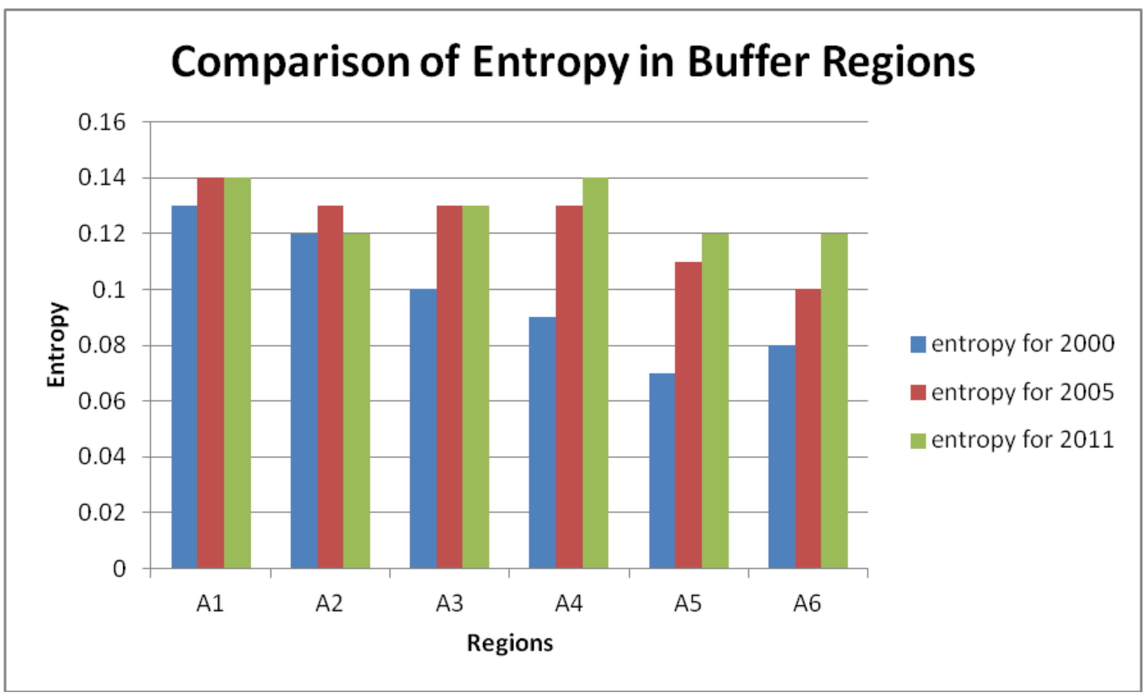

Figure 27: Comparison of Entropy in Buffer Regions.

5.3.2 From the center of the City (Buffer Type 2)

The center of the city is taken at Acharya Vihar. The mean entropy values are tabulated in Table 16 and the bar graph is depicted in Fig.28. The increase of entropy is from 0.93 to 0.98 over the years. This indicates more compactness in urbanization around the circular periphery of Bhubaneswar.

