Cover Page

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APPLICATION OF REMOTE SENSING AND GIS FOR URBAN SPRAWL MAPPING AND CHANGE DETECTION IN AGRICULTURAL LAND (1991 - 2011): A CASE STUDY OF SITAPUR CITY, SITAPUR DISTRICT, UTTAR PRADESH, INDIA

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ABSTRACT

Urban Sprawl, basically the spread of a city's boundaries, is a global phenomenon mainly in developing countries like India. Urban sprawl is taking its toll on natural resources at an alarming pace due to increased urban population which is mainly caused by migration from rural and small-town areas to cities. Urban sprawl leads to a variety of environmental issues like loss of agricultural land, open areas, loss of surface water, decreased air quality, increased runoff, flooding etc. Urban planners require information related to the growth rate, extent and pattern of sprawl for providing basic functions and amenities like water, electricity, transport, sanitation etc. and development of a region. In this paper, efforts have been made to analyze the land utilization and urban sprawl during the time frame of twenty years (1991-2011) for the city of Sitapur using Remote Sensing images, ArcGIS 10.5 software, Correlation Analysis, Regression Analysis and Shannon's Entropy. Furthermore, the future predictions relating to increase in population and hence sprawl are also done for the city using statistical tools.

Keywords: Urban Sprawl, Resolution Temporal Data, Interactive Supervised Classification, Reclassify Geoprocessing, Shannon's Entropy.

1. INTRODUCTION

Urban Sprawl is the low-density growth or unplanned growth of urban areas and suburbs around the outskirts of the city. All countries are experiencing the phenomenon of urban sprawl which is chiefly due to increase in population growth and developmental initiatives. The main cause of population growth is voluntary and forced migration in search of improved lifestyle and better employment opportunities.

Currently, more than half of the world's population is residing in urban areas (United Nations, 2014). In India, according to 1901 census, the population residing in urban areas was 11.4%, which increased to 28.53% by 2001 census. According to World Bank, presently, 34% of population of India is urban. According to a survey by UN, 40.76% of population of the country is expected to reside in urban areas by 2030.

Unprecedented population growth coupled with unplanned developmental activities has led to urban sprawl in Sitapur city which lacks basic urban amenities. Hence, there is a need to assess and quantify urban sprawl for framing of land use management policies and planning strategies.

Remote Sensing and Geographic Information System (GIS) are potentially powerful tools for monitoring urban sprawl and land use change using high resolution temporal data which is also cost effective and reliable and thereby providing a decision support system to urban planners. Because of synoptic view, repetitive coverage and real time data acquisition, the remote sensing data is very useful and reliable for spatio-temporal monitoring of a region.

The main aims of this study are (i) to monitor the urban sprawl and produce land use land cover maps of Sitapur city for two decades (1991-2011) that has experienced a rapid growth in urban population and subsequently increase in built-up and loss of green cover and (ii) to predict the further growth in population and subsequent sprawl.

2. STUDY AREA

Sitapur is a city located in Sitapur district of Uttar Pradesh. The area of study lies between the latitudes 27°25'N to 27°51'N and between the longitudes 80°31'E to 80°59'E. It is 90°N of Lucknow city. It has an area of 1327.68 km^2. To the east of the study area there is Biswan, Mishrikh in the west, Lakhimpur Kheri in the north and Sidhauli in the south. The region is a part of Indo Gangetic alluvial plain and is almost a flat terrain with its master slope towards southeast. It is formed of recent age alluvium and dun- gravels. It has an average elevation of 138 meters from mean sea level. The climate in winter is generally like temperate zone. In monsoon season, the region receives a good amount of rainfall, while the winters have very little.

Cover Page

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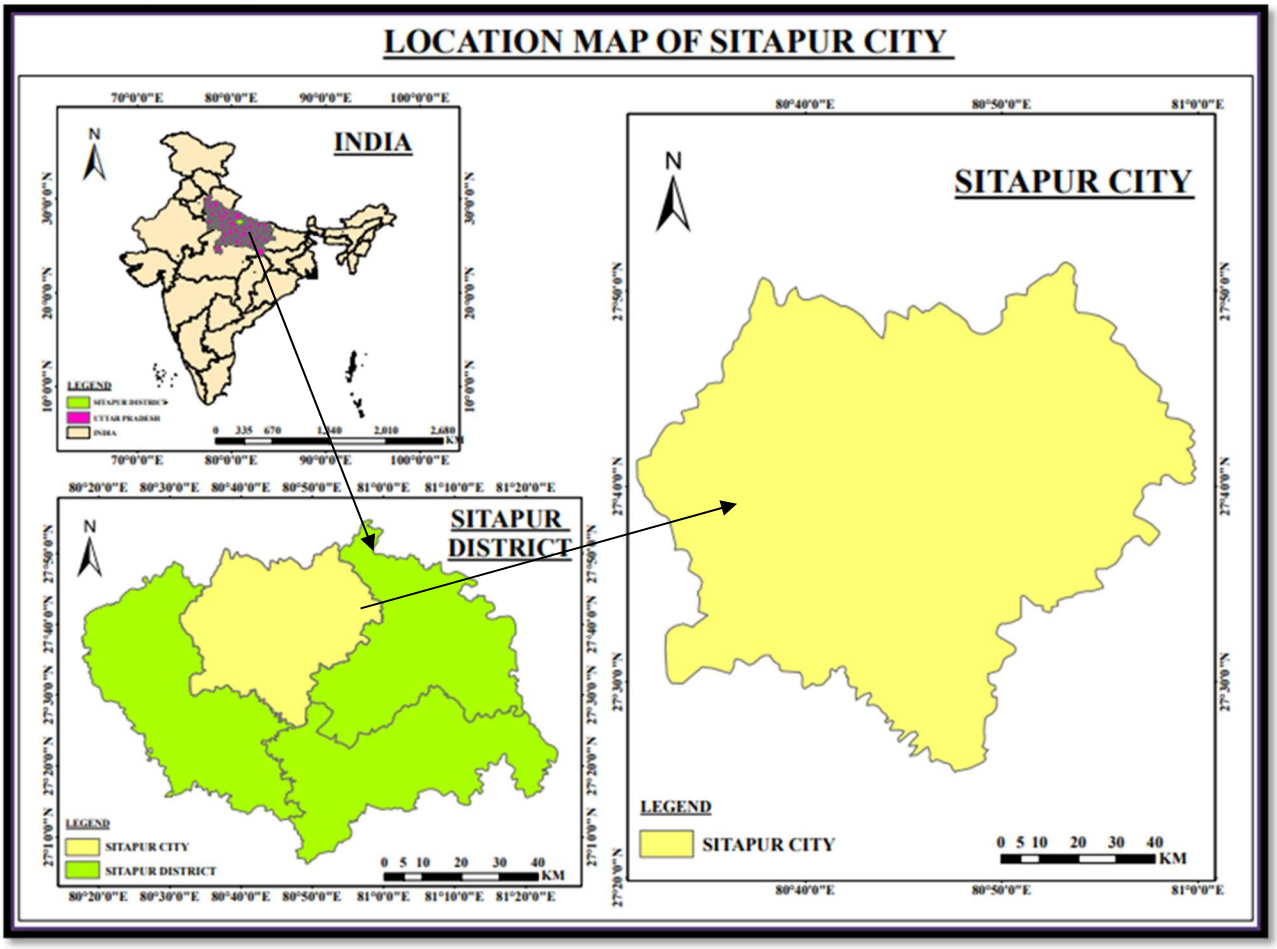
As of Census 2011, the region has a population of 8,89,474 of which 4,69,458 are males and 4,20,016 are females. The population of children between age 0-6 is 1,37,390 which is 15.45% of total population.