Table 17: Mean Different Entropy for Buffer Type 2

year	entropy	change	change%
2000	0.93		
2005	0.96	0.03	3.23
2011	0.98	0.02	2.08

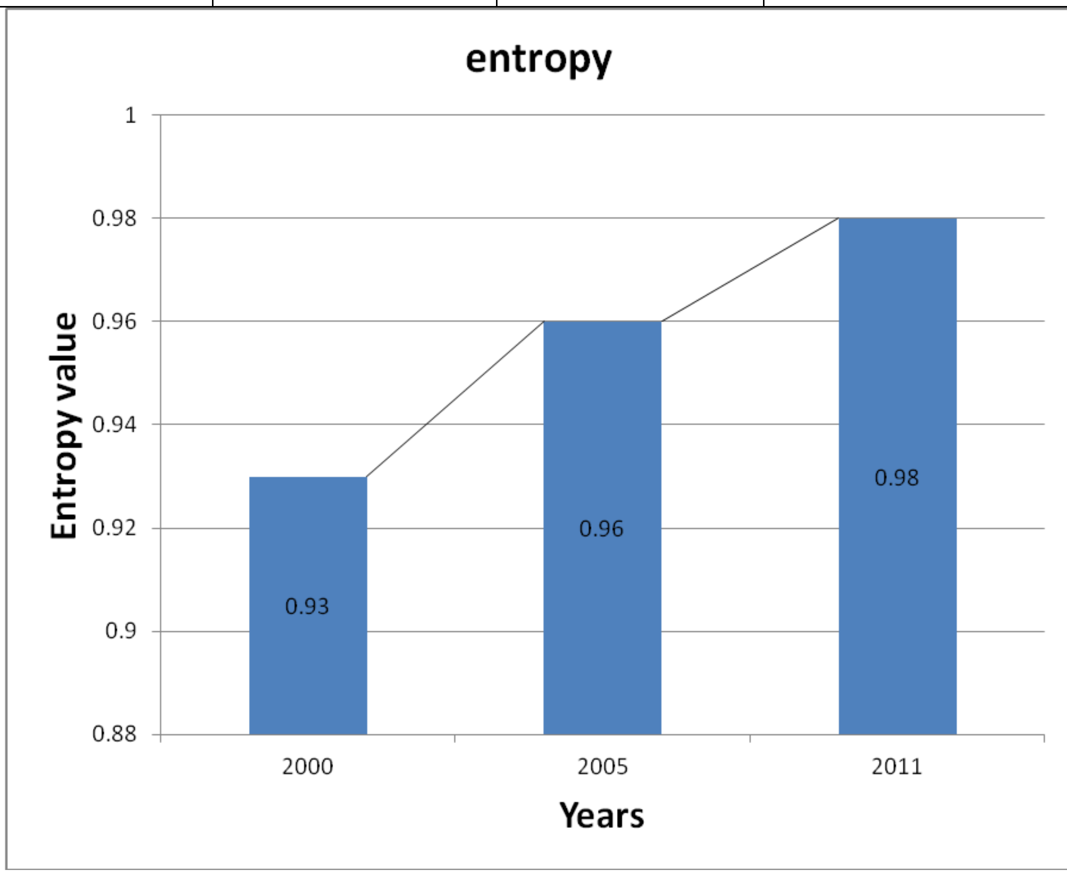

Figure 28: Mean relative entropy value for 2000, 2005 and 2011

The relative entropy for three years is represented in Fig 29, 30, 31. The entropy in year 2000 is low as compared to other areas... This indicated less sprawl of urbanization in the Bhubaneswar City.