Fig 1: Location Map of Study Area



3.METHODOLOGY

3.1 DATA COLLECTION

The data collection was done from secondary sources. Cloud free data was downloaded from USGS Earth Explorer. The datasets were are available free of charge, making them cost effective and efficient for multi-temporal monitoring of the study area. The data used were projected to EPSG:32644-WGS 84/UTM Zone 44N coordinate reference system (CRS). The data obtained have cloud cover less than 10% and were in Geo TIFF format. The details of data obtained are given in table 1 below:

Table 1: Satellite Data For 1991, 2001 and 2011

SENSOR	PATH	ROW	RESOLUTION	DATE
Landsat 4-5 TM	144	41	30m	16-03-1991
Landsat 7 ETM+	144	41	30m	03-03-2001
Landsat 4-5 TM	144	41	30m	07-03-2011

The shape file for the study area was freely downloaded from DIVA GIS portal and Google Earth Pro was used for classification of the images. All the images were then processed and analysed using **ArcGIS 10.5** software.
The population data for Sitapur city was obtained from Census 1991, Census 2001 and Census 2011.

Cover Page

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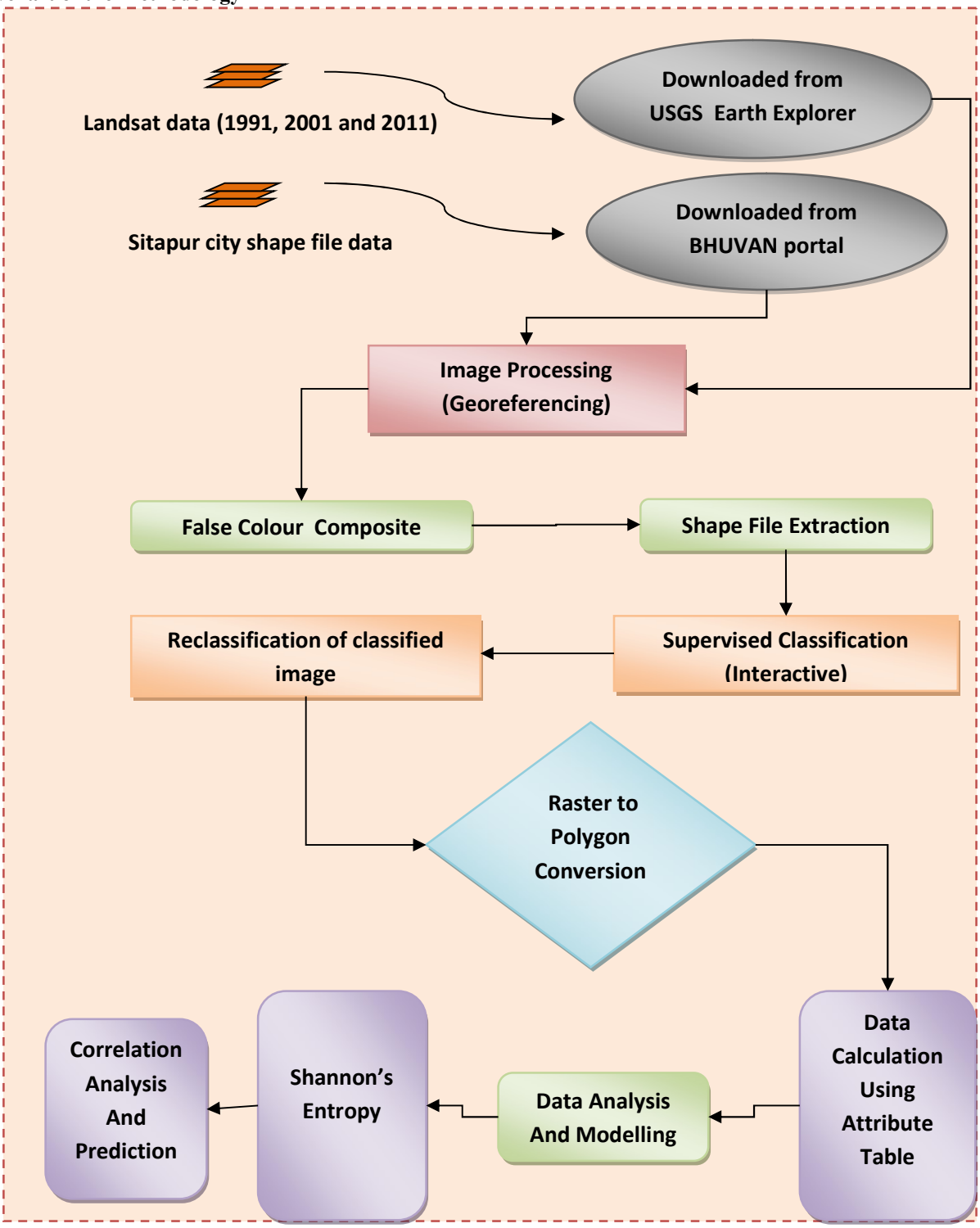
3.2 METHOD

The flowchart below illustrates the methodology used for classification of images:

Fig 2: Flowchart of the Methodology



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Urban sprawl was analysed using temporal remote sensing data for the period of 1991-2011. All the data used is geo-referenced. The methodology used is explained below:

The dataset of 1991 downloaded from USGS Earth Explorer were add as raster data to the Arc GIS software. Then the false colour composite (FCC) was created using seven bands and the obtained FCC was extracted to Sitapur city shape by using the mask layer downloaded from BHUVAN portal. For year 1991, the band combination adopted was 4(Near Infrared), 3(Red), 2(Green).

Then the Interactive Supervised Classification of the imagery was done by assigning training samples to the imagery for each class. The imagery was divided into 5 classes as:

1.) Water
2.) Built-up
3.) Vegetation
4.) Agricultural Field
5.) Barren Land

Then the classified image obtained is then reclassified using Reclassify Geoprocessing Tool in Arc Toolbox. As the reclassified image is in raster format so it is then converted to polygon file by using Raster to Polygon tool in Conversion toolbox under Arc Toolbox. Then the total area of each class is calculated from polygon file obtained using the Attribute Table.

Similarly, the datasets for year 2001 and 2011 are calculated. Here, the FCC band combination for the years i.e. 2001 and 2011 adopted were 6(Near Infrared), 4(Red), 3(Green) and 4(Near Infrared), 3(Red), 2(Green) respectively.

The data obtained for three years viz. 1991, 2001 and 2011 is then analysed and Shannon's Entropy is calculated for the study area to calculate the degree of dispersion of the built-up using the following formula:

Further, Correlation Analysis between population and built-up area was done and finally using Regression Analysis, further increase in population and hence sprawl were predicted.

$$H_n = -\sum_{i=1}^{n} P_i * \log_e P_i$$

4.RESULTS AND DISCUSSIONS

4.1IMAGE ANALYSIS OF FALSE COLOUR COMPOSITES (FCC)

The image processing techniques such as, image extraction, georeferencing, image classification and reclassification are some of the methods and techniques used in this study. The false colour composites of years viz. 1991, 2001 and 2011 are shown in figures 3,4 and 5 below:

Fig 3: FCC of Sitapur City (1991)

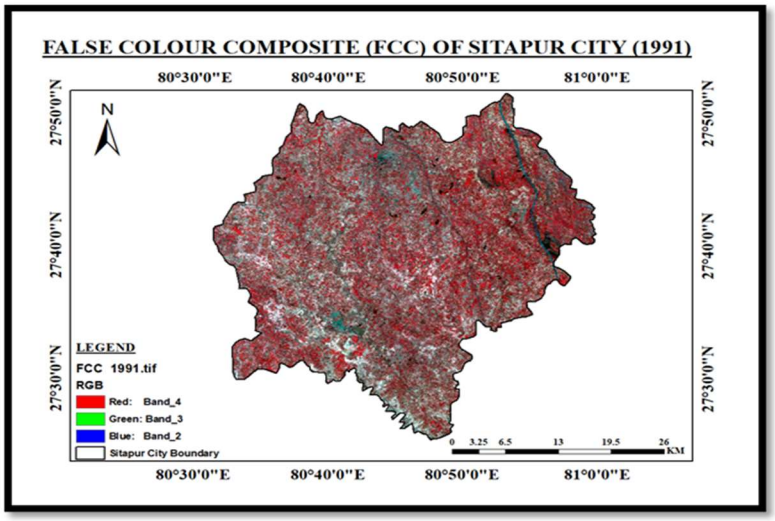

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Fig 4: FCC of Sitapur City (2001)

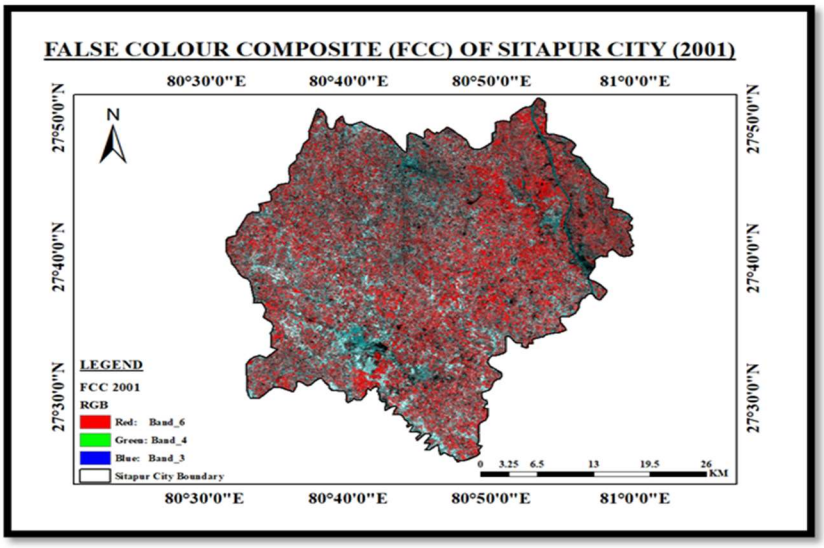
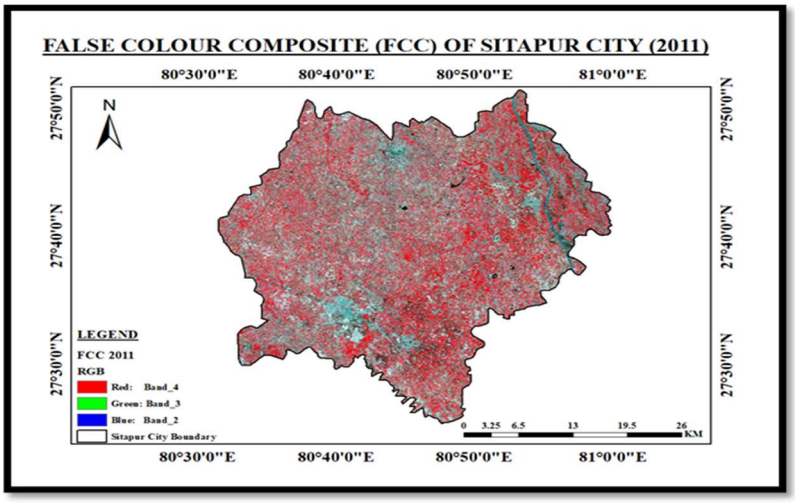