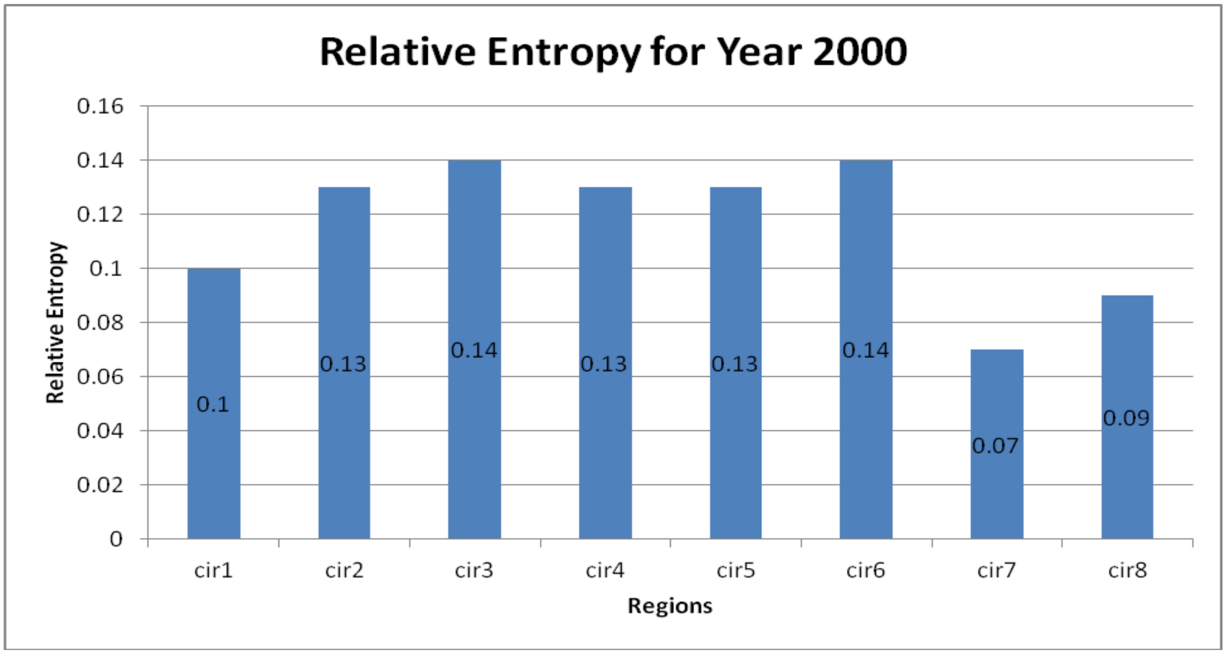

Figure 29: Relative entropy value for 2000 in circular regions

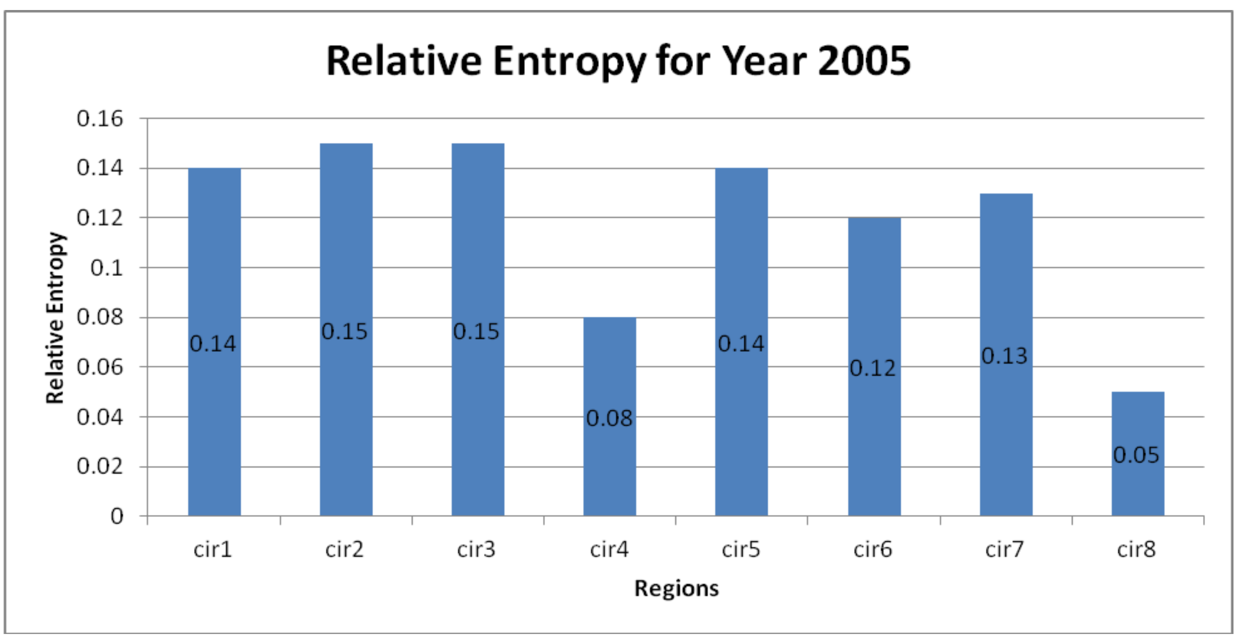

Figure 30: Relative entropy value for 2005 in circular regions

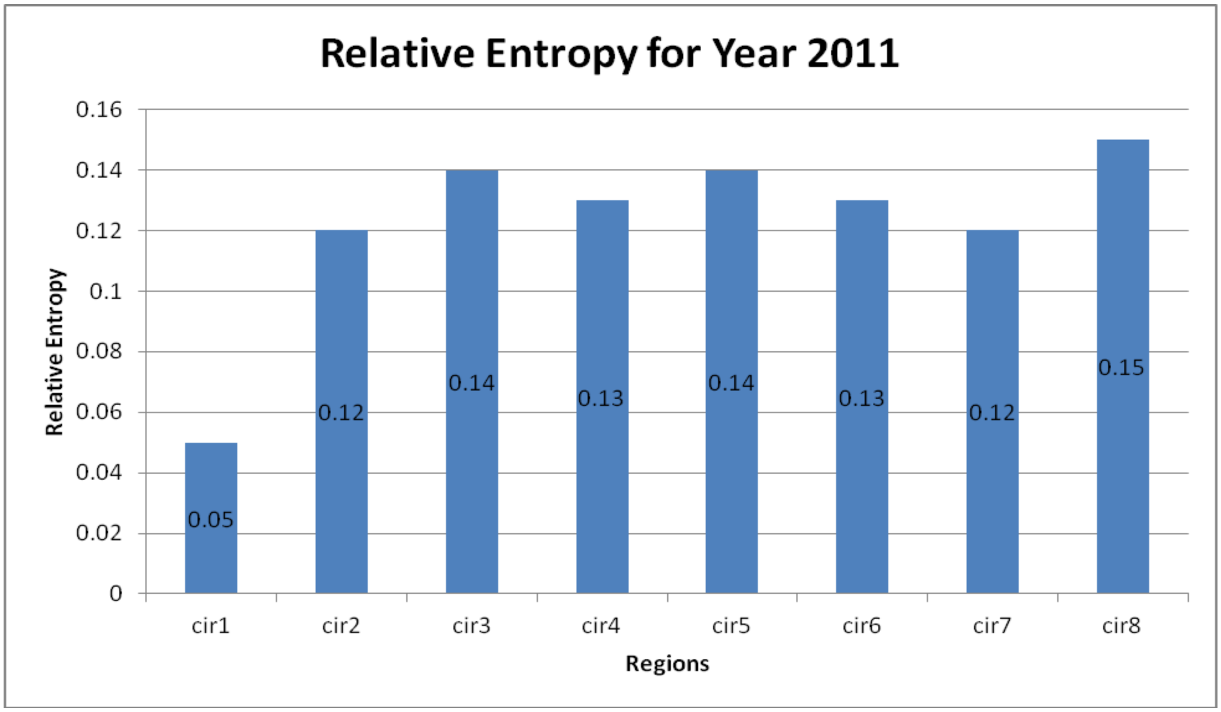

Figure 31: Relative entropy value for 2011 in circular regions

The Relative entropy value for three different regions is tabulated in Table 17 and the comparison of relative is demonstrated by Fig 32. We can find that from 2000 to 2005 there is gradual sprawl or even dispersal of land use. At the outer part of the city, the sprawl is less in 2005 as compared to year 2000. During 2011, the compactness is more in circle1 (Radius of 1 km region) as entropy is 0.05. In an overall scenario, the randomness is more in 2011.

Table 18: Relative Entropy for different years in circle regions

Year	cir1	cir2	cir3	cir4	cir5	cir6	cir7	cir8
2000	0.1	0.13	0.14	0.13	0.13	0.14	0.07	0.09
2005	0.14	0.15	0.15	0.08	0.14	0.12	0.13	0.05
2011	0.05	0.12	0.14	0.13	0.14	0.13	0.12	0.15