Fig 5: FCC of Sitapur City (2011)



From above images, the changes in land use and land cover can easily be demarcated as there is an increase in built-up and vegetation cover is decreasing spatio-temporally.

4.2 IMAGE ANALYSIS OF CLASSIFIED IMAGES

The total spatial area of Sitapur city is 1327.68 km^2.The land use has changed over a period of time within the administrative boundary which is shown in classified images of 1991, 2001 and 2011 in figures 6,7 and 8 below:

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Fig 6: Classifies Image of Sitapur City (1991)

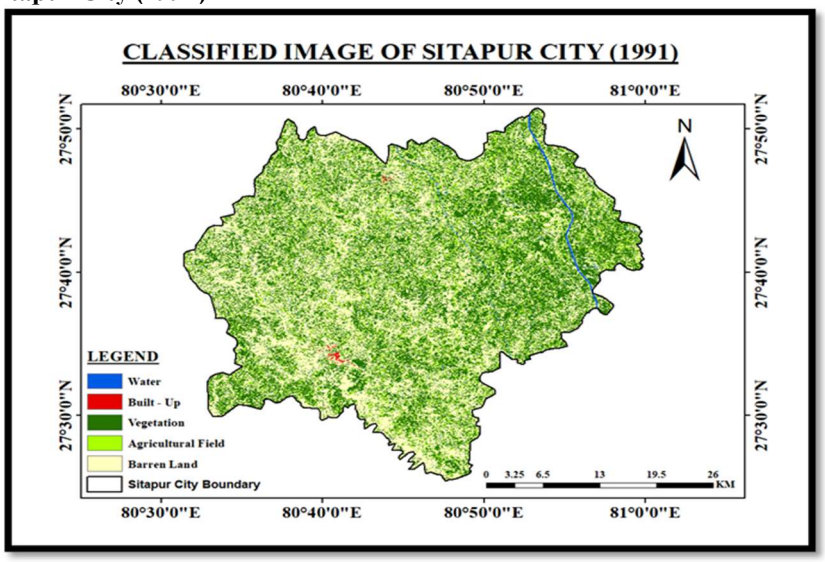

Fig 7: Classified Image of Sitapur City (2001)

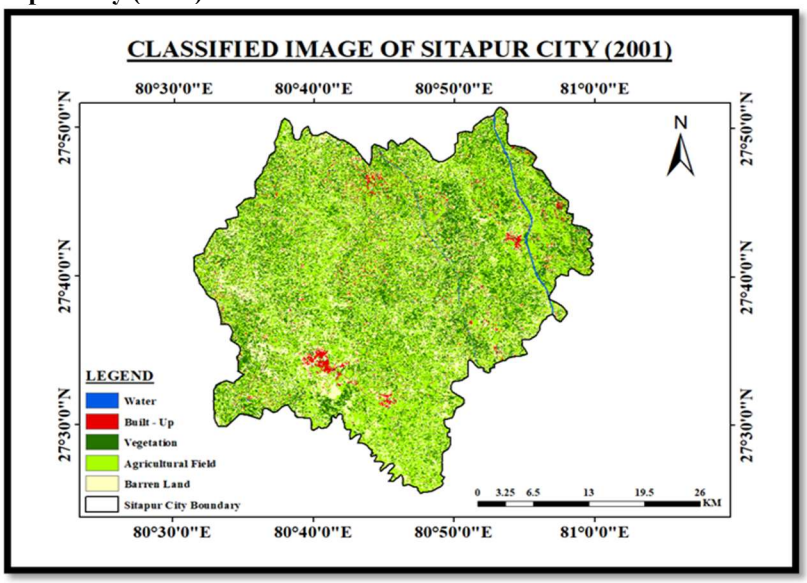

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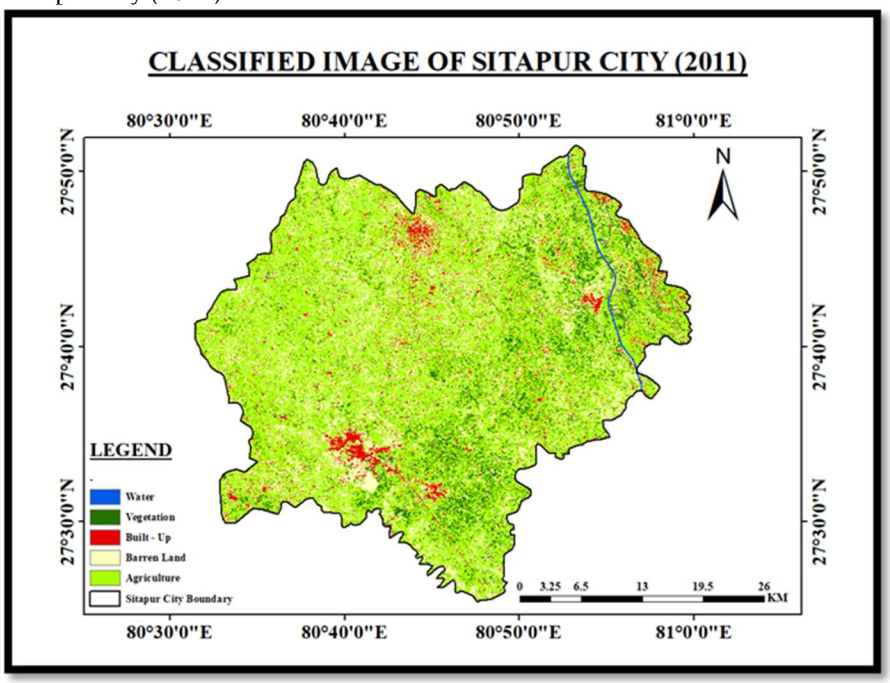
Fig 8: Classified Image of Sitapur City (2011)



The total area of Sitapur city was divided into 5 classes viz. water, built-up, vegetation, agricultural fields and barren land for years 1991, 2001 and 2011 and corresponding area in sq. km. is given in table 2 below:

Table 2: Area of 5 Classes of 1991, 2001 and 2011 (in Sq.Km.)

CLASSES	1991(Area in Sq.Km)	2001(Area in Sq.Km)	2011(Area in Sq.Km)
WATER	12.36	7.83	7.44
BUILT-UP	27.88	63.59	104.62
VEGETATION	514.52	317.49	149.38
AGRICULTURAL FIELDS	140.26	617.85	633.59
BARREN LAND	632.66	320.92	432.65
TOTAL AREA	1327.68	1327.68	1327.68

The following formula was used for calculation of area percentage of each class to total area of Sitapur city:

$$\%CLASS = \frac{\text{AREA OF CLASS}}{\text{TOTAL AREA OF SITAPUR CITY}} \times 100$$

Table 3: Area of 5 Classes of 1991, 2001 and 2011 (in %)

CLASSES	1991	2001	2011
WATER	0.93%	0.59%	0.56%
BUILT-UP	2.09%	4.79%	7.88%
VEGETATION	38.76%	23.91%	11.25%
AGRICULTURAL FIELDS	10.57%	46.54%	47.72%
BARREN LAND	47.65%	24.17%	32.59%
TOTAL	100%	100%	100%

From the analysis of data tables 2 and 3, it is evident that there is an increase of 2.7% and 3.09% in built-up area in 2001 and 2011 from 1991 and 2001 respectively. Again, a decreasing trend in vegetation cover is witnessed as it was 514.52 km^2 in 1991 which reduced to 317.49 km^2 in 2001 and then to 149.38km^2 in 2011. However, it is clearly noted that the agricultural fields have increased

Cover Page

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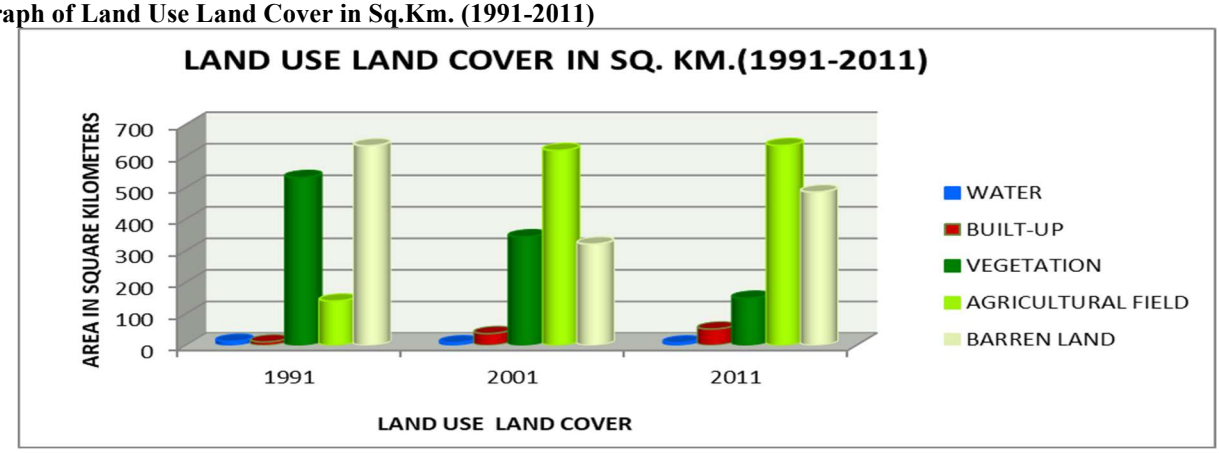
in area from 10.57% (1991) to 46.54% (2001) and then to 47.72% (2011) but barren land is reduced in area significantly with time. A reduction in area of water bodies is also noted.

The increase in built-up areas and agricultural fields and reduction in vegetation cover and barren land with time clearly indicate that as the population of an area increases with time, the built-up areas start expanding outwards into non-built-up environments (vegetation areas and barren land). These changes can be easily observed in classified images above where there is a notable change in built-up areas and others spatio-temporally.