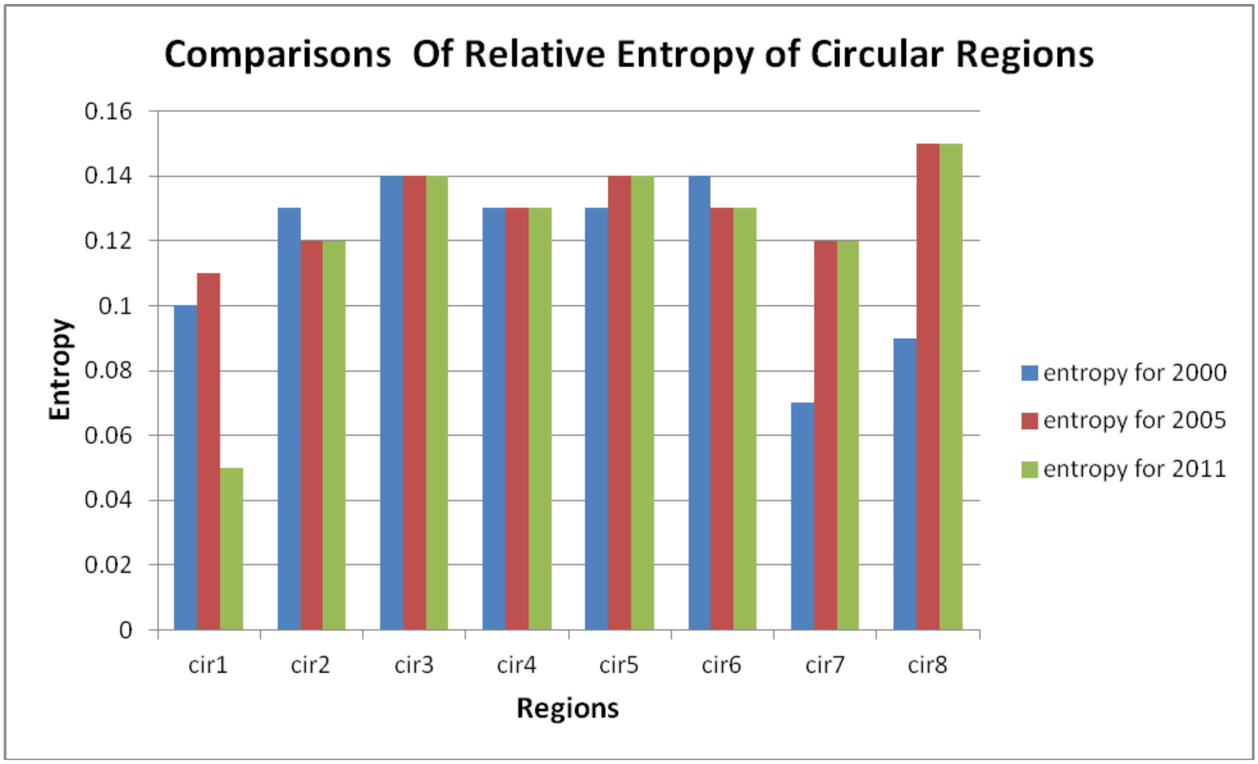

Figure 32: Comparisons of Relative entropy value of circular regions

Chapter VI

Conclusions

Conclusions

- The groundwater of Bhubaneswar is depleting day by day. The lowest groundwater level data is found in Unit-Viii (8.25m) and maximum decrease of level is found in Tankapani road area (decrease by 1.75m)
- The future urban population of Bhubaneswar is projected as 920328, 1067525 and 1214722 in the year 2021, 2031 and 2041 respectively.
- According to the results, a decrease of 66.6% in agricultural areas; an increase of 310% in the residential areas has been found from year 2000 to 2011.
- Using Buffer analysis (along the railway line) it has been determined that the left part railway line of Bhubaneswar city(corresponding to Vani vihar, saheed nagar, chandrashekarpur) is more urbanized than the right part of city (corresponding to kalpana talkies,buddha nagar, old town, gautam nagar). The left part has a residential contribution of 60% of the total area while the right part has only 26%.
- The buffer analysis (from the center of the city: Acharya vihar), it can be concluded that urbanization of Bhubaneswar is growing towards North (patia to raghunathpur), south-east (old town to uttara) and south-west (khandagiri –patrapada-janla) direction.
- Entropy Method on both the buffer along the railway line and from the Centre of the city shows that the urban development in Bhubaneswar is random and going in an unplanned manner.
- The future scope of this study will be finding the water demand, effect on soil conditions of urban sprawl in Bhubaneswar.

References

1. B. Hazen, “Distributed Implementation of the Land-Use Change Analysis System (LUCAS) using PVM”, *Master's thesis*, University of Tennessee, Knoxville, 1995.

2. J. Landis, “Imagining Land Use Futures: Applying the California Urban Futures Model”, *Journal of the American Planning Association*, Vol No.61, 438-457, 1995.

3. V. Merwe and J. Hendrik, “GIS-aided land evaluation and decision making for regulating urban expansion: A South African case study”, *GeoJournal*, Springer, Vol No. 43, 136-145, 1997

4.H. Samant and V. Subramanyan, “ Land use change in mumbai-Navi Mumbai Cities and its effects on the drainage basins and channels- A study using GIS”, *Journal of the Indian society of Remote sensing*, Vol No. 26,137-178, 1998.

5.P. Wadell, “ The Oregon prototype metropolitan land use model”, *ACSE Conference*, Portland, Oregon, 1998.

6. M. Batty, Y. Xian, and Z. Sun, “Modeling urban dynamics through GIS-based cellular automata, *Computer, Environment and Urban Systems*”, Vol No 23,205-233, 1999.

7. T. Carlson, “Satellite imagery is used to predict urban sprawl and its impact on surface hydrology”, Dept. of Meteorology in Penn State University, 2002.

8. E. Silva and K. Clarke, “Calibration of the SLEUTH urban growth model for Lisbon and Porto, Portugal “, *Computer, Environment and Urban Systems*, Vol No. 26, 526-540, 2002.

9.A. Manu, Y. Twumasi, T. Coleman and T. Baptiste, “ Investigation of the impact of urban sprawl in three sahelian cities using Remotely-Sensed Information”, *Geoscience and Remote Sensing Symposium* , Vol No.2, 421-434, 2003.