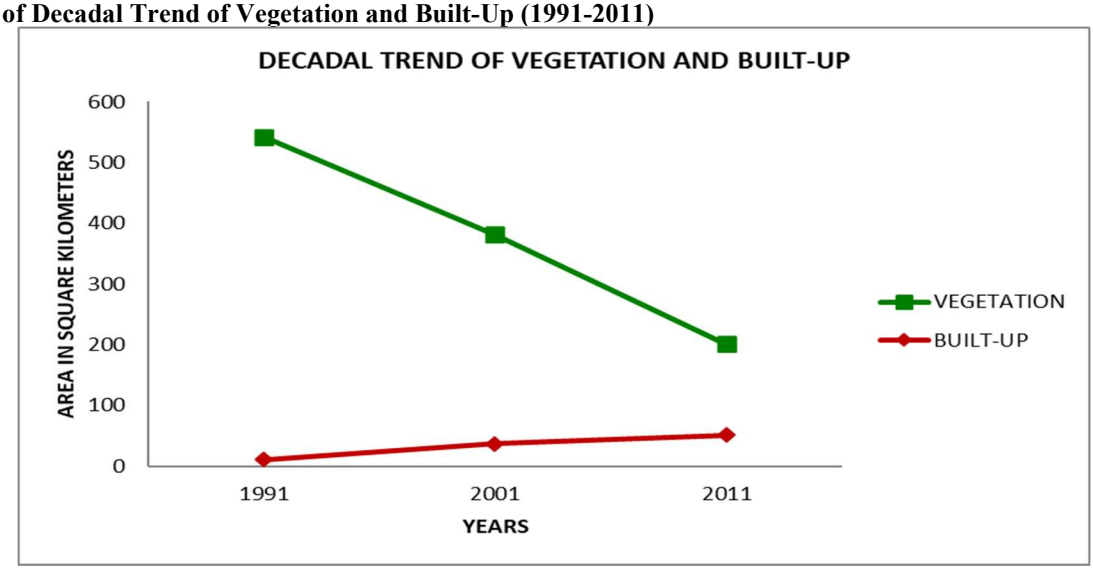
The graphical representation of land use land cover (1991-2011) is shown in figure 9 below:

Fig 9: Graph of Land Use Land Cover in Sq.Km. (1991-2011)



The decadal trend of vegetation and settlement is shown in graph below in figure 10. The graph clearly shows decline in vegetation and increase in built-up which is a direct result of increasing population of the area.

Fig 10: Graph of Decadal Trend of Vegetation and Built-Up (1991-2011)



4.3 MODELLING OF POPULATION GROWTH AND BUILT-UP AREA

The increase in built-up area in Sitapur is outstripping the rate of growth in population. Between 1991 and 2001, the built-up area increases by 128.08% against the population growth of 27.22% which implies that built-up area growth is nearly four times the growth in population. Between 2001 and 2011, the built-up area increased by 64.52% while the population grew by 23.42% which shows that population growth was only one-third compared to growth in built-up areas. This clearly indicates that the consumption of land has increased exceptionally over the decades. With time, the population increases and the urban sprawl occurs as there arises a

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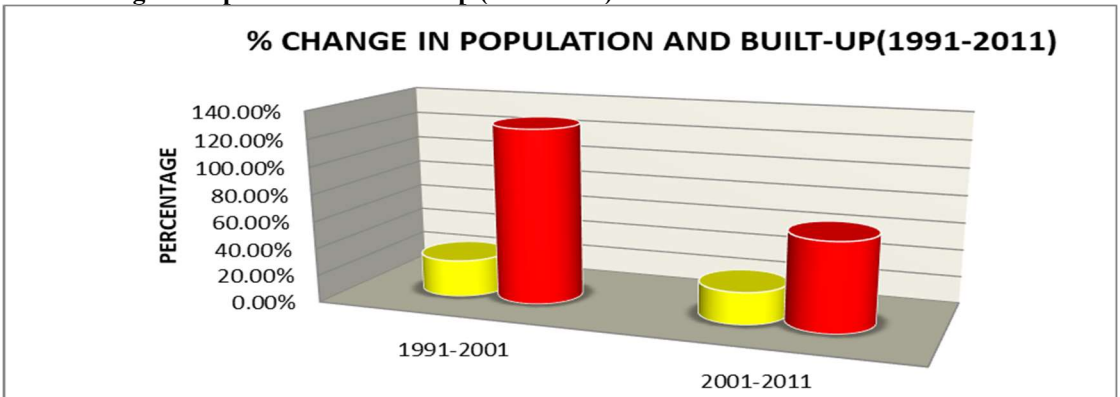
need of more accommodations for people to live and educational, industrial, commercial, recreational and other establishments to cater the needs of people like education, production of goods, livelihood and many more. The increased population also demands agricultural production to feed them. Hence the development of built-up area is a direct consequence of population growth. This leads to more encroachment of the agricultural land, expansion of road network and loss of vegetation.

Fig 11: Graph of % Change in Population and Built-Up (1991-2011)



	1991-2001	2001-2011
POPULATION GROWTH	27.22%	23.42%
BUILT-UP AREA CHANGE	128.08%	64.52%

4.4 SHANNON'S ENTROPY (H_n)

Shannon's entropy was computed to detect the urban sprawl phenomenon and can be calculated as:

Step1: Computation of P_i

$$P_i = X_i / \sum_{i=1}^{n} X_i$$

Where,n=total number of rows (or here, years) and X_i is total settlement area of a particular year.

Step2: Compute log value of P_i

i.e.

$$P_i * \log_e P_i$$

Step3: Compute entropy as

$$H_n = -\sum_{i=1}^{n} P_i * \log_e P_i$$

Step4: Calculate H_{max} value as

$$H_{max} = \log_e(n)$$

The value thus obtained ranges from 0 to $\log_e n$ which indicates very compact distribution for values closer to 0 and the values which are closer to $\log_e n$ indicates that the distribution is very dispersed. Larger value of entropy reveals the occurrence of urban sprawl in the region.

Cover Page

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4.4.1 COMPUTATION OF SHANNON'S ENTROPY:

The table 4 below shows the built-up area of study area for years 1991, 2001 and 2011:

Table 4: Built-Up Area of 1991, 2001 and 2011

YEAR	i	BUILT-UP AREA (X_i)
2011	i 1	104.62
2001	i 2	63.59
1991	i 3	27.88
		Total= $\sum_{i=1}^{n} X_i$ = 196.09

Table 5: Computation of Values for Shannon's Entropy

$P_i = X_i/\sum_{i=1}^{n} X_i$	$\log_e P_i$	$P_i * \log_e P_i$
0.5320924	-0.2740129	-0.1458002
0.3242899	-0.4890666	-0.1585994
0.1421796	-0.8471627	-0.1204493
		Total= $\sum_{i=1}^{n} P_i * \log_e P_i$ = -0.4248489

Now, $\mathbf{H_n = -\sum_{i=1}^{n} P_i * \log_e P_i}$

H_n = -(-0.4248489) = 0.42

H_n = 0.42

Now, $\mathbf{H_{max} = \log_e(n)}$= $\log_e(3)$ = 0.4771213=0.48

The value of entropy (H_n =0.42) obtained here is closer to the upper limit of $\log_e n$ (H_{max} =0.48) which indicates the degree of dispersion of settlement area in the region and hence indicating the occurance of urban sprawl in Sitapur city.

4.5 CORRELATION ANALYSIS BETWEEN POPULATION AND BUILT-UP AREA

The degree of association is measured by **Correlation Coefficient**, denoted by "**r**" which is also known as "**Poisson's Coefficient of Correlation**". It is a measurement of linear association between two variables. Correlation Coefficient(r) varies +1 through 0 to -1 where +1 denotes perfect positive correlation, 0 indicates no correlation and -1 denotes perfect negative correlation.

Correlation analysis was then done to find out the degree of association between population and built-up area which was as below:

Poisson's coefficient(r) = 0.9

r= 0.9 shows a very high degree of positive correlation between population and built-up area which indicates that the increase in population is majorly responsible for increase in built-up area hence leading to urban sprawl in the region.

The graph between decadal growth in population and built-up (1991-2011) is shown in figure 12 below:

Cover Page

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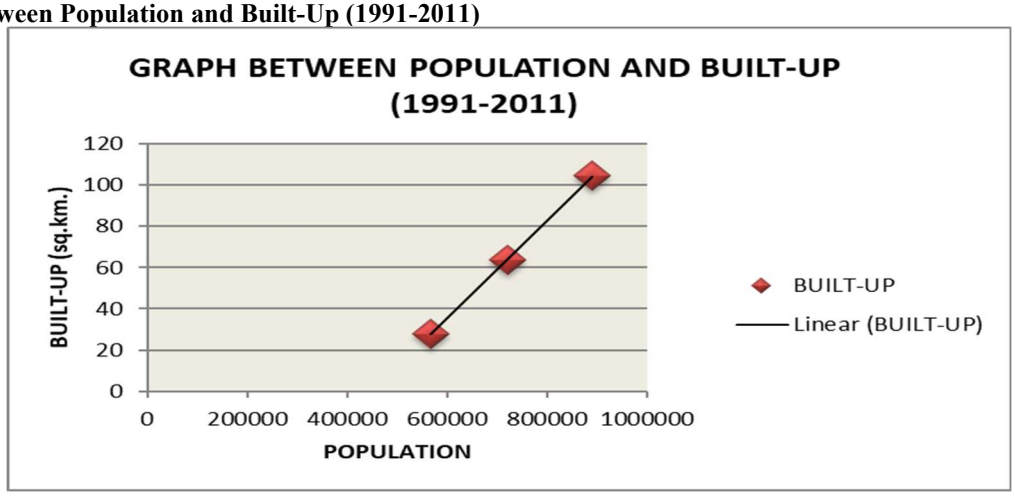
Fig 12: Graph Between Population and Built-Up (1991-2011)



4.6 PREDICTING SCENARIOS USING REGRESSION ANALYIS

If 'x' represents 'independent variable' and 'y' represents 'dependent variable', then the relationship between x and y i.e. regression of y on x is described by an equation known as "**Regression Equation**" and is given as:

$$y = a*x+b$$

Where a and b are constants.

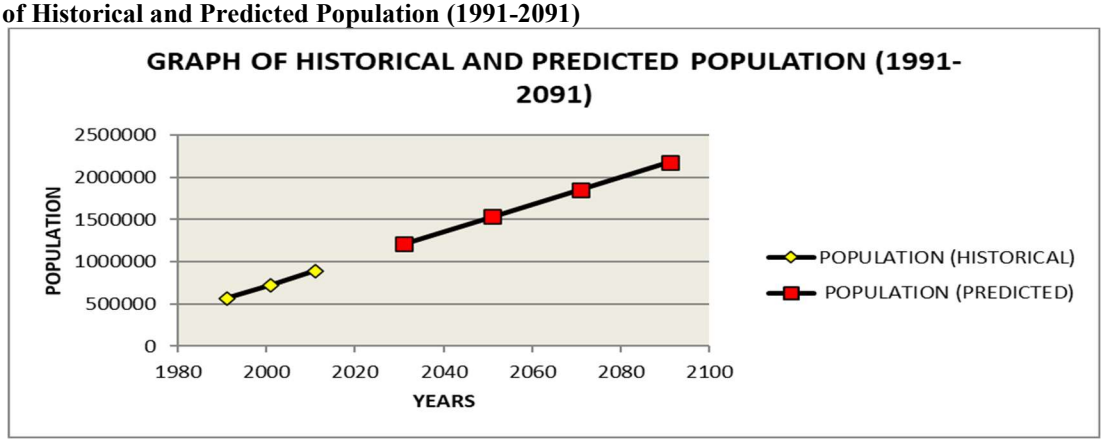
Using the above equation, the population of study area for years: 2031, 2051, 2071 and 2091 was calculated using the historical population data of years: 1991, 2001 and 2011 which is shown in table 6 below:

Table 6: Population of Sitapur City From 1991-2091

YEARS	POPULATION (HISTORICAL)	YEARS	POPULATION (PREDICTED)
1991	566511	2031	1210008
2001	720704	2051	1532971
2011	889474	2071	1855934
		2091	2178897

The graph below (Figure13) shows historical population (1991-2011) and predicted population (2031-2091)

Fig 13: Graph of Historical and Predicted Population (1991-2091)