10. Y. Liu and S. Phinn, “Modelling urban development with cellular automata incorporating fuzzy-set approaches”, *Computer, Environment and Urban Systems*, Vol No. 27, 640-645, 2003.

11. H. Liu, Q. Zhou, "Developing urban growth predictions from spatial indicators based on multitemporal images ", *Computer, Environment and Urban Systems*, Vol No.29, 585-592, 2005.

12.L. Jansen, G. Carrai, L. Morandini and A. Spisni, " Analysis of the spatio-temporal and sematic aspects of land cover change dynamics 1991-2001 in Albania at national and district levels ", *Environmental Monitoring and Assessment*, Springer, Vol No.119, 108-135, 2006.

13. C. Henrique, G. Azocar and H. Romero, "Monitoring and modelling the urban growth of two mid-sozed Chilean cities", *Habitat international*, Vol No.30, 955-961, 2006.

14. H. Liu and Q. Zhou," Developing urban growth predictions from spatial indicators based on multi-temporal images", *Computer, Environment and Urban Systems*, Vol No. 29, 582-592, 2006.

15. B. haack and A. Rafter, "Urban growth analysis and modeling in the kathmandu valley, Nepal", Habitat International, Vol No.30, 1057-1067, 2006.

16. Z. Hu and C. Lo, "Modelling urban growth in Atlanta using logistic regression*", Computer, Environment and Urban Systems*, Vol No. 31, 668-679, 2007.

17. Z. Patterson and M. Bierlaire, "An UrbanSim model of Brussels within a short timeline", *Proceedings of the 7th Swiss Transport Research Conference*, Monte Verita, Switzerland, 2007.

18. R. Jha, V. Singh and V.Vatsa , " Analysis of Urban development of Haridwar, India, using Entropy Approach", *KSCE journal of Civil Engineering*, Vol No. 12, 282-287, 2008.

19.F. Rienzo, P. Oreste and S. pelizza," 3D GIS supporting Underground Urbanization in the City of Turin(Italy)", *Geotechnical and Geological engineering*, Springer, Vol No. 27, 539-543, 2009.

20.A. Ibrahim and M. Sarvestani," Urban sprawl pattern recognition using remote sensing and GIS- case study shiraz city, Iran*", Urban remote sensing joint event*, 2009.

21. L. You, Y. Ku, L. Kai and Z. Jin," Study on the urbanization area expansion monitoring of Jiaozuo using Landsat images", *Urban remote sensing joint event*, 2009.

22. H. taubenbock, M. Wegmann, A.Roth, H.Mehl and S.Dech," urbanization in India-spatiotemporal analysis using remote sensing data", *Computer, Environment and Urban Systems*, Vol No. 33, 180-186, 2009.

23. D. Peijun, L. Xingli, C. Wen, L. Yan and Z. Huapeng ," Monitoring urban land cover and vegetation change by multi-temporal remote sensing information, *Mining Science and Technology*, Vol No. 20, 923-930, 2010.

24. W. Jing and L. Jianzhoung, "Study on the urban expansion and model of Lianyungang city based on the multi-Temporal Remote sensing images*", International conference on environmental science and information Application technology*, Vol No. 10, 2150-2162, 2011.

25. A. Belal and F. Moghanm ," Detecting urban growth using remote sensing and GIS techniques in Al Gharbiya governorate, Egypt ", *The Egyptian journal of remote sensing and space sciences*, Vol No. 14, 75-77, 2011.

26. Q. Zhinag,Y. Ban , J. Liu and Y. Hu," Simulation and analysis of urban growth scenarios for the greater shanghai area", *Computer, Environment and Urban Systems*, Vol No. 35, 127-137,2011.

27. A. Rahman, S. Aggarwal, M. Netzband and S. Fazal, " Monitoring urban sprawl using remote sensing and GIS techniques of a fast growing urban Centre*", IEEE journal of selected topics in applied earth observations and remote sensing*, Vol No. 4, 156-189, 2011.

28. C. Ikiel, B. Ustaoglu, A. Dutucu and D. Killic, " Remote Sensing and GIS-based integrated analysis of land cover change in Duzce plain and its surroundings (north western Turkey)", *Environmental Monitoring and Assessment*, Springer, 2012.

29. N. Mohajeri, J. French and M. Batty, "Evolution and entropy in the organization of urban street patterns", *Annals of GIS*, Vol No.19, 1-7, 2013.

30. http://wikitravel.org/en/Bhubaneswar