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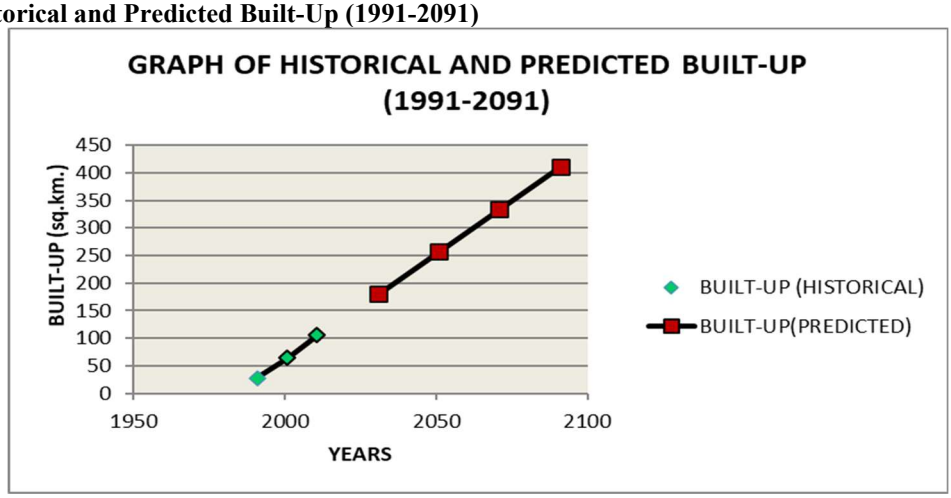
Then again using regression equation, the total built-up area for years: 2031, 2051, 2071 and 2091 was calculated using historical built-up area data of years: 1991, 2001 and 2011, given in table 7 below:

Table 7: Built-Up Area of Sitapur City From 1991-2091

YEARS	BUILT-UP (HISTORICAL)	YEARS	BUILT-UP (PREDICTED)
1991	27.88 km^2	2031	180.47 km^2
2001	63.59 km^2	2051	257.21 km^2
2011	104.62 km^2	2071	333.95 km^2
		2091	410.69 km^2

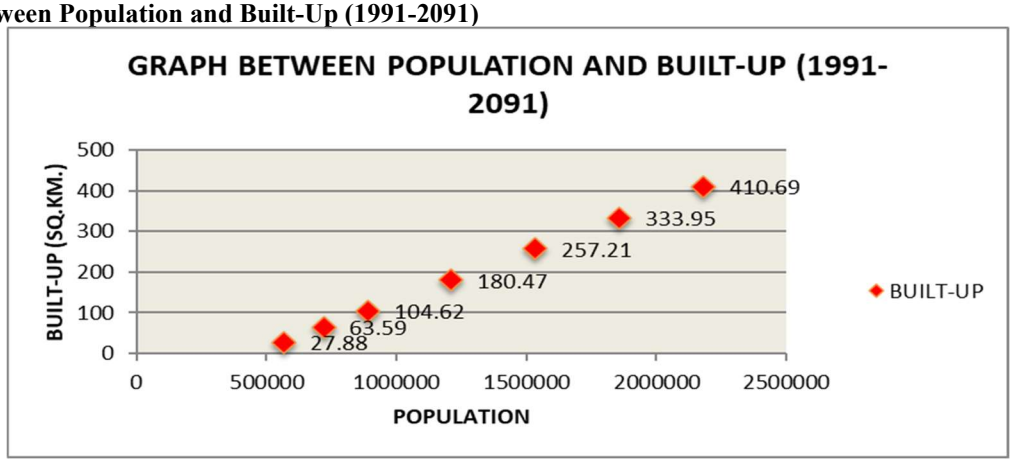
The graph below (Figure 14) shows historical built-up area (1991-2011) and predicted built-up area (2031-2091)

Fig 14: Graph of Historical and Predicted Built-Up (1991-2091)



Thus, it is found that the population of the region would be nearly 10 lakhs, 15 lakhs, 18 lakhs and 22 lakhs in 2031, 2051, 2071 and 2091 respectively and the expected built-up is approximately 180km^2, 257km^2, 334km^2 and 411km^2. This implies that by 2051 and 2091, the population would rise by 72% and 145% respectively from 2011 while the built-up would be nearly 146% and 293% in 2051 and 2091 respectively from 2011. Thus, it indicates that pressure of population on land would grow in future and further sprawling will take place in the region leading to the more and more loss of agricultural land. The graph between population and built-up from 1991 to 2091 is shown in Figure15 below:

Fig 15: Graph Between Population and Built-Up (1991-2091)



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5. CONCLUSION

This study attempted to provide a better understanding of the urban sprawl of the Sitapur city. The study also demonstrated the significance of Remote Sensing and GIS tools in detecting the urban landscape and its spatial pattern.

The land use land cover was determined for two decades from 1991-2011 and the results reveal that the built-up area tends to increase with the increase in population which is also verified by using Correlation Analysis. Entropy values obtained indicate the degree of dispersion of built-up area in the region and hence occurrence of urban sprawl. The agricultural fields are noticed in increasing trend in area from 10.57% in 1991 to 46.54% in 2001 and further to 47.72% in 2011 of the total area of the city. This is so to meet up the food demands as well as provided economic base to the increasing population. The agricultural land increase is compensated by decrease in barren lands and vegetation cover. Further, the future predictions done using Regression Analysis reveal that population in 2051 and 2091 is expected to rise by 72% and 145% respectively from year 2011 and the corresponding increase in built-up is expected to be 146% and 293% respectively from year 2011.

The increase in population subsequently leads to greater need for accommodation and hence loss of green cover. Thus, it is important for urban planners to understand the pattern of urban sprawl so that they can take proper measures for sustainable development and effective utilization of resources.

Need of the hour is that the urban planners can also encourage new techniques of urban farming in the periphery zone of the study area so that farmers of encroached land can be employed in new networking system of urban farming. This will lead to the holistic development and livelihood, food and environmental security of the study area.

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